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Integrated Curricula: Purpose and Design

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ABSTRACT

This paper has two objectives: 1) to define, describe, and discuss integrated programs and their advantages with regard to student and faculty outcomes, as well as student retention; and 2) to describe a design process used to successfully develop and deploy an integrated first year curriculum. This paper details the results of the design process and the content of the first year integrated program implemented by the College of Engineering at Texas A&M University. The curriculum integrates the first year components of calculus, chemistry, engineering graphics, English, physics, and problem solving.

I. INTRODUCTION

In 1993, the National Science Foundation (NSF) sponsored the fifth education coalition known as the Foundation Coalition (FC). It began with seven partner schools: Arizona State University, Maricopa Community College, Rose-Hulman Institute of Technology, Texas A&M Kingsville, Texas A&M University, Texas Woman's University and the University of Alabama. Its focus is providing undergraduate students with a foundation in engineering problem-solving, design, and teamwork that integrates the traditional fundamentals in mathematics and science without increasing the time required to graduate.

The FC focused on achieving major improvements to four components of the undergraduate engineering education. These include:

- Integration of science and mathematics into problem-solving and design;
- An emphasis on teaming and cooperative learning;
- The use of computers to improve design and problem-solving throughout the undergraduate education experience; and
- Continuous assessment and evaluation of methods and outcomes.

The FC has achieved impressive results that we believe are the result of the synergistic effect of the four components taken collectively. This paper will concentrate on the first component, namely curriculum integration.

This paper differs from previous works in curriculum design research (Waks[1] and Evans et al.[2]) in that we describe a method for integrating the content into a cohesive unit. In addition to discussing the design process, we discuss the advantages of curriculum integration. We also describe the first year FC integrated curriculum at Texas A&M University and provide some evaluation results. Although our curriculum can be copied and is available for other schools, we anticipate each school designing its own curriculum to accommodate differences in requirements and resources. We recommend our proven design process to develop the curriculum.

II. PURPOSE OF INTEGRATED PROGRAMS

A. Curriculum Integration Defined

For the purpose of this paper, we define curriculum integration as the act of making individual courses become integral components of a whole, while at the same time requiring them to be interdependent upon one another and bound by a common thread of knowledge. This interdependence goes well beyond traditional prerequisites and/or co-requisites. Classes within a given semester depend on each other to achieve their individual objectives. In the FC at Texas A&M University (TAMUFC), we have developed three different models of curriculum integration. We simply refer to these as "the first year model," "the second year model," and "the upper division model." While a brief description of each model is presented below, the primary focus of this paper will be on the design, development, and deployment of the first year model. The first year model focuses on fundamental concepts in engineering, mathematics, and physics. While the model also integrates English and chemistry, the principal thrust in curriculum development continues to be in the area of mathematics and physics, since our data indicate these are the most difficult subjects for the average student.

The second year model centers around the engineering sciences and presents a unified approach to engineering science based on an earlier curriculum project.[3,4] The second year TAMUFC model was designed to be common across engineering majors and consists of studies in momentum, energy, continuous media, materials, and electronics. The closest match to these classes taken from a traditional curriculum would be statics/dynamics, thermodynamics, material science, strength of materials, and electrical circuits.

The upper division model concentrates on specialized, discipline-specific courses that form connections between the fundamentals from the first two years and the application-specific methods or jargon employed by practicing engineers. One can view the first and second year models as performing horizontal integration, building a wide, highly interconnected foundation onto which the upper division builds vertically.

B. Advantages of Integrated Programs

Educational psychology[5] has long held the position that there are four distinct types of learning. They consist of:

1. rote learning, consisting of the memorization of seemingly "meaningless" word combinations*;
2. meaningful learning, where a person attaches meaning to the concepts under study;
3. concept formation, where a learner organizes ideas and information to formulate new ideas and concepts; and
4. problem solving, where an individual uses information and knowledge in new ways to solve problems.

The objective in most engineering curricula is to provide opportunities for students to learn meaningful concepts meaningfully.

1) Providing Motivation: One of the first steps in encouraging meaningful learning is to motivate the students for their studies. One important advantage of an integrated program, such as the TAMUFC first year model, is that it provides excellent motivation for non-engineering subjects. To make the point, consider the relationship between the engineering and mathematics courses in a traditional engineering curriculum at Texas A&M University. Starting in the first semester, entering students study Calculus I and Engineering Graphics. The second semester ushers in Calculus II and Problem Solving. The third semester brings in some kind of Statics and Calculus III. Many traditional early engineering classes do not use significant amounts of information from the mathematics classes. There are several possible reasons for this: (1) the engineering faculty member, for the most part, is not exactly certain what the students are learning nor when they are learning it; (2) the engineering faculty member cannot rely on the fact that the students know the mathematical material since they have no formal control over the mathematics class; and (3) the material covered in these classes is often not directly relevant to the introductory engineering subjects. A typical engineering major at Texas A&M University would not use the material from Calculus I to any significant extent in any engineering course until the fourth semester. Given this scenario, the curriculum reinforces the engineering student's belief that Calculus is unimportant. What we as educators are implicitly telling the student is, "Calculus is a weed out class because engineering classes don't use it and there is a high failure rate."

The TAMUFC's integrated first year curriculum resolves the utilization issue described above by designing the first year courses to be interdependent. It becomes obvious to the student that mathematics and science are critically important to engineering because they use the concepts in their first engineering course. Because the classes are interdependent, the faculties communicate with each other so they know what is being covered. Since examinations are also integrated, the faculties have some sense of control over each class.

TAMUFC's first year model builds interdependency into the program by reordering and restructuring traditional course material in mathematics,[6] science, and engineering. For example, an engineering faculty member might first introduce a problem that requires a particular mathematics or science topic to complete. The mathematics or science faculty member covers the topic with as little or as much detail deemed appropriate. Afterward, the engineering faculty member reenters the arena to put the material to use in another application.

Coppola et al.[7] suggests examinations should use authentic problems to elicit authentic skills. Although they may be difficult to formulate, authentic problems eliminate the student's ability to memorize solution tricks. Other researchers[8] distinguish between textbook problems and realistic problems. Since very few "real world" problems require knowledge drawn from a single discipline,[9,10] integrated curricula have a better chance at providing authentic and realistic problems. This helps establish increased relevance between the material being studied and the student's perception of their career needs. As a result, students may be more motivated to master material being presented.

Another problem with traditional nonintegrated non-engineering classes is that there is no guarantee that the material the student learns is really what engineering professors value. Continuing with the example of a traditional engineering major, in the fourth traditional semester engineering professors ask students in dynamics classes to differentiate functions using the chain rule. The chain rule was covered 18 months earlier. It is possible the student scored poorly on the chain rule because it was covered just before the thanksgiving break and scored high on the epsilon/delta proofs covered earlier in the semester. The averaging used for the class grade computation indicate the student to be highly competent yet the student is weak in the areas needed most in an engineering career. The TAMUFC first year model alleviates this problem by rapidly focusing the student's attention on essential topics by engaging them in engineering applications. Epsilon/delta proofs are covered, and the student knows that the proofs are more important to understanding mathematics than for engineering. Some may argue that this will cause the students to disregard proofs, but we suggest it guarantees students are more motivated to learn topics most important to engineering.

Another advantage of the TAMUFC integrated first year program is that it implements an integrated component on all exams. A key feature of the integrated examinations is the requirement for the student to draw information from multiple classes. In addition, the lines between mathematics, science and engineering are blurred. The student begins to realize that mathematics and science are necessary components of the solution to an engineering problem and not unrelated and irrelevant courses.

2) Better Control of the Curriculum: Integrated programs allow better management of repetition in the curriculum. One example from the TAMUFC first year model is the coverage of vectors. In the traditional program, vectors are first quickly introduced in physics. Then in the sophomore year they are covered in engineering statics and finally in detail in Calculus III. The traditional classes are not coordinated nor integrated; thus the coverage is not handled consistently. To make the point, consider as an example the response given when one traditional student was asked to draw a vector, "Do you want a physics, a

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*There are different levels of meaningful learning. For example, learning the words of a language can be thought of as being close to rote yet the words themselves have meaning and can be fit into the student's cognitive framework.

Number of Students in the Study Still Enrolled in the College of Engineering.

End of School Year	1994 Frosh				1995 Frosh				1996 Frosh				1997 Frosh			
	TAMUFC		Traditional		TAMUFC		Traditional		TAMUFC		Traditional		TAMUFC		Traditional	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
	98	100%	656	100%												
1994	68	69%	375	57%	199	100%	623	100%								
1995	59	60%	269	41%	156	78%	410	66%	181	100%	712	100%				
1996	54	55%	238	36%	121	61%	309	50%	129	71%	473	66%	142	100%	726	100%
1997	53	54%	227	35%	113	57%	278	45%	93	51%	364	51%	98	69%	467	64%

Table 1. Retention of TAMUFC compared to equally qualified nonTAMUFC students.

mathematics, or an engineering vector?" In contrast, in the TAMUFC first year students learn a little about vectors in mathematics, while in physics they derive equilibrium equations in vector form, followed by application of equilibrium to solutions of a truss problem in engineering.

3) Framework is Easier to Develop: An integrated curriculum makes meaningful learning easier to achieve. An important requirement to facilitate meaningful learning is that the student chooses to attach new material to existing related knowledge rather than merely adopting an arbitrary framework for memorizing the material in a verbatim fashion.[5,7] It is our thesis that integrated curricula increase the probability that students will value material by linking what often seem to be disjointed pieces of information. For example, if the student makes a knowledge framework connection for a mathematics concept, and a physics concept is related to the mathematics, the student could potentially connect the physics alone to the framework or could connect the physics concept to the mathematics concept. This will facilitate what Smith and Waller[11] claim is the teacher's responsibility: to create conditions for students to construct meaning.

Few deny that engineering education is becoming diversified. Some suggest that engineering will be the liberal education of the future.[12] With such a wide range of material, it is imperative to develop a means for drawing the concepts together in a way that makes understanding them more likely for more students. We believe an integrated curriculum will provide that organization. Bordogna, Fromm, and Ernst[13] describe the desired curricula with the words, "just in time." We believe that the TAMUFC first year captures the spirit of a just in time curriculum.

Coppola et al.[7] support the idea that students construct their understanding by forming interconnections among ideas. In essence, learning is something the student does, not something that is done to them. Students who "learn," do not passively accept knowledge from the teacher or curriculum; they work at learning by building connections, often done without consciously recognizing it. Coppola et al. insightfully suggest that, once a student builds interconnections among ideas, there is a resistance to breaking them even if new information does not appear to fit. In other words, once the students formulate intricate interconnections between information, these interconnections can be very persistent. Students do not like to reject a piece of their puzzle. This helps explain why it is so difficult to get students to abandon incorrect intuition. What this means to curriculum designers is that we must do everything we can to help the students construct a valid knowledge representation or be prepared when students construct incorrect representations that must be destroyed.

Group	TAMUFC Initial	TAMUFC After 1 year	TAMUFC %	TRADITIONAL Initial	TRADITIONAL After 1 year	TRADITIONAL %
Majority	515	374	73%	2367	1510	64%
Minority	105	77	73%	350	215	61%
Men	493	361	73%	2092	1322	63%
Women	127	90	71%	625	403	64%

Table 2. Retention from first year to second year of 94 + 95 + 96 frosh by group.

4) Other Reasons: Another reason for considering an integrated curriculum is that there are many schools implementing such curricula reforms.[14] The fact that other schools are developing an integrated curriculum is not a scientific reason for integrated curriculum; however, it does provide significant anecdotal evidence for such integration. Insight can be gained by considering the motivation behind restructuring curricula. Carnegie Mellon[15] wanted to emphasize ideas over technique. They point out that teaching mathematics and science, for example, then adding engineering does not work in part because the students in K-12 are typically weak in mathematics and unmotivated to learn. Part of their solution was to use first year engineering to motivate learning mathematics and science. The Foundation Coalition and in particular the TAMUFC approaches this problem in a similar fashion.

There is some evidence that the new curriculum offers advantages in student retention. While some of the benefits derive from the synergistic effect of the four components described earlier, integration is surely an important part. Integrated curricula may offer more opportunities to connect with different student learning preferences. The calculus track TAMUFC experience resulted in the data shown in table 1.[16] In each case, the traditional students are those students who were eligible to participate in the coalition pilot program, but elected to take traditional classes.

By connecting with many learning preferences, integrated curricula improve the retention of under-represented groups.[17,18] As reported elsewhere, this approach benefits all students, with the real advantage being long-term benefits.[17] Retention data by group for the TAMUFC is shown in table 2.

III. THE DESIGN PROCESS

When considering the problem of developing new curriculum and instruction initiatives, Bloom et al.,[19] posed four questions that they felt were imperative to address to obtain the desired student outcomes for a given course. These questions are:

1. What educational purposes or objectives should the course seek to attain?
2. What learning experiences can be provided that are likely to bring about the attainment of these purposes?
3. How can these learning experiences be effectively organized for the learner and help him/her in integrating what might otherwise appear as isolated learning experiences?
4. How can the effectiveness of learning experiences be evaluated by the use of tests and other systemic evidence-gathering procedures?

As educators, we instinctively tend to sequentially answer these questions. Specifically, as engineering educators, we tend not to apply our training in the design process to curriculum development issues, that is, the process of iterating or looking back to ensure that we are still solving the same problem and/or that we have not violated a basic constraint. This ordinarily is not a problem when we are working alone, we iterate (or correct) as we go through the class or from semester to semester. However, when curriculum development is a synergistic effort between a number of faculty members from different colleges, having a clearly developed iterative plan is imperative to obtain successful results. The section that follows describes the basic procedure used at Texas A&M University for the development of the Foundation Coalition Integrated First Year Program.

In the beginning, there were many "what if" scenarios posed. For example, "what if a student enters the curriculum and is not ready to take calculus." These would eventually have to be addressed before full-scale implementation of such a program. We intentionally chose to limit the initial number of constraints of the problem to include: 1) the amount of content had to be greater than or equal to the traditional program; 2) contact hours (or course credit hours) had to match the traditional program; 3) students would be required to take all courses associated with the program (no transfer credit) and they would not be able to withdraw from any one course during a semester; and 4) students must be calculus-ready. This was defined by a combination of SAT/ACT test scores and a mathematics placement examination administered to all incoming engineering freshmen. Once this "calculus track" was implemented, a team developed an integrated "pre-calculus track" for those students who do not enter the university calculus-ready. It is important to realize that attempting to solve all of the problems initially may prove to be a fruitless venture.

Given our constraints, we assembled a team of faculty members from each of the participating departments to develop a strategy for how to proceed. The outcome was a process that would be iterated several times before the courses were actually delivered.

A. Developing Our Vision: Defining the Outcomes

As a team, we initially set out to discover the meaning of an integrated curriculum. We had several team meetings where the issue was discussed and even visited another school that had developed an integrated curriculum. It was important for the team to develop a collective vision regarding how an integrated curriculum varies from the traditional. We believe this was a pivotal time in the process. Specifically, visiting another school gave the team a sense that the mission was possible.

Once the team had a common vision, we worked in discipline-specific subgroups to list the content covered in each traditional class. For example, the mathematics faculty members on our team produced a list of topics covered in the first two traditional calculus classes. With these lists in hand, the subgroups presented their findings to the team. These presentations served two purposes: 1) to educate the team members on the content of courses taught in other disciplines, and 2) to clearly define the objectives for each topic. For example, the mathematics subgroup might report covering parametric curves and an engineering faculty member might ask for an example. All topics on the coverage list had to be justified by the subgroup by giving specific reasons why each topic was covered. Covering a topic for historical reason was considered invalid. The justification for each topic became a list of the educational outcomes for each course.

The list of content and their associated outcomes was an iterative process. For example, the engineering faculty members listed topics related to FORTRAN programming. When justifying the topic, an initial reason given was the fact that FORTRAN programming had always been in the curriculum and was therefore obviously important. The team tasked the engineering faculty members to either remove the concepts or discover valid reasons for their inclusion. Eventually, the justification was that learning to program helped demonstrate the need for precision. That computer programs like many other things, are either right or wrong, they run or they do not run, and the logical problem solving skills required for programming are valuable tools for an engineer. These arguments were considered valid by the team and the concepts remained in the curriculum.

Actually, the discussion about programming was much more complex than can be adequately documented. However, this simplified anecdote serves to make a point about the iteration of outcome specification.

We spent approximately one semester generating the list of content and outcome specifications for the classes in the first year program. The team met approximately two hours per week and implemented accepted team procedures. Team members asked candid questions, and although tempers sometimes flared, the team worked through the conflicts and pressed onward.

B. Initial Integration

After the curriculum contents were listed, we transcribed them onto large Post-It® notes. Each discipline had a unique color so we could determine from a distance whether the note contained mathematics, physics, engineering, chemistry or English. The faculty members used one note for each lecture in the traditional curriculum. For example, the first two calculus classes meet the students four hours/week for approximately 28 weeks total (not counting exams). Hence, the mathematics faculty members filled approximately 112 notes with one to two keywords indicating each class' topic. The discipline-specific faculty members, outside a team meeting, accomplished the transcription to notes. The team did not initially place any restrictions on the amount of time allocated to any concept; this decision was left to the faculty members with experience teaching the material. Team feedback and iteration came in later, as will be seen.

During a team meeting, we discussed what would be required to reorganize each course. It became clear that the physics curriculum had the least flexibility. Since our initial implementation, we have significantly reordered physics but we did not see this possibility early in the project. Because we felt physics had the least flexibility, we selected it as the pacing course.

The full team gathered together for two full consecutive days. These sessions occurred approximately 3 months before the integrated curriculum was to be taught for the first time. During these 16 hours, the initial integration was performed. We taped 30 poster boards on the walls, one poster for each week in the first year (two extra weeks allowed time for exams). Physics, the pacing course, placed their first note on the first poster board then described the mathematics concepts that were needed for the concept. Next, the mathematics faculty members determined how many classes were needed to cover the required mathematics concepts identified by physics. This often required negotiation. Once the required number of mathematics classes was known, the mathematics faculty members placed these onto the first few poster boards and moved the physics topics to a later position. The mathematics faculty members did an excellent job reorganizing their materials so they could quickly cover enough of the material to be useful to physics, yet not so much detail that they would dominate the schedule.

As the poster boards began to fill, "slack" times were discovered when physics did not need new mathematical concepts. During these slack times, the mathematics faculty members would post a re-visit to an earlier concept to elaborate details and complete its coverage. As the poster boards began to fill with physics and mathematics, engineering and English looked for concepts on their notes that could be related to the concepts on the poster boards. The objective was to keep each week reasonably balanced between mathematics, physics, engineering and English and not to overwhelm students with excessive amounts of any subject. For example, in the initial implementation, physics was not taught for several weeks, giving time for mathematics to cover the requisite material. During this time, we used engineering, graphics and English to help fill the time not used by physics.

As an example, one of the early physics concepts was projectile motion. To define motion in two dimensions, physics wanted to use vectors and compute derivatives of polynomials using vector notation. Mathematics managed to cover the materials by using just enough of the information on vectors from third semester calculus to provide what physics needed. Once vectors were covered, engineering graphics covered graphical methods for adding and decomposing vectors and problem solving, and worked on examples other than projectile motion that used vectors. This unexpected turn of events demonstrated that some of the first year content was taken from second year material and vice versa. Essentially, some Post-It© notes were created on demand during the 16-hour meeting.

The posting sessions were highly iterative. The team would post a few weeks worth of material, then discuss and reorganize earlier weeks, then post a few more. It was very much a "three steps forward, two steps back" experience. After our lengthy posting session, our team met at regular times for one to two hours to reorganize material slightly and develop weekly themes. A weekly theme consisted of a title that captured the basic concepts being covered in all subjects that week. Some themes were obvious, whereas others required careful deliberation. The themes were helpful in keeping the faculty members focused on the week's outcomes.

We believe the lengthy posting session was the best way to accomplish our initial integration. Some discussions became very involved and the extended time allocated for the posting enabled us to focus in depth on the problem. The session was not rigidly organized. Teammates essentially stayed for the full 16 hours but moved about the room, formed sub-teams and engaged various members in discussion and debate.

During the summer after the posting session and before teaching the class in the fall, the team worked to refine the actual teaching process. Faculty from all the involved departments worked together to formulate synergistic lectures and activities. By the time classes began, we had prepared most of the course material for the fall semester.

IV. RESULTS & DISCUSSION: THE FIRST YEAR INTEGRATED CURRICULUM

The central goals of the engineering component of the curriculum are:

- to provide the student with skills to perform effective problem solving;
- to help the student develop a logical thought process;
- to introduce the students to basic engineering tools;
- to increase students' spatial analysis skills;
- to help the students develop appropriate sketching skills;
- to teach the students how to read and/or interpret technical presentations; and
- to help the students develop an ability to think both critically and creatively, in an independent and cooperative manner.

The Foundation Coalition provides several additional enhancements to the traditional first year engineering curriculum. Students can be held accountable in all courses for information that is presented in any one of the disciplines because the entire curriculum is highly coordinated. For example, students might fail an engineering examination if they have not learned their Calculus. While the "Problem Solving Methodology" is introduced in engineering, it is continually reinforced in all Foundation courses and students learn how to use their technology tools to solve realistic interdisciplinary problems. Integration of the courses results in the following enhancements to the engineering course:

Time savings allow for team training and team development. It actually takes less time to cover the engineering material.

Students not only know the mathematics and science but also actually understand why they need to know it.

Students develop a sense of community, which means they regularly attend class, study in groups, and help each other.

Preexisting content has been enhanced in the following areas:

- Statics—through coordination with physics
- Curve Fitting—through coordination with mathematics coverage of derivatives to motivate the idea of least error

- Ethics—through coordination with reading and writing exercises in the English component
- Engineering Science—through coordination with both chemistry and physics coverage of fundamental laws

Since the initial design of the first year integrated curriculum, we have modified the material. The most significant changes made were the inclusion of chemistry and a second physics course. The second physics course was integrated with the first one by covering mechanics and electricity/magnetism concurrently, using mathematics to bond the courses together. For example, once the work function is defined for mechanics, it is used for electricity/magnetism as well.

The current calculus-track integrated freshman year of the TAMUFC consists of the courses shown in table 3. Table 4 follows with the current content on a week-by-week basis, and table 5 highlights some of the links in the components of the TAMUFC first year curriculum.

Course	Fall Sem.	Spring Sem.	Total Hours
Chemistry & Lab		4	4
English writing	2	1	3*
Engineering (Graphics and Problem Solving/Computing)	2	3	5
Mathematics – Calculus	4	4	8
Physics – Mechanics & Electricity/Magnetism & Optics	4	3	7
Total	12	15	27

Table 3. The integrated freshman year at Texas A&M.

The pre-calculus track differs from what is shown in table 4 in that it includes an additional semester. This extra semester contains an engineering seminar, a pre-calculus course, chemistry, and electives. Following this extra semester, students move into a calculus-track minus chemistry.

V. CONCLUSIONS

The process used by the TAMUFC to design a cross-discipline engineering, science and English curriculum can be summarized in the following steps (the process consists of iterating through these steps):

- Identify the "traditional" freshman curriculum components.
- Create a detailed list of educational objectives for each course.
- Organize the educational objectives by their commonality to most disciplines.
- Select one course to pace all others. One should consider the creativity and enthusiasm of the faculty when making this decision. For example, if the faculty in a given department cannot imagine their material being revised in any way, then they would be candidates for the pacing course.

wk	GRAPHICS	PROBLEM SOLVING	COALITION PHYSICS	COALITION MATH	COALITION CHEMISTRY	COALITION ENGLISH
1		Introduction to Teaming & Active Learning	Optics, reflection	Maple, functions		Course Introduction
2		Introduction to Problem Solving, Math Models, & EXCEL	Optics, refraction	Graphs, limits		Defining Science, Paper 1 (P1) Thesis
3	Graphical Sketching	EXCEL and Introduction to Table and Graphs	Kinematics, 1D	Derivatives		Roles in Science/Tech, Writing Introductions
4	Sketching Methods and Pictorial Sketching	Significant Figures, Fundamental Dimensions	Equations of motion	Anti-derivatives, vectors		P1 Introduction Workshop
5	Graphical Scales	Least Squares & Derivatives/Engineering Ethics/Projectile Lab	Vectors, 2D motion	Differentiation, rules		P1 Workshop
6	AutoCAD Applications to Vector Diagrams	Ethics and Engineering Job Functions	Forces, Newton's Laws	Trig functions, parametric curves		Engineering Ethics, P1 due
7	Dimensioning /Orthographic projection	Dimensions and Unit Systems	Central forces, systems	Chain rule, related rates		Ethics (cont.), P2 Thesis
8	Teaming/Design Process/Assign a Paper Design	Stress & Strain/Projectile Lab	Fields, superposition	Definite integral		P2 Introduction,
9	TRUSS lab	Statics	Work, Work-energy theorem	Numerical integration, fund. theorem 1D		Documentation, Annotated Bibliography
10	Tolerances of Size & Break-Even Graphs	Statistics and Probability	Conservative forces, potentials	Integrals as areas, line integrals		Integrated Team Project
11	Project Demos	Statistics: The Gaussian & Non-Gaussian	Conservation of energy	Vector fields, gradients		P2 Workshop, Intro Maple Lab

Table 4. Detailed content of the TAMU first year integrated curriculum.

12	Design Documentation	Logical Processing and Using the computer	Electric fields and potentials	Fundamental theorem 2D		Writing Instructions, P2 due
13	Region Modeling/Boolean Operations	Fortran: Constants, Variables and Arrays	Center of mass, cons. of momentum.	2D integrals		Car Project Report
14	Graphic Applications	Fortran: Assignment Statements and I/O	Gauss' Law	Curve sketching		Analysis Memo, Writing Portfolio, Maple Lab
15	Graphics Review	Review Teaming	Capacitors, circuits	3D vectors, max-min	Composition Stoichiometry	"Practicing Science," electronic documents
16		Intrinsic Functions, Subroutine and Function Subprograms	Current, resistors, circuits	Differentials, Newton's method	Reactions And Reaction Stoichiometry	"Practicing Science" (cont.)
17	Region Modeling/Boolean Operations	Selection Structure and If Statements	Velocity and acceleration in polar coordinates	Exponential, logs	Solutions; Acids & Bases	"Applying Technology," Research Papers
18	3D Solids/3D View point	Looping Structure and Do Loops	Magnetic fields, Lorentz force	L'Hospital's Rule, max-min	Light, Energy Levels, Orbitals	"Applying Technology," Research Paper Thesis
19	Output to paper space/Solid Modeling	Looping Structure and While Loops	Torque, conservation of Angular Momentum	Integration by parts, volume integrals	Electron Configuration & Periodic Properties	"Controlling Nature w/Tech"
20	Mass Properties/Design Process	Files and Formatted I/O & Arrays	Moments of inertia, Toque = I alpha	Volumes, moments, centroids	Bonding, Lewis Structures, Molecular Shapes	"Controlling Nature," annotated bibliography, writing exam
21	Area Integration/Solid Modeling	String and Character Data	Ampere's Law	Moments of inertia, polar coordinates	Bonding: Molecular Orbitals, Solids	Integrated Proposals, Workshop Research Intros
22		Explore Options [e.g. spreadsheet to do previous exercise]	Faraday's Law	First order differential equations	Chemical Dynamics: Kinetics & Equilibrium	"Writing to Construct Science & Technology"
23	Sectioning	Choosing Programming Structure	RC,RL, simple harmonic motion	Second order differential equations	Chemical Dynamics: Kinetics & Equilibrium	19th C Sci Fi, Integrated Project Workshop
24	Threaded Fasteners/Design Process and Rendering	Programming Application	Forced, damped oscillator, RLC circuits	Taylor polynomials	Chemical Dynamics: Kinetics & Equilibrium	Modern Science in 19th Century,
25	Design Proposal/Presentation/ Analysis	Programming Application	Heat transfer, ideal gas laws	Logic, limits	Gases	Early 20th C Sci Fi, Workshop Research Papers
26	Geometric Tolerances	Excel - Modules	PV work, first law	Infinite limits, improper integrals	Liquids & Solids	Modern Sci Fi
27		Fortran or Excel or Maple Application	Engines, second law	Sequences, series	Thermo: Energy & First Law	Research Paper Due
28	Design Project – Design Drawings & Demonstrations	Fortran or Excel or Maple Application	Entropy, applications	Convergence tests, Taylor series	Thermo: Entropy & Second Law	Analysis Memo/Portfolio Due, Math History Assignment

Table 4. (Continued)

It is important to work toward increasing the flexibility of all faculty in the project. As a case in point, one faculty member working in the TAMUFC project began with the attitude that nothing in his class could be changed. By the second year of the project, his class was one of the most flexible in the project.

- Determine the prerequisite and support material from other classes for each concept in the "pacing" course. It may be necessary to draw material from more advanced courses to supply the required information.
- Lay out the course material from all departments allowing sufficient time to develop the prerequisite materials in time for the pacing course. During the layout process, the objective is not to develop all the material before using it in another class but to develop enough to enable students to use the information as they work on other subjects.
- Materials that are "left over" are distributed across the semester trying to maintain a weekly theme if possible.
- Revise and iterate.

The multi-departmental, multi-college team of faculty that worked on the TAMUFC applied the process and developed an integrated freshman year. The course descriptions were given in the paper. Retention of students (by our definition, students remaining in the college of engineering are considered retained) was significantly better than in the traditional

wk	GRAPHICS	PROBLEM SOLVING	PHYSICS	MATH	CHEMISTRY	ENGLISH
3				***Derivatives***		
4			**Equations of motion**	VECTORS		
5		***Least Squares & Derivatives/*** *Engineering Ethics/* **Projectile Lab**	VECTORS, **2D motion**			
6	APPLICATIONS TO VECTOR DIAGRAMS	*Ethics and Engineering Job Functions*				*Engineering Ethics*
7			CENTRAL FORCES, SYSTEMS			*Ethics (cont.),*
8		**Projectile Lab**				
9	TRUSS LAB	STATICS				
11				VECTOR FIELDS,		
18			MAGNETIC FIELDS,			
19				*volume integrals*		
20	*Mass Properties*		*Moments of inertia,*	*Volumes, moments, centroids*	*Molecular Shapes*	
21	*Area Integration/Solid Modeling*			*Moments of inertia*	*Bonding: Molecular Orbitals, Solids*	
23			*SIMPLE HARMONIC MOTION*	*SECOND ORDER DIFFERENTIAL EQUATIONS*		
24			*FORCED, DAMPED OSCILLATOR, RLC CIRCUITS*			
25			ideal gas laws		*Gases*	
26			PV work, first law			
27			Engines, second law		Thermo: Energy & First Law	
28			Entropy, applications		Thermo: Entropy & Second Law	

Table 5. Selected highlights of the TAMU first year integration links.

first year. Retention was slightly better for women and underrepresented minorities than white males, but all categories were improved. Scores on standardized calculus and physics examinations were improved. Students were pushed harder in their engineering classes and performed well. Exit attitude surveys indicated acceptance by the general student and faculty member enjoyed the experience as well. Content integration was not the only major change made in the first year curriculum, so direct conclusions cannot be drawn concerning the importance of integration alone, but it is the belief of the faculty involved that integration is a major factor contributing to our success.

It is assumed that the cost of the TAMUFC program may be slightly higher than the traditional curriculum, however a detailed cost analysis has not been performed. Certainly during the transient period of adoption, any new curriculum is expensive. Once our program reaches steady state we expect costs to drop. Some of the contributing factors to the cost include:

- Class size—At present the TAMUFC teaches students in class sizes of approximately 100. This number is slightly larger than the traditional size in some departments but is smaller in others. It is not clear how the costs will break down at steady state.
- Teaching assistance—At present, the TAMUFC uses approximately the same number of teaching assistants as the traditional program.
- Faculty load—We believe the in-class load on faculty will decrease slightly at steady state. The instructor begins to act more as a facilitator than a lecturer. We also plan to experiment with more economic modes of information transfer. One area of increased faculty load is in the coordination required by them. Currently the faculty gather for a weekly 1.5-hour meeting to make sure all the classes remain synergistic. This is an activity that most faculty members are not accustomed to performing. Based on our experience, we believe these activities can provide a method for intellectual cross-fertilization among the faculty and may provide a net positive impact on the university as a whole.
- Student failure rate—In a very real sense, a student failure costs the university. If the student drops due to failure, they consumed resources that are not directly converted to university productivity. Though it may be true that the person is a better citizen because of the experience, it is difficult to measure such benefit. If the student repeats the class, they are consuming more resources than optimal. Since the failure rates in the TAMUFC are lower than in the traditional program, there will be at steady state a more efficient use of resources.

VI. SUMMARY

There are resources available to assist other schools in developing integrated programs of their own. One source of help can be found at http://Coaltion.Tamu.Edu/. Other help can be obtained by contacting one of the authors. It may be possible, in some cases, to schedule a visit to Texas A&M or to have a team visit your campus.

There are several schools that have experimented with and implemented integrated engineering curricula. Experience shows that integrated curricula can be significantly different from non-integrated curricula and involve a large number of departments and faculty. In some schools, it may be difficult to reach consensus on curriculum matters in a single department making a cross department/college collaboration seem practically out of reach.

Statistically significant data are beginning to appear which indicates improved student performance in an integrated program versus the traditional approach. There are also years of anecdotal information available that indicate higher levels of student motivation, performance and satisfaction, as well as improved faculty satisfaction when involved in integrated programs. The authors believe that there is sufficient justification to make developing an integrated engineering curriculum a priority for all schools.

Once a school decides to design an integrated program, the problem of exactly how to coordinate the large number of faculty and departments arises. Although one can find literature that describes the resulting curriculum changes made at various schools, there is essentially no information documenting the design process itself. This paper has addressed this issue.

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