Session 2793

PROACTIVE TEACHING AND LEARNING IN THE AEROSPACE ENGINEERING CURRICULUM 2000

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Abstract

The inception of the Aerospace Engineering Sciences, Aerospace Engineering Curriculum 2000 provided a unique opportunity to introduce the ProActive Philosophy for Teaching and Learning. The curriculum was reformed both in content and teaching methods. It shifted emphasis from compartmentalized basic science, mathematics, and engineering science courses to those designed to integrate topics, provide hands-on experiential learning, and a renewed focus on product design. The new curriculum employs the resources of the Integrated Teaching and Learning Laboratory to incorporate a hands-on component for core undergraduate courses. The ProActive Teaching and Learning Philosophy was implemented with the new curriculum. This philosophy enforces student preparation and capitalizes upon this preparation to replace the conventional, passive lecture with an interactive session in which all students actively participate in topical discussions. In addition, team teaching is now the standard in the sophomore and junior courses.

Introduction

The ProActive Philosophy for Teaching and Learning was introduced with the Aerospace Curriculum 2000 (AE 2000), in the fall of 1997. The new curriculum for the Department of Aerospace Engineering Sciences (AES) was reformed in content and a new teaching and learning paradigm was introduced. Course content reform primarily focused on horizontal integration of the engineering sciences, hands-on experiments, and design in a teaming environment. There is a renewed emphasis on the implicitness of computing and communications. The MATLAB programming environment is incorporated into most courses and writing and presentation skills are emphasized. The Integrated Teaching and Learning Laboratory[*] (ITLL) made the reforms realizable.[2] Seebass and Peterson[9] provide a detailed discussion of the motivations and decisions made in creating the AE 2000. In particular, they acknowledge lessons learned from MIT,[3,4] the Universities of Maryland[1] and Cincinnati[11], and an industry perception of desired attributes of engineering graduates.[5] They also discuss the enabling potential of the ITLL.

The following discussion is in two major parts. First is a discussion of knowledge and curriculum that motivated the ProActive Philosophy for Teaching and Learning that forms the core of the pedagogical reform. This is followed by the second major part, a status report on the

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[*] For a “virtual tour” of the ITLL visit http://itll.colorado.edu.

AE 2000, midway through year five. The sophomore course ASEN 2002 Introduction to Thermodynamics and Aerodynamics is discussed in detail to illustrate horizontal integration, hands-on experiments, design projects, and implementation of the proactive philosophy. Finally, challenges and compromises in maintaining the AE 2000 are discussed.

Engineering Knowledge, Curriculum, and a ProActive Philosophy

Engineering curricula are continuously revised and updated in the United States, usually in response to timely studies of pedagogical reform in the Academy. The full impact of these reforms, however, may not be realized without corresponding reforms in teaching, and the instruments and tools necessary to assess teaching and student performance. In the following, the author proposes ideas, many probably well known, which are essential for engineering curriculum and teaching reform. This is followed by a discussion of the ProActive Teaching and Learning Philosophy

Engineering knowledge consists of three components with the third combining the first two:

1. *Conceptual knowledge* is based on understanding the “framework”, i.e. the concepts and laws, of the physical world. It is more fundamental than the mathematical representation of the basic or underlying laws because it based upon observations and experience. It is derived from basic scientific facts, often after these facts have been observed repeatedly, until they become part of one’s expectation. For example, everyone quickly learns that when an elevated object is released within a gravitational field, it will fall. Likewise, conceptual knowledge includes the observation that heat flows from a hot object to a cooler one. With conceptual knowledge, and provided with a set of circumstances, one can ‘expect’ or ‘predict’ a qualitative outcome. In general, conceptual knowledge does not require a mathematical formulation. However to be applied in general, it must be presented in a mathematical context.

2. *Operational knowledge* is required for the application of methods, tools, and strategies, i.e., knowledge to solve a problem. This type of knowledge includes calculus, differential equations, statistics, etc. and other learned techniques for elucidating the problem at hand with the goal of finding a solution. Thus operational knowledge includes different strategies for approaching a problem such as visualizing the problem with a sketch, diagram, etc. It also includes examining the problem to seek simplifications and approximations. It could involve a possible reformulation of the problem into a simpler one. In engineering, this will usually include the application of mathematical tools to determine a solution. In the classroom environment, operational knowledge is exemplified in the classical homework and exam problems. With operational knowledge, a student can ‘predict’ a quantitative result; however without conceptual knowledge he or she may have difficulty explaining what the result means.

3. *Integral knowledge* is the synthesis of the conceptual and operational. This synthesis is unique to the engineering profession and is essential for technology development. With this knowledge, engineers that *know* can *do*.

Figure 1 is simplistic illustration of the interplay of these types of engineering knowledge with a technology as the product of the application of integral knowledge.

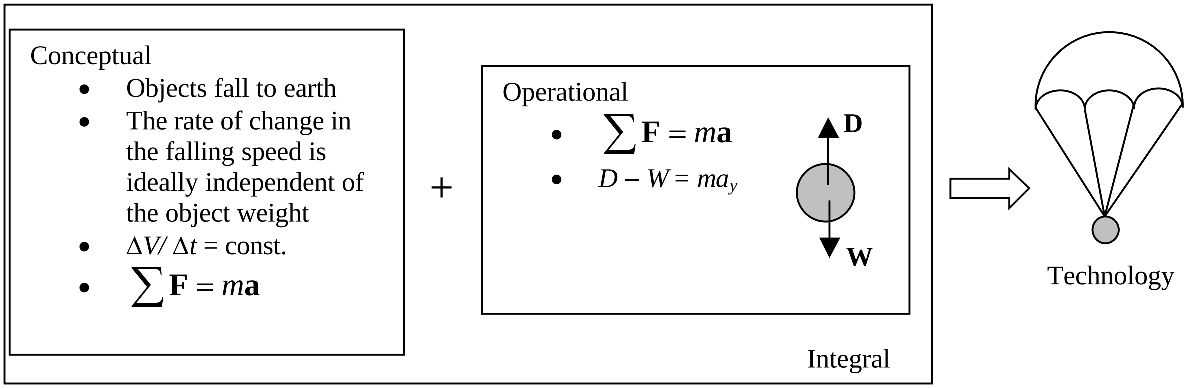

Figure 1 Interplay of engineering knowledge to produce technology.

Most engineering curricula correctly emphasize these components; however, the emphasis is usually discrete, creating a series of distinct, unconnected elements. *Disconnects* arise if one component is emphasized at the expense of the others. At the lowest level of a curriculum, disconnects are evident when students are unable to connect conceptual and operational knowledge. For example, given a function $f(x) = 4x^2 - 1$, virtually any sophomore-level engineering student will compute the derivative df/dx with no difficulty. Change the context, however, to: “Given the function $f(x) = 4x^2 - 1$, if x is changed by some infinitesimal amount, what is the approximate corresponding change in $f(x)$?” and even good students may struggle. This is especially true if the question is asked in an engineering course and not a mathematics course. Regardless of the context, students directly associate concepts with the course label. Although the concept of the derivative was probably presented in the context of a rate of change in a mathematics course, probably even in the context of an engineering example, many students will view it purely as a mathematical operation, devoid of any physical or applied interpretation. This is partly because they have not mastered enough engineering science to appreciate the mathematical formulation of engineering concepts. Once the mathematics course is completed, operational knowledge is usually retained, to some degree. Conceptual knowledge evaporates—if it was ever present. Consequently, engineering students may not see a connection between the concepts of preparatory mathematics courses and engineering courses. They cannot appreciate that mathematics is the language for representing and manipulating engineering concepts in an operational form. The situation is exacerbated when sophomore-level engineering science courses focus on problem solution, i.e., operational knowledge, with minimal emphasis upon conceptual or integral knowledge. Students are shown *how* without understanding *why*, consequently they are unable to generalize to *do* beyond the scope of the assigned problems.

To illustrate these observations, consider assignments and examinations for a typical sophomore engineering science course. Good textbooks are designed to present concepts in textual passages coupled with example problems that display operational details in solution strategies and methods. Students often complete reading assignments with little comprehension of concepts, and little attention to examples—unless they are similar to assigned homework problems. Typical problems again emphasize solution techniques, and with enough examples good students can reproduce the steps to solve specific types of problems, with little understanding of the underlying physical principles. Examinations, typically two or three for the entire course, are patterned after the homework, emphasizing solution techniques. Students usually prepare for an examination, not by carefully reading the text to ensure comprehension but by working as many problems as possible, in the hope that the examination problems will be similar. Based on the criteria of the course, students may excel based solely on their operational knowledge with virtually no conceptual or integrated knowledge.

Conceptual and operational knowledge should *both* be emphasized at every level of the curriculum. Incorporating integral knowledge at every level is not imperative, however. For example, a “traditional” curriculum, generally reserves integral-knowledge emphasis for design and capstone courses. The prerequisite courses are designed to help students achieve proficiency with conceptual and operational knowledge before placing an emphasis upon synthesis and integration. Emphasizing integral knowledge throughout the curriculum, however, helps to eliminate disconnects, enriches the overall educational experience, and encourages students to develop an early “engineering identity.” This is the approach embraced in the AE 2000.

ProActive Teaching and Learning

The ProActive Philosophy emerged primarily from the author’s learning and teaching experiences, and from observing the interactions of instructors, teachers, and students. True teachers supplement instruction and *enable* students to learn. The teacher’s primary objective is to enable students to master the components of knowledge. Thus, a teacher must develop a set of enabling tools and must be able to assess their effectiveness. Enabling students to learn necessarily requires active participation and responsibility for their learning experiences. This is the essence of the ProActive Philosophy:

> *Instruction and learning begin with teacher and student preparation. The classroom is not a place for teachers to show how much they know—the classroom is the place to learn what students do not know so those things become known.*

The proactive approach is aggressive and will expose weaknesses in both students and teachers. Students are active participants in the learning process instead of passive recipients. Teachers must have topical mastery and must be spontaneous with an ability to conduct a classroom session without a script. As the rubric implies, proactive learning requires action before students and teachers enter the classroom. Once in the classroom, everyone is engaged. You will not find newspaper reading or other extracurricular activity in the classroom, unless of course, it is assigned.

Obtaining Student Respect, Cooperation, and Participation

We often discuss pedagogy in terms of curriculum reform, teaching and learning styles, etc. without addressing the classroom environment in a social context. Petroski[8] reflects on the deteriorating behavior of students in classrooms. An engaging learning environment must first have mutual respect between the teacher, students, and student assistants. The author has been approached on numerous occasions for advice on controlling classrooms, especially during the past five years or so. The following are few anecdotal tools and techniques to maintain appropriate conduct in the classroom:

1. Outline all rules, expectations, and goals in the syllabus and take the time to go over the details in the first class. Then stick to this "contract."

2. Learn the students' names as quickly as possible and address them with Mr. or Ms.—no first names. Students view this as a sign of respect and it establishes a level of formality that both they and the teacher appreciate. This "friendly formality" emphasizes that the teacher is in charge and that the students have the teacher's respect in return. Many students have commented that they appreciate this show of respect and even more have commented that they appreciate that a professor has taken the time to learn their name.

3. Openly discuss ethical/nonethical behavior. Make students aware of the consequences of unethical behavior in the classroom, in the workplace, and in society in general. If their behavior is unacceptable, let them know and enforce the appropriate consequences.

4. Require attendance—indirectly. Graded in-class activities, such as unit quizzes (discussed later), group exercises, etc., encourage attendance. Peer pressure and general enjoyment of an interactive classroom also contribute to low absenteeism.

5. The *late-assignment trial* allows the students to enforce their own late-assignment policy. Assignments are due at the beginning of class. Late students must come to the front of the class and state their reason for tardiness. The class then votes by show of hands to decide if the teacher should accept the assignment. This policy puts the fairness issue completely in the hands of the students—the teacher does not have to deal with enforcing a late-assignment policy.

A couple of additional tools that prove useful for keeping students informed and prepared are:

6. The *e-mail update and class log*, in addition to a class website, are very effective tools keeping students informed. After each class, e-mail a summary of the class activities emphasizing and reinforcing the key ideas and concepts. (This should be done as soon after class as possible and should not take more than 10-15 minutes of your time.) Also, a list of assignments, with due dates and reminders can be included in the e-mail, even if this information is also on the class website. Students feel as though the instructor is talking directly to them. The updates are copied to the class log, a file that presents a continuous documentation of daily events. This day-by-day record is a valuable assessment tool.

7. The *question of the day* keeps mathematics and basic science integrated with engineering in the minds of the students. These are usually timely questions that may, or may not, be directly related to the primary discussion topic. Repeated reference to mathematical and scientific concepts helps students continuously integrate conceptual and operational knowledge from requisite science and math courses.

The proactive approach ensures that students enter the classroom prepared to learn and it optimizes faculty-student and student-student interaction. As stated, students often do not prepare for in-class learning, even when it is in their best interest. Most students, however, will prepare if there is an *immediate* negative consequence for lack of preparation. Often they are more responsive avoiding negative consequences than they are at seeking positive outcomes. The timing of the negative consequence is much more important than its magnitude. This is the philosophy of the *unit quiz*, a primary instrument used to emphasize and measure conceptual knowledge. The unit quiz is particularly effective in the engineering science courses that may emphasize operational knowledge at the expense of conceptual knowledge.

The Unit Quiz (a.k.a. the Reading Quiz)

Originally referred to as a "unit quiz" because it is based on a "reading unit," in practice it is often referred to as a "reading quiz." This is an inaccurate description, however, since it involves more than reading comprehension. The unit quiz is the defining tool of the ProActive Philosophy. It is somewhat based on the Socratic method with the modification that there is a mixture true/false statements, and short-answer questions, some requiring operational knowledge. It is designed to immediately determine the things that are unknown and the class discussion is directed to make the unknown known. It also provides some measure of the students' abilities to extrapolate conceptual knowledge to answer questions or come to conclusions that are not specifically spelled-out in the text. Panitz[7] and Mazur[6] discuss a similar approach developed by Mazur. Students may initially be confused by the requirement to extrapolate knowledge. They often think that if they read and retain some facts then preparation is complete. This is why a unit quiz should not be referred to these as a reading quiz. Use of this tool requires teacher spontaneity and an ability to enable a learning experience without a script.

The first requirement for effective unit quizzes is a "readable" textbook, or other primary reading source. (Wankat, P. and Oreovicz[12] present a nice discussion on textbook selection.) The tool is not effective unless this criterion is satisfied. The unit quiz has several functions:

- It requires student preparation before class. Students avoid the negative consequence of a low score by reading for comprehension. After one or two quizzes, the importance of reading comprehension is evident.

- A properly constructed unit quiz promotes discussion of the fundamental concepts and ideas that would be covered in a conventional lecture. The added benefit, however, is that it provides immediate in-class feedback allowing teachers to respond to knowledge gaps. Engaging the students in arguments to defend their responses, gives an immediate indication of their depth (or lack thereof) of understanding.

- Fundamental concepts are reinforced with simple questions requiring illustrative operations that highlight the mathematical expression and application of fundamental physical laws.

The unit quiz requires the teacher to prepare by also reading and comprehending the assigned material to anticipate where the students will have difficulty. The quiz is prepared to highlight the important concepts and ideas presented in the reading, and to probe the depth of comprehension. They must be short, requiring no more than 10 minutes to distribute, complete, and collect for a typical 50-min or 75-min class. As mentioned previously, the questions are usually a series of true/false statements, short-answer questions, and simple mathematical manipulations. Simplicity is paramount, so calculators are not allowed and any calculations requiring a numerical response usually involve only integers and integer ratios.

Immediately after collecting the quizzes, discussion begins with the teacher selecting students to defend their answers—to "get 'em while they're hot." The time to learn is when the students are still mulling their answers over in their minds. If the quiz is collected, graded outside class, then returned at some later time, this opportunity is lost. When asked to respond to a true/false statement, the student must not only state whether the statement is true or false, they must also articulate their reasoning. This is the primary learning experience. If the student answers correctly and gives the appropriate reason for the response, the teacher determines if there is need for further discussion. This is where it is important to observe the class to spot students who do not understand, but are reluctant to ask questions. Generally, once the students become accustomed to a proactive approach, they are less reluctant to ask questions. After the teacher determines that all, or a sufficient number of students, are comfortable with the concept or operations in question, the next statement or question is addressed. The teacher must always be prepared to deliver a mini-lecture. Discussion of a properly designed unit quiz with a mixture of about seven or eight true/false statements, and two or three short-answer and operational questions, generally requires the remaining 40-60 minutes of class time.

If the students can argue that a true/false statement was too ambiguous to be reasonably interpreted, everyone will receive credit. The satisfaction students receive from proving a statement was incorrectly stated is a good motivator. Many students relish an opportunity to "one-up" the teacher. Some true/false statements should be designed to be provocative, even controversial, i.e., the students should perceive it as an intentional trick question. The anticipation of discussing such statements and the ire they sometimes evoke, evidently taps into their adrenaline reserves—often they are literally on the edge of their seats. It is very important, however, that the teacher remain in control and not irk the students to the point that real anger is generated. Finally, because the review of the quizzes presents an opportunity to perform, care must be taken that a few, usually well prepared, students do not completely dominate the discussion. The goal is to have everyone engaged or at least everyone should anticipate that they will be called upon to be involved in the discussion.

The ProActive Philosophy demands that students take responsibility for their learning experience. *Learning does not begin with the teacher—–it begins with the desire and responsibility of the student.* Students should not be passive receptacles of an instructor's unidirectional lectures, destined to become masters of operational knowledge until they are forced to integrate their knowledge in special design and capstone courses. A proactive approach provides a rich, interactive learning experience for both students and teachers, without placing an undo burden upon the teacher. As the students become more responsible for their learning, they begin to impose peer pressure, since classroom discussions and group interactions prevent anonymity. They are reluctant to miss class because they are afraid they will miss something—and they will!

Aerospace Engineering 2000, A Re-Engineered Curriculum

The Need for Reform

Seely[10] discusses the history of education in American engineering colleges:

> *"Recent efforts to re-emphasize design in engineering schools and develop a better balance with engineering science fit into a history that extends further into the past than two decades … the changes being proposed in the 1990s seek to undo an earlier "re-engineering" of engineering education in the United States, an effort that dominated the first half of this century. Those earlier changes culminated in a substantial reworking of engineering education in the period 1945-1965, and brought into place the style that current reformers wish to overturn, or at least modify. It was only after World War II that American engineering colleges completely embraced engineering science as the foundation of engineering education. That decision led to sharp reductions in the time and coursework devoted to practical skills such as drafting, surveying, and other traditional features of engineering curricula. Replacing them were courses in fundamental sciences, mathematics and engineering science."*

The lesson here is:[10] "A good engineer … must strike a balance between knowing and doing." The recognition of this balance was the impetus for the re-engineered curriculum that is the AE 2000; a curriculum with renewed emphasis on design and hands-on learning to balance the theory of the engineering sciences. Horizontal integration of engineering science topics with hands-on and design experiences is a priority. This is within a learning environment where communications and teamwork development is ubiquitous. Specifically, we have:[9]

Established a core curriculum
Integrated the material in this core
Made the curriculum relevant to applications
Made it experiential, i.e., "hands-on"
Integrated communication and teamwork skills into all courses
Provided more curricular choice at the upper division
Implemented continuous improvement procedures

Near the completion of the AE 2000 planning, the Accreditation Board for Engineering and Technology (ABET) announced new guidelines and criteria for program accreditation. The 1997 aerospace engineering program criteria proposed by the American Institute of Aeronautics and Astronautics (http://www.aiaa.org) helped to finalize the first iteration of the AE 2000, particularly the upper-division courses. The outcomes-based AE 2000 assessment plan was in the spirit of that to be used by ABET evaluators. In 1999, the AE 2000 was successfully reviewed by ABET. We view this as validation of the new program plan and implementation.

Table 1 outlines the AE 2000. Fundamental science and mathematics courses, e.g., physics, calculus, etc., are taught outside the Engineering College. These are typically large courses designed to be non-discipline-specific in targeting their engineering audience, so they may service an entire college, or several colleges within the university. The content of these courses cannot be rapidly changed to accommodate the reforms of a single engineering department or school. This arrangement is a common source of the educational disconnects, discussed earlier.

Table 1: Aerospace Engineering Curriculum 2000 for B.S. degree in Aerospace Engineering Sciences, effective fall 2000 semester.

Year	Semester		Credit Hrs	Prerequisite / Co-Requisite (CR)
FRESHMAN	**Fall**			
	APPM 1350	Calculus 1 for Engineers	4	C or better in MATH1100
	ASEN 1000	Intro to Aerospace Engineering*	1	Freshman in Aerospace Engineering
	CHEM 1211	General Chemistry for Engineers	3	One year high school chemistry
	CHEM 1221	General Chemistry for Engineers	2	One year high school chemistry
	GEEN 1400	Engineering Projects	3	Freshman in Engineering
		Humanities/Social Science Elective	3-5	Variable
		Semester Credit Hours	**15-18**	
	Spring			
	APPM 1360	Calculus 2 for Engineers	4	APPM 1350
	PHYS 1000	General Physics 1	4	CR APPM 1350
		Computing Elective**	3-4	Variable
		Humanities/Social Science Elective	3-5	Variable
		Semester Credit Hours	**14-17**	
SOPHOMORE	**Fall**			
	APPM 2350	Calculus 3 for Engineers	4	APPM 1360
	ASEN 2001	Aerospace 1	5	APPM 1360, CHEM 1211/1221, PHYS 1110
	ASEN 2002	Aerospace 2	5	APPM 1360, PHYS 1110
		Humanities/Social Science Elective	3-5	Variable
		Semester Credit Hours	**17-18**	
	Spring			
	APPM 2380	Ordinary Differential Equations	4	APPM 2350
	ASEN 2003	Aerospace 3	5	APPM 2350, ASEN 2001; CR APPM 2380
	ASEN 2004	Aerospace 4	5	APPM 2350, ASEN 2002
		Humanities/Social Science Elective	3-4	Variable
		Semester Credit Hours	**17-18**	
JUNIOR	**Fall**			
	ASEN 3111	Aerodynamics	4	APPM 2350, ASEN 2002, ASEN 2004
	ASEN 3112	Structures	4	ASEN 2001; CR APPM 2380
	ASEN 3113	Thermodynamics & Heat Transfer	4	APPM 2350, ASEN 2002
	PHYS 1120	General Physics 2	4	PHYS 1110
		Semester Credit Hours	**16**	
	Spring			
	ASEN 3128	Aircraft Dynamics	4	APPM 2380, ASEN 2002, ASEN 2004
	ASEN 3200	Orbital Mech/Att Determ & Control	4	APPM 2380, ASEN 2003, ASEN 2004
	ASEN 3300	Electronics & Communications	3	APPM 2380, ASEN 2003, PHYS 1120
	WRTG 3030	Writing Science & Society	3	Junior Standing in Engineering
		Humanities/Social Science Elective	3	Variable
		Semester Credit Hours	**18**	
SENIOR	**Fall**			
	ASEN 4013	Foundations of Propulsion	3	APPM 2380, ASEN 3113
	ASEN 4018	Senior Projects 1	4	Senior standing in Aerospace Engineering
		Professional Area Electives	6	Variable
		Free Elective	3-4	Variable
		Semester Credit Hours	**16-18**	
	Spring			
	ASEN 4012	Aerospace Materials	3	APPM 2380, ASEN 3112, ASEN 3113
	ASEN 4028	Senior Projects 2	4	ASEN 4018
		Professional Area Electives	6	Variable
		Free Elective	3-5	Variable
		Semester Credit Hours	**16-18**	

*Not required, may be applied to Free Elective Requirement
**Programming experience is an implicit prerequisite for ASEN courses ≥ 2000-level. Recommend GEEN 1300-3, or CSCI 1300-4.

Our colleagues in the sciences and mathematics recognize this and make attempts to lend engineering relevance to their topics. Ultimately, however, the responsibility is that of the engineering faculty to design curricula that ameliorate these disconnects. This is addressed in the AE 2000.

The AE 2000 provides maximum flexibility in the choice of professional electives. There is no requirement that any of these electives be AES courses. This flexibility reflects the interdisciplinary nature of contemporary aerospace engineering is evident in. While all AES undergraduates are provided a common “core competency,” the multidisciplinary diversity of AES graduates is quite broad.

Sophomore Year: 2000-Series

The sophomore year of the AE 2000 was the starting point of the curriculum redesign. The 2000-series courses, described here, are the most critical courses in the curriculum:

- ASEN 2001: Introduction to Statics, Structures, and Materials, introduces the fundamental analytical tools for statics and structural analysis in the context of the physics of aerospace materials. Topics include force/moment equilibrium, truss analysis, beam theory, stress and strain, material structure, alloy phase diagrams, polymers, ceramics, composites, and aerospace structural design.

- ASEN 2002: Introduction to Thermodynamics and Aerodynamics, introduces the fundamental concepts and principles of thermodynamic and fluid dynamic systems. The focus is in areas of general importance to the aerospace engineering discipline. The primary goal is the synthesis of basic science (physics), mathematics, experimental methods for quantitative and qualitative analyses and design of general aerospace technology systems.

- ASEN 2003: Introduction to Dynamics and Systems, introduces the principles of particle and 2D rigid body dynamics, vibrations, systems, and controls. The topics covered include kinematics, kinetics, energy methods, system modeling, and simple feedback control.

- ASEN 2004: Aerospace Vehicle Design and Performance, introduces the design and performance analyses of aircraft and spacecraft. Aircraft topics include wings, propulsion, cruise performance, stability and control, structures, and preliminary design. Spacecraft topics include orbital mechanics, orbit and constellation design, rocket equation and staging, launch systems, and spacecraft subsystems.

These courses are the foundation of the AE 2000. They are designed for horizontal integration of engineering science with the practical aspects of contemporary aerospace engineering. A detailed description of ASEN 2002 is now presented as a prototype of the 2000-series.

A Closer Look at ASEN 2002

ASEN 2002 is nominally organized into bi-weekly curriculum blocks, as shown in Table 2. Other 2000-series courses are similarly organized although the details of organization (e.g., frequency of exams, group exercises, etc.) vary.

Table 2 ASEN 2002 bi-weekly curriculum block.

Week	Monday (110 min)	Tuesday (75 min)	Wednesday (110 min)	Thursday (75 min)
1	Experiment & Design Lab	Unit Quiz, Discussion/Lecture	Experiment & Design Lab	Group Exercise, Discussion/Lecture
2		Homework Solutions, Consolidation		Exam

The Monday/Wednesday laboratory activities take place in the ITLL. Student teams are simultaneously involved in experimental laboratories and design projects. Graduate teaching assistants supervise student teams as they are rotated through the experimental apparatus. Groups not involved in experiments are usually involved in design activities. The faculty teaching team interviews each design group. The interview schedule is coordinated with experimental group activities. The faculty team plays the role of project consultants to keep the student teams on task.

Activities in the Tuesday/Thursday lecture period are shown in Table 2. The bi-weekly unit is based on an initial reading assignment. The unit quiz forms the basis of the proactive preparation and classroom activities and it is the focus of week 1. If necessary, discussion of the unit quiz and formal lecture may spill into the Thursday activity. In the first week, the Thursday activity is usually focused upon a group exercise. While conceptual knowledge is the primary focus of the unit quiz, group exercises are designed to integrate conceptual and operational knowledge in the context of timely and relevant engineering problem. Groups are typically given 20 minutes to work the in-class problem. The remainder of the period involves discussing the solution (presented by the first group to get the correct answer, otherwise by the teacher) and any necessary lecture. The Tuesday of week 2 is devoted to consolidating the learning objectives. This includes homework solutions and a review lecture in preparation for the individual examination on Thursday of week 2. The Thursday exam typically takes 45-50 minutes of the 75-minute period. The remaining time is used to preview the next unit.

Table 3 shows the schedule for ASEN 2002 for the fall 2001 semester. The times listed in the activity headings are estimates to help students organize their time. Under the homework heading, reading assignments are chapters from the two textbooks.[1] Experimental labs provide hands-on experience to supplement in-class activities and amplify conceptual knowledge. Experiments are performed in groups, data is shared among group members, and individual reports are submitted. Design projects require synthesis of conceptual and operational knowledge

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[1] C: Cengel, Y A., *Introduction to Thermodynamics and Heat Transfer*, McGraw-Hill, 1997; S: Shevell, R. S., *Fundamentals of Flight, 2nd Ed.*, Prentice Hall, 1989. Note that the Shevell text is also used in ASEN 2004 and the Cengel text is used in ASEN 3113.

into integral knowledge. Group reports and/or oral presentations are required with a peer score accounting for 10% of the individual grade.

Table 3 Fall 2001 Schedule for ASEN 2002.

Classwork (3 hr/week)		**Experimental Labs (2 hr/week)**	**Design Labs (2 hr/week)**	**Exams**	**Homework (15 hr/week)**	
Week	**Concepts/Topics**				**Problem Set**	**Reading**
1	Basic concepts of thermodynamics	Lab safety and procedures			P1	C 1-2
2		E1: Basic Temperature Measurement and Thermodynamic Efficiency • Thermocouples • Reference temperature: real and software compensation • Efficiency of a hairdryer				C 2
3	Properties of pure substances		D1: Large Inflatable Spacecraft Radio Antenna	EX1	P2	C 2
4						C 3
5	Conservation of energy: the first law for closed systems and control volumes (flow systems)			EX2	P3	C 3
6						C 3, 4
7				EX3	P4	C 4
8	Introduction to aeronautics, aerodynamic forces, and dimensional analysis	E2: Bernoulli's Equation, Flow Measurements, and Low-Speed Wind Tunnel Testing • Flow meter comparison • Intro to wind tunnel testing • Pitot static probe and flow speed • measuring pressure distribution on a circular cylinder.l				S 1-3
9	1-D incompressible flow			EX4	P5	S 4-6
10	1-D compressible flow					S 7
11			D2: Sounding Rocket—X - Prize	EX5	P6	S 7
12	Two-dimensional flow: lift and drag	E3: Pressure and Lift Measurements, Viscous Flows • How wings produce lift • Viscosity measurement and comparison				S 8
13				EX6	P7	S 8
14	Viscous flow					S 10
15				EX7	P8	S 10
16	Summary & Review					

Challenges and Compromises for AE 2000

Team Teaching

As previously discussed, the reforms embodied in the AE 2000 are not just related to the content and sequence of courses, a new teaching paradigm was also introduced, of which the ProActive Philosophy was but a part. A major teaching challenge was the decision to team-teach the requisite courses in the sophomore and junior years. This is a significant, and potentially threatening, change for some of us educated, and educating, in a traditional curriculum. It has been, however, one of the most successful and rewarding aspects of the new teaching paradigm—both for the students and the faculty.

Assessment

As expected, proper assessment presents a formidable challenge. AES is pursuing a multi-pronged approach to assessment that includes outcomes assessment for each core course, graduate surveys, student review teams, and other instruments. This is the least developed and implemented part of the new program plan. At the heart of the assessment effort is an outcomes-based assessment tool used to map assignments according to the desired outcome and learning goals. This is essentially a spreadsheet that allows content mapping and weightings to insure learning goals and desired outcomes are achieved. When individual grades are distributed onto this spreadsheet, students and teachers receive direct feedback to determine areas of strengths and weaknesses. In the end, this tool provides information on the overall effectiveness of the course, specifically the general areas of strength and weaknesses. This is then the basis for a continual improvement feedback loop for course content. It also allows teachers to assess their methods in achieving the desired outcomes.

The primary challenge of this assessment tool is the diligence required to make it effective. Teaching assistants, trained to assist in using the assessment tools, have made the process manageable. We continue to work to incorporate the assessment tool along with traditional surveys, etc. and to streamline the assessment process.

Resources and Facilities

Resources and facilities constrain curriculum integration. While faculty may control teaching and learning paradigms at the department level, overall space and resource allocations are generally administered at the college-level. The needs of a unilaterally re-engineered curriculum may not fall into categories used in college budget formulas, and if they do, they may appear exaggerated compared to the needs of conventional curricula. Conventional lecture/recitation engineering science courses are less expensive than a course that integrates these components, in terms of faculty-student contact time, teaching assistants, and experimental and computational facilities. This was evident during the planning of the AE 2000. The ITLL is critical in enabling the delivery of the AE 2000. The ITLL, however, only addresses a portion of the resources and facilities issue. Faculty must be compensated for developing new courses to maintain a selection of relevant professional electives, and continuous development of a relevant hands-on component. Expendables become a recurring issue for a hands-on curriculum. Graduate teaching assistants are required in larger numbers and they must be prepared to deal with a teaching paradigm that may be very different from that where they obtained their degrees. These are but a few of the manpower and resource issues that had to be addressed for the curriculum re-engineering. Seebass and Peterson[9] discuss the external fund raising effort to develop and sustain the AE 2000.

Conclusions

In 1997, AES introduced the Aerospace Curriculum 2000. This new curriculum provided an opportunity for reformation of the teaching and learning paradigm to employ the ProActive Teaching and Learning Philosophy. The new curriculum has been reviewed by ABET and continues to receive praise from peers, industry, the AES External Review Board, and most importantly, AES graduates. Many AES faculty are invigorated by the proactive approach, it has added new energy to a curriculum that is now dynamic in content and methods of delivery.

Any endeavor worth pursuing will always have enduring challenges. One of the most important issues addressed in re-engineering the curriculum was acknowledgement that the AE 2000 would require a substantial increase in both physical and financial resources, and teaching effort. The teaching-effort issue was addressed; the AES faculty accepts the increased contact time with students and the increased loads associated with delivering a hands-on curriculum with increased emphasis on design. This was not an easy decision to make for a department also recognized for its research output. We feel, however, that it is the correct decision. Realistically, there will never be enough physical space or state-based funding, so garnering external support will remain a challenge. The Integrated Teaching and Learning Laboratory is a fantastic facility, however the entire College shares its 34,400 square feet. Presently, AES dominates the use of this facility, and as more departments begin to fully exploit its capabilities, it must be expanded.

Space prevents a more detailed description of the upper-level courses in the AE 2000, particularly the Senior Projects courses, and details of our primary assessment tool. These topics will be addressed in more detail in upcoming publications. Because of the dynamic nature of the AE 2000 and the efforts of continuous improvement, be assured that the story to be told in the future will also be improved.

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