Learning More From Class Time: Technology Enhancement in the Classroom

Marilyn J. Smith, Narayanan Komerath
School of Aerospace Engineering, Georgia Institute of Technology

Abstract

The traditional classroom lectures in engineering do not permit professors or students to keep pace with technological changes within rapidly changing disciplines. By using technology, the classroom lecture can be modified so that class time becomes a laboratory of learning and *reinforcement through iteration and application*. This approach is also very timely since it directly develops the engineering attributes set forth in ABET 2000 Criterion 3. Traditional teaching methods have relied on the Capstone Design classes to fulfill the tasks of tying four years of learning together, as well as to fulfill the ABET 2000 Criterion 3. The methods described herein permit effective implementation of the ABET guidelines across many classes using technology as the leveraging tool.

This paper discusses how this methodology was developed for two senior-level classes: Vibration and Flutter (required core class) and Flow Diagnostics (an elective class). The paper describes in further detail the classroom experiences, examples of the implementation, and the results of the assessment. Positive and negative factors from teacher and student viewpoints are also discussed, including the Hawthorne effect and how students with different learning styles behave with respect to the new methodology introduced in these classes. While the two classes discussed herein are Aerospace Engineering classes, the techniques are applicable across any engineering discipline.

I. Introduction

The rapid pace of technology has created a dilemma for engineering educators. There is a certain amount of core theoretical material that must be covered so that a basic understanding of the mathematical and physical principles are understood by the student. The students may develop the "ennui" syndrome while learning this material, which may ultimately lead to retention problems. In addition to the core material, there are always new research developments that change or extend the course topics, which must also be squeezed into an already full course curriculum. Finally, it has always been a priority of professors at Georgia Tech to introduce some applications to develop the "practical" skills of the students. The ABET 2000 Criterion 3[1] recognizes the importance of this as a goal[2].

One weakness in many engineering syllabi is that most of the "practical" applications are left to the senior Capstone Design courses. Thus, the student gains the false impression that design is where all of the "exciting" and "practical" work is performed. This false impression can have two major impacts. First, the student may not interview well in areas other than design. In addition, this can lead to a large pool of students designating their field of interest as design in graduate school, unaware of areas where much of the discovery and innovation of engineering occurs.

These two classes, while taught at approximately the same undergraduate level, contain differences in the student population. *Vibration and Flutter* is a required core course in the undergraduate curriculum. Thus, the students in the course exhibit both learning- and performance-oriented behavior[3]. The learning-oriented students typically welcome new challenges, while performance-oriented students tend to be more concerned with outcomes such as grades. *Flow Diagnostics*, as an elective course, is typically populated by more learning-oriented students who wish to be challenged and to learn about new material. Because both these classes occur late in the undergraduate experience, indications of the Hawthorne effect[3,7] (reaction of students to a new methodology of teaching) were also evaluated.

The development of these classes was based on the requirements of ABET 2000, as well as the industrial and research experience of the professors. Different approaches that best met the needs of the course material were evaluated in the classes, and feedback from students was obtained. In addition, the student performance (grades) in the classes were correlated with the level of learning.

II. Course Technical Descriptions

Vibration and Flutter (Aeroelasticity)[4]

The first course considered in this paper is a senior-level, required course in Aerospace Engineering. It is characterized by both students and faculty as a very "tough" class because of its interdisciplinary nature. Students are required to recall major elements of theory from dynamics, structures, fluid mechanics, aerodynamics, and differential equations in order to solve problems and develop the underlying theory. The course has no reference textbook, but rather a set of printed notes developed by senior Aerospace Engineering faculty over the past 30 years is provided. Students were required to take a pre-requisite senior-level mathematics course in advanced engineering mathematics that encompasses Fourier series, boundary value problems, Bessel functions, and Legendre Polynomials. Generally, the attitude of the students entering this course depended greatly on their experience in the mathematics course.

Flow Diagnostics

The second course is a senior elective course on Flow Diagnostics, where students must learn across several disciplines such as laser optics, digital signal processing and turbulence to develop and conduct their own experiments. It is simply not feasible for students to have taken courses in all the “pre-requisite” disciplines, so the student has to learn, during the course, to acquire, distill and apply knowledge from other disciplines where they have never taken a course. This course also had to overcome many of the difficulties of implementing advanced laboratory courses in a research university setting[5]. Here, internet resources were provided to the student, along with focused introductions to each area, so that they easily grasp the current state of the art, and find information from research resources. The experience of this class is also discussed.

III. Course Modifications and Outcomes

Vibration and Flutter

This course was modified to incorporate technology in a manner so that learning was reinforced by a number of methods. This course served as a good test case because it relies heavily on previous material in other courses, yet a portion of the material is new to the student, requiring derivations to understand the methodology. Two classes (Spring 1998 and Spring 1999) were used to provide feedback on the modified approach. Limited data from class 1 (Spring 1998) were used to develop a more comprehensive anonymous survey for class 2 (Spring 1999).

The approach taken in this class is depicted in Figure 1. Full-time lecturing has been replaced by assigned pre-lecture reading and augmentation of notes through the Aerospace Digital Library (ADL).[6] Instead, lectures are based on questions from the pre-assigned reading or explanations of traditionally difficult material. The time freed from lecturing is now spent by giving demonstrations of current research related to the topic, problems that are worked in groups or interactively with the professor, or hands-on demonstrations. Traditional homework problems were augmented by writing & running codes relevant to specific problems, as well as a group project. The overall correlation of the student response appears to be weighted (though not 100%) with respect to the student's experience in the Math prerequisite, as shown in Figure 2. If the student had a poor experience in the prerequisite, he/she was more likely to have a more negative perception of this class than students who had a positive experience in mathematics were. Each of these responses are further discussed and evaluated in the following sections.

a) Pre-Assigned Reading - Motivation

The question that faces each professor when giving non-graded material for homework is how to motivate the students to do the assignment. For this class, only the material covered in the upcoming lecture was assigned, typically 3 to 5 pages of the printed notes. Approximately 50% of the class are typically graduating seniors, so a technique recommended in Reference 7 was employed to combat "senioritis". This technique used a positive reward concept. At the beginning of class a simple question on the reading content from the previous assignment was asked. Students wrote their answers on a slip of paper and passed them to the professor. A correct answer was given a “1” and a wrong answer a “0”. These results were added throughout the quarter. At the end of the quarter these points were added to the students final homework average, which was approximately 25% of their total grade. These “quizzes” were given randomly, and not every class period. At the end of the quarter, students were asked to write their thoughts on this as part of the review process. Interestingly, the two classes had different opinions on these quizzes, as seen in Table 1.

Table 1. Response of Students to Motivational Quizzes on Outside Reading

	Class 1	Class 2
Positive	45%	31%
Negative	20%	69%
No Response	40%	0%

Correlation of the data with the verbal comments indicates that the positive comments came from the students who did read the material, while the negative comments came from students who "had too many other things to do", or who felt that the questions were too specific (e.g., the name of an important equation, such as the wave equation). Interestingly, one of the most common positive comments from students was that the reading helped her/him to better understand the material and that it helped in preparing for the homework and quizzes.

As part of the class, explanations for topics that should have been learned in previous courses were referenced using the Aerospace Digital Library (ADL). Math, fluid mechanics, structures, and dynamics topics were available without requiring the student to visit the library. These links became more important as it became apparent that a number of students had sold their math and dynamics textbooks once their classes were completed. Additional information on this topic is included in Reference 6.

b) Engineer-In-Training Problems

The ABET 2000 Criterion 3 (Program Outcomes and Assessment) list several characteristics which are desirable in graduating engineers:

- An ability to apply knowledge of mathematics, science and engineering
- An ability to design and conduct experiments, as well as to analyze and interpret data
- An ability to identify, formulate and solve engineering problems
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

A series of problems, which were designated as engineer-in-training (eit) problems were developed to help develop the skills listed above. Typically, a problem was introduced in class where, as a class, the correct methodology to solve the problem was discussed. This might include important parameters, numerical methodologies, accuracy, engineering assumptions, etc. The students were then given the problem to solve at home as homework. Not only were the results expected to be handed in, but a discussion of the engineering observations and conclusions reached were also expected. As an example, the students were asked to determine the number of modes that were required to match a particular shape given the loading of a beam or string. The exact shape may or may not be provided. The students had to numerically program the problem, typically in MATLAB, and determine how many modes were required to model the problem. Here, they had to analyze the data and determine what was a suitably accurate engineering approximation. Since there was no one answer, some thought was required. In addition, students learned about diminishing tradeoffs in accuracy versus numerical requirements.

The response to these problems was very positive from class 2 (no quantitative data was available from class 1). 72% of the class was receptive to the problems and felt that they were learning to make better decisions. Only 15% of the class were not receptive, primarily from comments that they felt their overall workload (in all classes) was too high. Another concern cited was that there was no definitive answer (i.e., a number), and so the problems required much thought on their part. 13% of the class had no opinion about the effectiveness of these problems.

c) Classroom Demos/Current Research

A knowledge of contemporary issues was cited as one of the ABET 2000 criteria for young engineers. This goal was accomplished through the introduction of current research performed by the professor and other researchers into the classroom lecture time. This material was not graded, but was provided to give a flavor of how their classroom experience related to "real" problems. For example, when discussing modal analysis and mode shapes, examples of the classic aeroelastic test case, the AGARD445.6 wing were shown to the class and CFD results for rigid and flexible (aeroelastic) cases were discussed. Papers were not handed out, but rather links to papers and library search results were provided, which could later be used on their project.

As seen in Figure 2, there was almost 100% agreement (yes) that this was beneficial in understanding the class and its objectives. From the written responses to the question, most students asked for even more examples and noted that it was very useful - while they were still learning the material - to see that it is used, even when they did not understand all the details. The minority opinion that it was of no value came from students (with two exceptions) who did not provide any positive comments on the class or their math experience.

d) Group Project

This project was developed to provide exposure to the ABET 2000 outcomes of

- an ability to function on multi-disciplinary teams
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- a knowledge of contemporary issues

Groups of four students were assigned together based on their common interests in several topics provided as project assignments. The topics were developed from current research topics, but were designed to be broad in scope to allow student creativity. In class 1, a group presentation was made to the class, while in class 2, set of web pages was designed. When the projects were turned in, students were given the chance to grade each other's performance on the team, so that some students received different grades on the same team. This provided a measure of ethical and professional responsibility when working on team projects.

Again, the majority of the response was positive, with a 31% negative response. In 80% of the negative responses, the reason cited was simply the timing of the project. Several classes had exams or other presentations due during the same week. The project was assigned with 6 weeks notice, but time-management is apparently a problem at the senior level.

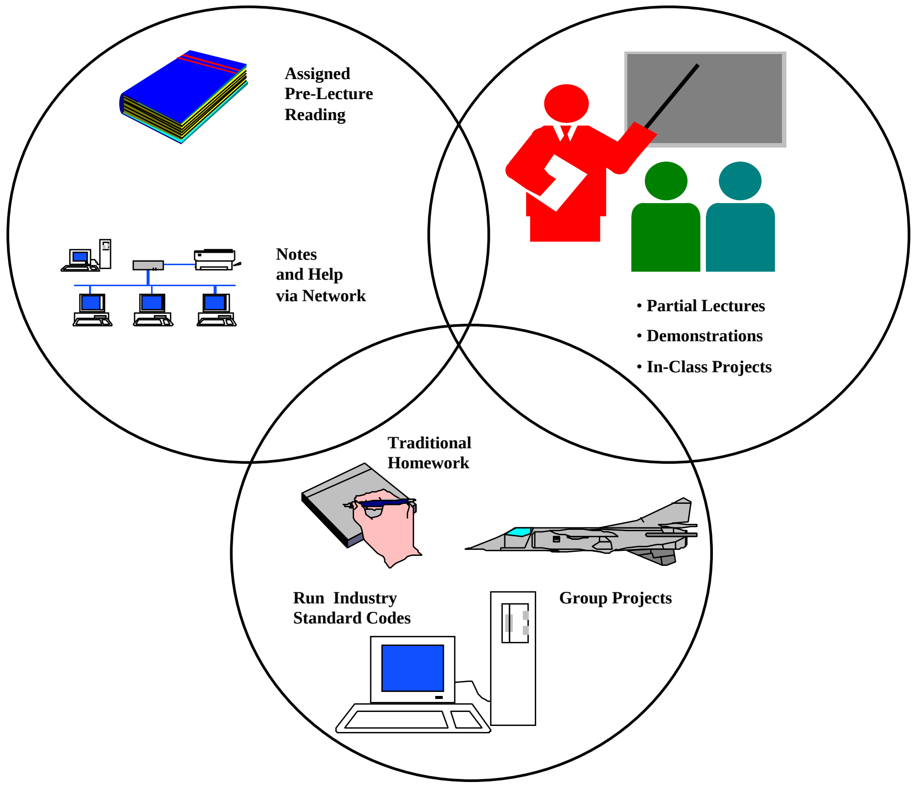

Figure 1. Augmentation of Classroom Experience Through Technology

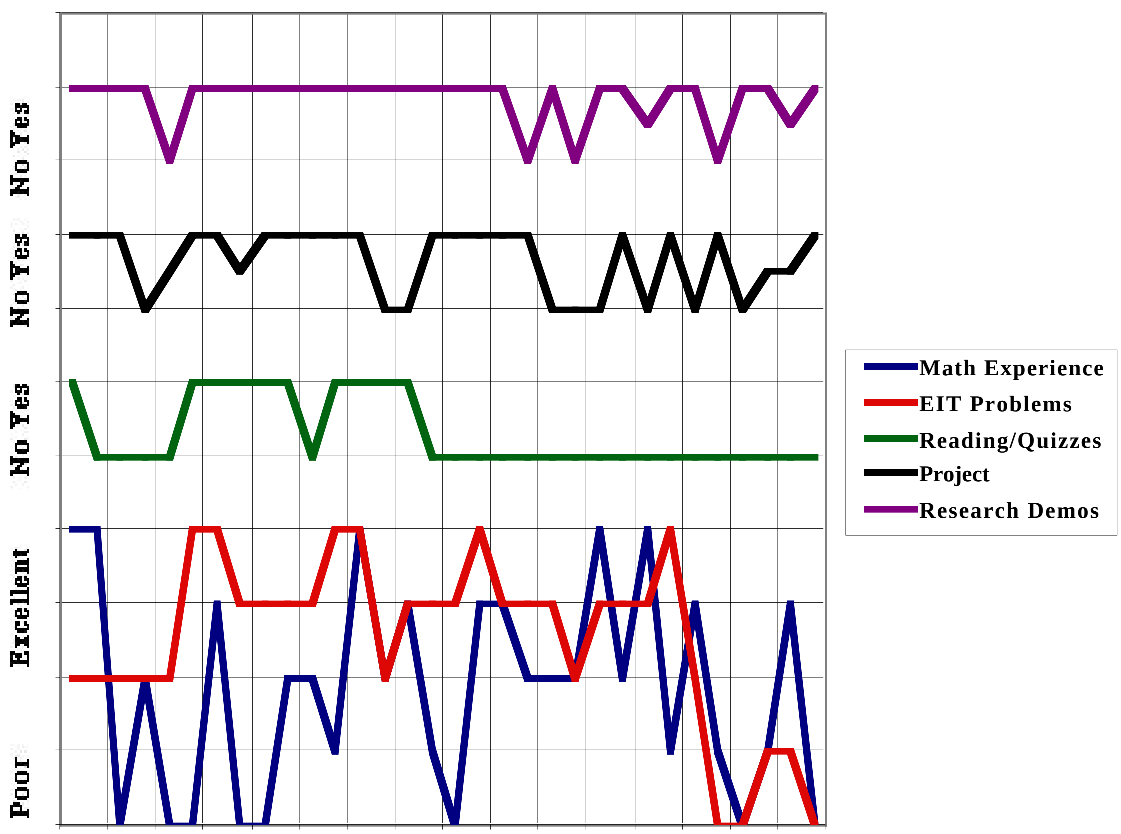

Figure 2. Correlation of Individual Student Response to Various Aspects of the Modified Teaching Method in Vibration and Flutter (Class 2 - Spring 1999).

AE4010: The Flow Diagnostics Course

The second aspect of technology usage in courses is considered in the context of a course on Flow Diagnostics. In this course, students must learn a substantial amount of the theory, principles and analytical methods behind advanced diagnostic technique. Yet, in the space of an 8-week Quarter, teams of 2 students each, also have to set up, operate, and analyze one research-grade experiment, as well as use and understand the experiments developed by all the other teams in the class. Here, technology comes into play in all aspects, from finding information and knowledge across disciplines and levels, to conducting experiments, analyzing results, creating their own web resources to let others use their work, and reporting on the work in classroom presentations. The course is generally conducted in a multi-media-equipped classroom, where the students and instructor can access the internet, and project material onto screens. The speakers in the room are also used to demonstrate such things as changes in frequency of sound as a diagnostic of flow effects.

In the early 1990s, an NSF ILI/LLD project[5] enabled the second author to crack the problem of introducing such advanced laboratory courses at the undergraduate senior elective level. These courses solved two difficult problems of the traditional curriculum:

1. There were no students "TAs" qualified to conduct the experiments in these labs, where each experiments was directly linked to research leading-edge problems.
2. Advanced diagnostics and flow control experiments required knowledge of a considerable amount of theory, and the different teams in a class had to work on experiments derived from various aspects of the course. In a sequential lecture mode, some of the required theory would have been learned far too late to allow the relevant team to develop their experiment.
3. There were no instruction manuals of monographs for these experimental courses, where every project was an innovation.

In such courses, it was shown that empowering the students paid off handsomely, as they learned by iteration to develop the experiments and the manuals for the experiments, and then served as the experts on each experiment to help the others in their class use each experiment. By the end of the quarter, each experiment had its manual, a well-organized set of instructions on the experiment, along with a documentation of the difficulties experienced, to guide future users.

The difficulty with sequencing lectures was solved by dividing the course lecture content into 3 sections. Students were asked to keep notes in 3 sections, too, so that lectures in these 3 areas could be interspersed to suit the scheduling constraints of the experimenter teams.

A list of experiments is given in Table 2 for both of these elective courses.

Learning Across Levels and Disciplines

In 1998, the Aerospace Digital Library[6,8] was brought into use in these courses. The full notes for each of these courses was developed on the internet. Students who browsed these note pages were heard to remark that the pages gave them the "uncanny feeling of listening to old so-and so teaching".

The course content and assignments can be accessed at:
http://www.ae.gatech.edu/research/windtunnel/classes/flodiag/gen/ae4010.html

The ADL was also used to introduce cross-level, cross-disciplinary learning. First, the Flow Diagnostics course used the Glossary Pages and links of the American Institute of Aeronautics and Astronautics' Technical Committee on Aerodynamics Measurements (AIAA AMT), which at the time were being managed by the second author's research team. Students were asked to study and discuss various advanced diagnostic techniques from descriptions written by practicing experts.

Each experiment team was also asked to prepare their own web page, and these were linked to the ADL pages. Each web page was to serve as a comprehensive resource for that experiment. The links are given in the table, and the reader is welcome to explore these. This process served to explore the development of systematic knowledge bases through student work on the internet, linked across disciplines and levels using the ADL.

Table 2. Experiments Performed in the Flow Diagnostics Classes

Experiment	Tools / techniques	Theory
Perpendicular interaction of a vortex with a wing. Winter '99	Light sheet visualization, video image processing, wind tunnel operation; model alignment and pressure measurement	Vortex Aerodynamics; airfoil aerodynamics;
Acoustic Shaping: signal processing. W'99	Sound measurement; spectral analysis	Digital signal processing.
Acoustic Shaping: flow vis & numerical modeling	Videography	Acoustics; fluid mechanics
Laser-based surface measurement on a parafoil.	Laser sheet imaging; precise angle measurement; wind tunnel experiments; video analysis	Photogrammetry; laser optics; parafoil aerodynamics.
Turbulence in the 42" tunnel.	Tufts; video; Hot-film and microphone surveys: spectra, cross-correlations.	Turbulence, flow separation, Digital signal processing.
Flow and sound measurements in the Acoustic Shaping experiment	Spatial Correlation Velocimetry with argon ion laser. Microphone spectra Matlab simulations of sound & velocity fields	Digital image processing; signal processing for cross-correlations and spectra. Acoustics.
Periodic flowfield of a fan	Fan performance: orifice meter; inclined-tube manometer. Power measurement. Phase-resolved Laser Doppler Velocimetry.	Prediction & verification of turbomachine performance. Turbomachine velocity diagrams Fluid mechanics.

In each of the experiments listed above, the students had to work in teams, and coordinate activities with the schedules of graduate students as needed for facility safety and operations. They had to survey the relevant research literature and find what they needed for their experiment. They had to develop project plans from given specifications and deadlines, discussing these with various people. They learned to make their own drawings to get parts built in the machine shop, dealing interactively with the machinists. They learned to do the experiments, with a good deal of preparation as well as several iterations, going through periods of great frustration until they got the variables under control, and learned to live with the imperfection of the experimental results. The analysis techniques had to be applied, days after learning the theory in the classroom. At the end of the 8-week course, they had to distill their experience into a presentation before the class, with the instructor asking the hard questions that they very well knew to expect, as well as questions that they had never thought about.

Impact of the course

The number of students taking this experimental course is small, and does not permit meaningful statistical surveys. The impact of the course is measured in terms of

1. The excellent graduate students that GIT is able to recruit through this mechanism: all recent students in the Experimental Aerodynamics Group have taken this course, either as undergraduates or as graduate students. The Ph.D. theses from this group have been selected by the school thesis nomination committee as being in the top 10% of theses from the school for that year, every year that there was someone graduating with a pH from this group: 6 in the past 7 years. Of these, 3 have been selected by the Institute thesis review committee in the top 3 or 5 theses in the Institute, a top 1% ranking.

2. The impact of the experimental work itself:

a. The Acoustic Shaping diagnostics experiments performed by the AE4010 team in Winter 1997 went directly into the successful flight experiments[9] by a team of sophomores (who had taken no classes on acoustics) in April of that year, and in the following year[10]. Acoustic Shaping diagnostic experiments in Winter ’99 enabled us to design the more advanced flight experiment for the ’99 flights, also successful[11].

b. The parafoil photogrammetry experiment in Winter ’99 enabled wind tunnel experiments later that year on a NASA grant to study the dynamics of parafoil operation, as part of a study on the NASA X-38 Crew Return Vehicle. The parafoil experiments were the first to show the detailed mechanism of the observed nose lip collapse phenomenon, and led to its resolution. The EAG was awarded a letter of recognition by NASA Johnson Space Center for this contribution. The photogrammetry work was also published in an AIAA Conference Paper[12] in January 1998.

c. The fan flowfield experiments led to results that enabled Nidec Corporation to refine the design of a later-generation fan, enabling a significant reduction in noise and improvement in efficiency.

d. The wing-vortex experiment is part of a continuing research project funded by the US Army Research Office.

e. The systematic study of turbulence sources in the low-speed wind tunnel has led to a substantial reduction in tunnel noise and turbulence level, and an accompanying increase in the top speed of the tunnel from 50 fps to 85 fps. The recommendations of that study continue to be implemented.

IV. Conclusions

From these classroom experiences, it is evident that technology can be utilized to enhance the classroom experience for the students, as well as to satisfy the new ABET 2000 outcome criteria. This experience need not be relegated only to the Capstone Senior Design classes, but with some thought can be incorporated into other classes as well.

Classroom demonstrations using the computer or the internet are very well received, as are group assignments using the internet as the forum. The problem of "clearing" enough lecture time in order to permit these items can be met by requiring incremental reading assignments, but it is clear that the students need to be introduced to this concept at an early stage in their engineering education. Likewise, problems that require thinking or that have no definitive answer should be introduced earlier so that the students' thinking skills are honed prior to graduation.

In the required senior level course, it was apparent that although most students felt that they benefited from the experiential opportunities provided during class time, many were still very resistant to preparations outside of class (reading material that was previously class lectures). Because this method of teaching is different than the traditional methods utilized in other core courses, it appears that the Hawthorne effect is apparent when new methods are introduced at such an advanced level in the curriculum. It is noted that this effect was only obvious in the required course; student opinions on the elective course did not reflect the same attitudes. This may be because the elective class was taken only by students who were learning-oriented, as opposed to the required course, which contained both performance- and learning-oriented students.

In experimental courses, internet and multimedia technology becomes a natural asset in finding knowledge across disciplines and levels, as well as presenting experimental results. Technology facilitates group projects, enabling people with different schedules and other constraints to share information and work as effective teams.

Bibliography

1. "Criteria For Accrediting Engineering Programs," URL: http://www.abet.org/eac/EAC_99-00_Criteria.htm
2. Tooley, M. S., and Hall, K. D., "Using a Capstone Design Course to Facilitate ABET 2000 Program Outcomes," ASEE Paper, Session 1625, 1999 Annual Conference of the ASEE.
3. *How People Learn : Brain, Mind, Experience, and School,* Committee on Dev. in the Science of Learning, Commission on Behavioral and Social Sciences and Education, NRC, http://bob.nap.edu/books/0309065577pre/html/, 1999.
4. *General Catalog 1997-1999,* Georgia Institute of Technology.
5. Komerath, N.M., "Experimental Curriculum in Diagnostics and Control of Unsteady Flows", *Journal of Engineering Education*, Vol. 85, No. 3, July 1996, p. 263-268.
6. Komerath, N.M., Smith, M.J., Bodo, B., "Learning Across Disciplines: The Aerospace Digital Library", Session 2793, ASEE 2000 Annual Meeting, St. Louis, MO, June 2000.
7. McKeachie , W. J., Teaching Tips, D. C. Heath and Company, Lexington, MA, 1994.
8. Aerospace Digital Library, URL: http://www.adl.gatech.edu

9. Wanis, S., Akovenko, J., Cofer, T.,Ames, R.G., Komerath, N.M., "Acoustic Shaping in Microgravity", AIAA Paper 98-1065, 36th Aerospace Sciences Meeting, Reno, NV, January 1998.
10. Wanis, S., Sercovich, A., Komerath, N.M., "Acoustic Shaping in Microgravity: Higher Order Modes", AIAA Paper 99-0954, 37th Aerospace Sciences Meeting, Reno, Nevada, January 1999.
11. Wanis, S., Matos, C., “Acoustic Shaping : Application to Space-Based Construction”, AIAA Paper 00-1020, 38th Aerospace Sciences Meeting, Reno, Nevada, January 2000.
12. Matos, C. A., Mahalingam, R., Ottinger, G., Klapper, J., Funk, R. B., and Komerath, N.M., " Wind Tunnel Measurements of Parafoil Geometry Aerodynamics", AIAA Paper 98-0606, 36th AIAA Aerospace Sciences Meeting, January 1998, Reno, NV.

Biographical Information

MARILYN J. SMITH, Ph.D.
Marilyn J. Smith earned her Ph.D. in aerospace engineering at the Georgia Institute of Technology in 1994. She joined the faculty as an Assistant Professor in the School of Aerospace Engineering at Georgia Tech in 1997 after fifteen years of industry experience at Lockheed-Georgia (now LMAS), McDonnell-Douglas Helicopter (now Boeing Helicopter-Mesa), and the Georgia Tech Research Institute. She was awarded the 1999 Outstanding Faculty Member by the GIT Women's Leadership Conference. She is an Associate Fellow of AIAA and a member of the AHS Fluids Technical Committee.

NARAYANAN KOMERATH, Ph.D.
Dr. Narayanan Komerath, Professor in AE and director of the John J. Harper wind tunnel, leads the Georgia Tech Experimental Aerodynamics Group (EAG). He has taught over 1600 AEs in 19 courses in the past 15 years. He is a principal researcher in the Rotorcraft Center of Excellence at Georgia Tech since its inception in 1982. He is an Associate Fellow of AIAA. He has won GT awards for Outstanding Graduate Student Development, Outstanding Ph.D. thesis advisor, and Most Valuable Professor (GTAE Class of '91). EAG research projects have enjoyed the participation of nearly 100 undergraduates over the past 14 years. EAG is a leader in multidisciplinary team-oriented projects, including the Aerospace Digital Library Project at Georgia Tech: http://www.adl.gatech.edu