An Integrated Approach To Engineering Education In WPI's Discovery Classroom

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*An integrated analytical - numerical - experimental approach to engineering education has been developed and implemented in introductory fluid-thermal science courses at Worcester Polytechnic Institute (WPI). Central to the implementation of these innovations is a facility at WPI known as the Discovery Classroom. In this facility the traditional lecture hall is redefined to combine a multi-media classroom, an adjoining experimental laboratory, and computational facilities. We have designated the approach using this facility as the DIANE philosophy: **D**aily **I**ntegration of **A**nalytical, **N**umerical, and **E**xperimental methods into engineering classes. In a typical application, experimental apparatus are demonstrated directly in class during an engineering lecture. Real-time quantitative data are acquired from the apparatus, and the data are analyzed and compared to concurrently developed theory by the students in class. The objective of this approach is to help students better understand relationships between the physical experiments and theory. Three introductory undergraduate engineering classes at WPI, fluid mechanics, heat transfer, and aerodynamics, have been re-designed using this approach. Student assessment of the innovations indicates that approximately 90% of 275 students prefer the re-designed courses to traditional lecture-oriented courses, while also believing that they gain a better understanding of engineering fundamentals.*

THE INTEGRATED APPROACH

Over the past few decades, there have been dramatic changes in the way engineering principles are applied to practical problems in industry. Increasingly, an integrated approach using analytical, experimental, and computational methods is being utilized. The development of powerful digital computers has been one prime mover in these changes, with computational algorithms now often replacing experiments as primary analytical tools. However, experimental testing still plays a crucial role in engineering design. Additionally, the analytical (exact solution) approach still has an important place in bringing intuitive insight into a problem.

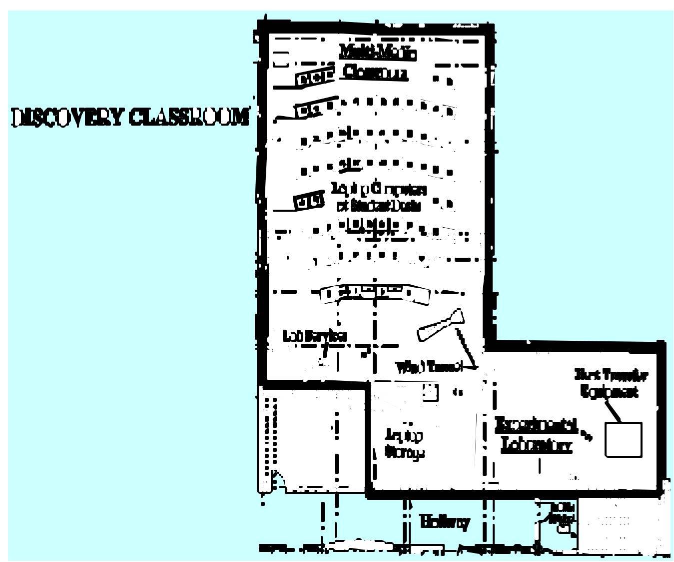

FIGURE 1. The Discovery Classroom at Worcester Polytechnic Institute.

There is concern that engineering education has failed to meet the challenges arising from these changes in engineering practice. For example, the overwhelming majority of student-faculty contact hours in engineering education remains based on the in-class lecture. However, many feel that the exclusive use of lectures can create a passive learning environment that reinforces pre-existing “teach me” attitudes in students. The National Science Foundation, while addressing areas for education improvement, has specifically encouraged the development of discovery-oriented learning environments and technology-based instruction that capitalize on the full power of new information and visualization technologies.[1] Since many concepts in the fluid-thermal sciences are particularly difficult for students to grasp, we felt that an approach that substantially extends simple classroom lectures was needed. The National Science Foundation, in turn, has supported our approach through the NSF Instrumentation and Laboratory Improvement Program.

To address these concerns, an integrated analytical-numerical-experimental approach to engineering education was developed and implemented in introductory fluid-thermal science courses at Worcester Polytechnic Institute. Central to the implementation of these innovations is the Discovery Classroom shown in Fig. 1. In this facility a multi-media classroom, an adjoining experimental laboratory, and computational facilities (WPI owned laptop computers loaned to students) are combined to produce an environment where non-traditional learning takes place. We have designated the approach using this facility as the DIANE philosophy: **D**aily **I**ntegration of **A**nalytical, **N**umerical, and **E**xperimental methods into engineering classes (see Fig.2).

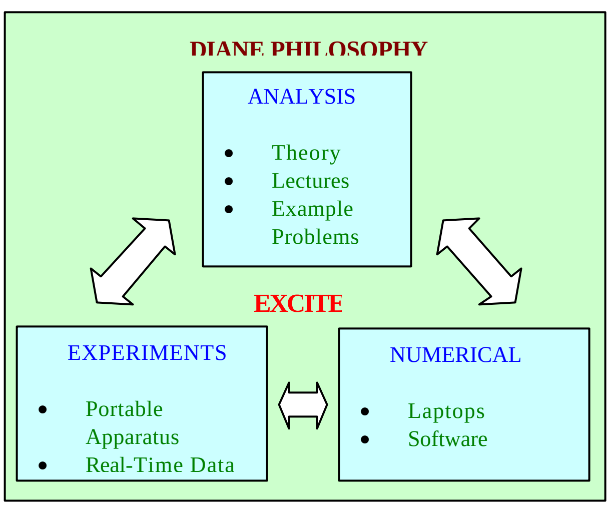

Figure 2. The DIANE Philosophy

The objectives of this effort are to:

- Bring the excitement of discovery into the engineering classroom by stressing real-time acquisition of data.
- Allow students to better understand relationships between physical phenomena and concurrently developed theory through interactive exercises.
- Develop student awareness of the integrated nature of various modes of engineering analysis.
- Provide students with hands-on experience in modern experimental, data acquisition, and computational techniques.

In a typical application, an experimental apparatus is demonstrated directly in class during an engineering lecture. These apparatus range from the simple (draining tank for mass conservation concepts) to the complex (portable wind tunnel experiments for aerodynamic principles). Real-time quantitative data are acquired from the apparatus, and the data are immediately analyzed and compared to concurrently developed theory by the students in class using computational software.

The innovations are implemented within the Aerospace Engineering Program in the Mechanical Engineering Department at WPI. We have re-designed three introductory undergraduate engineering classes at WPI (fluid mechanics, heat transfer, and aerodynamics) using this approach with implementation occurring over the past four academic years.

EXCITE PROBLEMS

The classroom innovations in the courses generally consist of an integrated sequence of: 1) non-traditional lectures which utilize the experimental apparatus directly in the lecture hall, leading to; 2) highly interactive classroom exercises in which students compare real-time data from in-class experiments to concurrently developed theory and computational simulations. We have termed these faculty-student interactions as EXCITE problems (**EX**ample Problems **C**omparing **I**n-class **T**heory and **E**xperiments). For example, in a typical EXCITE problem in the aerodynamics course flow over a NACA 4412 airfoil is demonstrated in a portable wind tunnel directly during class. Figure 3 shows the wind tunnel in use during an engineering lecture. Lift and drag data are obtained and immediately correlated with thin airfoil theory results and a computational software code based on a vortex panel method using the laptop computers. This immediacy between the data acquisition and correlation with theory and numerical results cannot be achieved in a traditional laboratory session, which are often conducted by a graduate teaching assistant with less experience than the faculty member. Also, labs take more time, and are more focussed on collecting data rather than prompt analysis.

All EXCITE experiments are selected to illustrate fundamental concepts in a simple, clear manner. In the fluid mechanics and aerodynamic courses, EXCITE problems are incorporated into approximately 50% of the course lectures. Specific EXCITE problems stressing velocity measurement and integration of pressure distributions, airfoil lift-drag curves, finite wing theory, and aircraft stability have been incorporated into the Aerodynamics I course. In the fluid mechanics course, EXCITE problems stressing unsteady mass conservation (draining tank experiment), momentum principles (jet impact apparatus), velocity measurement, the Bernoulli principle and equation, dimensional analysis and Reynolds scaling, external viscous flow, and drag coefficients are incorporated.

In the heat transfer course, demonstrations stressing conduction, forced convection in cross-flow and tube-in-tube heat exchangers, and radiation experiments are conducted. Fig. 4 shows the cross-flow heat exchanger apparatus in use in the experimental laboratory adjoining the Discovery Classroom. Students conduct standard laboratory sessions using the apparatus after the EXCITE problems have been introduced during class lectures. In these sessions students are asked to extend the EXCITE problems, for example by studying a wider range of parameters or addressing additional fundamental concepts. A complete description of the DIANE approach can be found in Ref. 2.

FIGURE 3. The wind tunnel and laptop computers in use during an aerodynamics class. A virtual tour of the Discovery Classroom can be viewed at http://www.me.wpi.edu/Resources/discovery.html

STUDENT RESPONSE

The student response to the introduction of the DIANE Philosophy and EXCITE problems into the classroom has been strongly positive, as seen from the results presented in Table I. The overwhelming majority of students responding to the survey feel that the in-class experiments, and the associated data analysis, help improve their understanding of fundamentals in the thermal and aerospace sciences (even though the approach requires extra student effort). Student assessment of the innovations indicates that approximately 90% of 275 students prefer the re-designed courses to traditional lecture-oriented courses, while also believing that they gain a better understanding of engineering fundamentals. Typical student comments in course evaluations include;

"Application + analysis = understanding!"

"The DIANE and EXCITE methods were excellent. The days when the wind tunnel was used in the classroom were the best!"

FIGURE 4. Heat transfer apparatus in experimental laboratory adjoining the Discovery Classroom.

CONCLUSIONS

An integrated analytical - numerical - experimental approach to engineering education has been developed and implemented in introductory fluid-thermal science courses at Worcester Polytechnic Institute. To support these innovations, a unique facility known as the Discovery Classroom has been developed. The innovators have observed improved in-class interactions with students concerning relevant physical principles using this approach. This leads us to believe that students are indeed gaining a better understanding of fundamental concepts through methods that have a good likelihood of being widely adopted in an affordable manner. The innovators are currently working to disseminate videos of the EXCITE problems via the Internet in a distance learning mode.

ACKNOWLEDGEMENTS

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Table I. Summary of Course Effectiveness Survey Results

Course	**Heat Transfer (ES3003)**		**Aerodynamics I (ME 3711)**		**Fluid Mechanics (ES3004)**	
Statement	SA+A	D+SD	SA+A	D+SD	SA+A	D+SD
The in-class experiments helped me better understand the material in this course	80% N = 97	20% N = 24	96% N = 68	4% N = 3	86% N = 74	14% N = 12
I felt that comparing experimental data from the experiments with analysis was beneficial	87% N = 102	13% N = 19	NA	NA	93% N = 80	7% N = 6
Given a choice, I would rather take <u>this</u> course, rather than a "traditional" course (e.g., solely 'lecture based,' with no experiments)?	90% N = 103	10% N = 18	98% N = 66	2% N = 1	91% N = 78	9% N = 8

Explanations: "SA+A" is the percentage of respondents stating they either agreed or strongly agreed with the statement; "D+SD" is the percentage that either disagreed or strongly disagreed. "NA" indicates that the question was not included in the survey for a specific course.