Integration of Laptop Computers into a Freshman Mechanical Engineering Curriculum

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Abstract

The implementation of the Notebook Computer Program at Milwaukee School of Engineering (MSOE), in which all new incoming students are provided with a laptop computer, has had a major impact on curriculum development in the Mechanical Engineering Program. The implementation of this program resulted in a number of curricular changes, including a revision of the first course in programming, a revision of the *Introduction to Engineering Concepts* course, and most importantly the development of a new course entitled *Computer Applications in Engineering*. This new course, taken by all Mechanical Engineering Department freshmen as of the 1999-2000 academic year, was designed to meet four specific curricular objectives: 1) To familiarize the students with the laptop computing environment and infrastructure at MSOE; 2) To familiarize the students with specific software tools required for both their academic careers at MSOE and professional practice; 3) To develop formal problem solving methodologies which integrate the use of the computer; 4) To expose the students to the various areas of technical concentration available in the Mechanical Engineering Department. Software packages including *Microsoft Excel* spreadsheet software, *Matlab* mathematical analysis software, and *SolidWorks* solid modeling software are used extensively in this new course. Mathematical concepts such as linear algebra, numerical integration, root finding, and optimization are introduced, and are applied to a variety of physical systems encountered in mechanical and industrial engineering applications. The implementation of this new course, taught during two quarters by a total of four instructors, has proven to be a success from both the student and faculty perspective.

I. Introduction

In the fall of 1999, Milwaukee School of Engineering (MSOE) introduced a Notebook Computer Program for all incoming students. As part of the initiative, each new student was provided with a Compaq Armada 1750 notebook computer and a standard suite of software. Conventional classrooms were provided with network connections and projection equipment to facilitate the integration of notebook computers into select classes. In conjunction with this program, a revised Mechanical Engineering curriculum was launched, designed to exploit the availability of notebook computing technology. The highlight of this curriculum revision is *Computer Applications in Engineering*, a freshman-level Mechanical Engineering Department course designed to expose the students with the computing infrastructure and professional tools required for both academic and professional success. In this paper, the details of the curriculum revision, including the development of the *Computer Applications in Engineering* course will be highlighted.

In Section II, a description of the general curriculum modifications that took place in response to the introduction of the Notebook Computer Program will be detailed. Assessment practices used to motivate these curriculum changes will be described. Section III will focus on the details of the *Computer Applications in Engineering* course. In Section IV, conclusions drawn from one year of implementation of this curriculum will be presented, including both student and instructor feedback.

II. Curriculum Revisions Motivated by the Notebook Computer Program

Prior to the implementation of the Notebook Computer Program in Fall 1999, the Freshman Year of the Mechanical Engineering Curriculum at MSOE consisted of the following:

- 8 quarter credits of mathematics
- 12 quarter credits of basic science (physics and chemistry)
- 15 quarter credits of general studies (English and humanities/social sciences)
- 4 quarter credits of engineering graphics, including both traditional methods and CAD
- 3 quarter credits of computer programming, with FORTRAN as the language of choice
- 4 quarter credits of "introduction to engineering"

Upon implementation of the Notebook Computer Program, it was this Freshman Year that was the focus of curricular revision. As the time frame for implementation of the program roughly coincided with the formulation and implementation of a formal assessment plan for the Mechanical Engineering Department (under *ABET EAC2000* guidelines), the program objectives and outcomes were used to guide the curriculum revision[1]. In particular, the curricular outcomes that needed to be considered in a curriculum revision centered around the Notebook Computer Program included:

- *The student will have a knowledge of and an ability to apply multivariable calculus, differential equations, linear algebra, and statistical methods to the solution of engineering problems.*
- *The student will have the ability to identify, formulate, model, and solve engineering problems.*
- *The student will have the ability to select and use the modern computer tools and techniques required for professional practice.*

Under the pre-Notebook Computer Program curriculum, assessment via Senior Exit Surveys and Alumni Surveys with respect to these objectives yielded the following general results:

- Students were not exposed to a sufficient amount of linear algebraic concepts.
- There was a perception that the only computing language formally taught in the curriculum, FORTRAN, was no longer meeting the needs of employers.
- There was insufficient integration of computer programming concepts into the Mechanical Engineering Curriculum.

- There was insufficient formal exposure to modern solid modeling tools and techniques.

With these assessment results and potential curriculum revisions in mind, a roundtable discussion with a panel of engineers and managers assembled from Milwaukee-area industrial partners was convened. The discussion, centered on the proper integration of computing tools and techniques into the curriculum under the new Notebook Computer Initiative, yielded the following general results:

- Knowledge of some type of mathematical analysis software (*MathCad*, *Matlab*, *TK Solver*) is highly desirable. *Matlab* is the most common such tool used by discussion participants, and is seen as a potential replacement for a traditional high-level language.
- A switch from FORTRAN to C/C++ is recommended.
- An increased need for solid modeling skills is replacing the need for more traditional 2-D drafting skills.
- An exposure to finite element analysis is becoming a necessity.
- The use of word processing and spreadsheet software is still important.

Based on recommendations of the roundtable discussion group and assessment data collected with respect to curricular objectives under the previous curriculum, the following curricular changes were made:

- A new first course in programming was developed. This course maintained the focus of the previous course on algorithm development and engineering problem solving, but was designed around the use of C++ instead of FORTRAN. In addition, with the ability of the students to bring a computer with them into every class session, the course was revised to contain a greater number of hands-on computing experiences.
- The freshman-level *Introduction to Engineering Concepts* course was revised to include a greater emphasis on computing applications. The use of spreadsheet software for data reduction and analysis was emphasized.
- Finite element analysis, previously a popular elective in the Mechanical Engineering Program, was added to the program as a required Senior Level course. This move was made possible by the implementation of the Laptop Computer Program, as the availability of computing laboratory resources is no longer a concern for such software-intensive courses[2]. The second course in a two-course junior-level Machine Dynamics sequence was dropped from the curriculum to make room for the FEA course.
- The two-course junior-level sequence in Numerical Methods was redesigned to include the use of *Matlab* as the primary computing language.
- A new two-credit freshman-level course entitled *Computer Applications in Engineering* was developed. The course was designed to make extensive use of the student laptop computers, expose the students to an array of tools required for both future academic and professional work, and increase the integration of computing techniques into Mechanical Engineering courses. In order to make room in the curriculum, the second course in a two-course freshman-level engineering graphics sequence was dropped from the curriculum. This was justified based on the solid modeling component of both the new *Computer Applications in*

Engineering course and the newly-required finite element analysis course.

The most important curriculum revision in response to the Notebook Computer Program initiative was the creation of the *Computer Applications in Engineering* course. This represents the point in the curriculum where the foundations of computer usage and engineering problem solving techniques are established. In the next section of this paper, the details of this course will be described.

III. A New Course in Computer Applications

The main hallmark of successful integration of computing tools into an engineering curriculum is transparency; computational tools and techniques should be understood by the students such that they not only know *how* to use the tools, but also *when* to use them, and *which* to select when such usage is appropriate. In essence, it should never be necessary to explicitly assign a "computer project" in an engineering course; computer usage should be an option for the student in every project and assignment, with judicious selection and application of computing tools a potential component of every assignment. With notebook computers and a suite of engineering software in the hands of every student, the ability to judge the appropriateness of various computing tools and integrate these tools into the problem-solving method is a critical skill to be fostered. It is with this philosophy in mind that a freshman-level course entitled *Computer Applications in Engineering* was developed.

The course is required by all engineering students in the Mechanical Engineering Department, which includes students in both the Mechanical Engineering Program and the Industrial Engineering Program. In accordance with the educational outcomes of the two programs, the following course goals were established:

- *To familiarize the students with the laptop computing environment and infrastructure at MSOE:* Students entering the Mechanical Engineering Department as freshmen have had widely varying computer experiences. Some have had advanced programming courses at the high school level, while some have had only cursory experiences with computer usage. Therefore, one purpose of this new course was to provide extensive hands-on opportunities for computer usage in an attempt to make students who have not had extensive computing experience comfortable with their laptop computer and the network environment at MSOE.
- *To familiarize the students with specific software tools required for both their academic careers at MSOE and professional practice.* The curricular modifications described in Section II assume that Mechanical Engineering Program students will be intimately familiar with a variety of computing tools, which will be integrated into a variety of new and existing courses. The specific tools selected for the initial implementation of the course, based on feedback from the roundtable discussion with industrial partners, were as follows:
    - *Matlab* mathematical software
    - *Excel* spreadsheet software
    - *SolidWorks* solid modeling software

Meaningful experiences with these software packages, coupled with additional experiences throughout the curriculum, including:

- additional experience with spreadsheet software in the revised *Introduction to Engineering Concepts* course,
- two-dimensional and three dimensional CAD experience with *Cadkey* software in the engineering graphics cours,
- extensive use of word processing in the general studies curriculum,
- experience with C++ programming in the introductory programming course,
- experience with finite element software in the senior year

will provide the student with a full complement of software tools for use in their academic and professional careers.

- *To develop formal problem solving methodologies which integrate the use of the computer.* As was stated previously in this section, the ultimate goal of a computer-integrated curriculum is the transparency of computer usage. Therefore, a goal of this new course was the integration of computer tools into a formal problem solving methodology. The ten-step engineering problem solving methodology presented by Palm[3] is introduced in the course; both front-end modeling and back-end interpretation of results are stressed in the course.
- *To expose the students to the various areas of technical concentration available in the Mechanical Engineering Department.* At the freshman level, many students are unaware of the various technical specialties available to mechanical engineering students, and do not have great familiarity with the required and elective upper-division courses in the program. One goal of this course is to introduce realistic and representative mechanical and industrial engineering problems. These problems, while simplified for the freshman level, provide an opportunity to motivate course material that will follow in upper-division courses. This stimulates student interest in both their chosen engineering discipline and their academic plan of study.

Structurally, the course meets for a total of four hours per week, with one hour designated as "lecture" time and three hours designated as "laboratory" time. Both lecture and laboratory sessions are held in a networked classroom with projection equipment; therefore, lecture and laboratory sessions blend together seamlessly. Lecture sessions are used to introduce software tools and mathematical concepts; laboratory sessions are devoted to application of computer tools to the solution of realistic engineering problems. Course textbooks are selected from the McGraw-Hill *BEST* Series[3,4]. Topically, the course syllabus is as represented in Table 1. It includes topics in programming/software applications (building on the concepts of loops, logic, and algorithm development developed in the first C++ course), mathematical concepts (root finding, numerical integration, optimization, linear algebra), and engineering topics that draw on upper-division course topics (statics, dynamics, heat transfer, fluid mechanics).

Table 1: Topical Outline for *Computer Applications in Engineering*

Topic	Number of Lectures/ Laboratories	Example Engineering Applications
• Introduction to Computing • Engineering Problem Solving	1/1	• Kinematics of piston motion • Projectile motion
• Use of loops and logic in programming	1/1	• Economic break-even analysis • Static analysis of structures
• Root finding techniques	1/1	• Cantilever beam design • Four-bar linkage kinematic analysis
• Linear algebra • Solution of simultaneous equations in matrix form	2/2	• Electrical circuit analysis • Finite difference method for steady-state heat transfer
• Engineering optimization	1/1	• Transportation problems (linear programming) • Production scheduling (linear programming) • Economic optimization of a piping system (nonlinear programming)
• Numerical Integration	1/1	• Analysis of a draining water tank • Dynamic analysis of a rocket flight
• Solid modeling	0/2	• Modeling of a mechanical part • Integration of part models into an assembly • Creation of 2-D drawing

Testing involved both a combination of traditional "pencil-and-paper" problem-solving and solution of problems using computer tools.

IV. Conclusions

One year after implementation, the Notebook Computer Program and the resulting Mechanical Engineering curriculum revisions have shown great promise. The logistic and technical challenges of maintaining a notebook computing infrastructure have been handled admirably by the Computer and Communication Services Department at MSOE. The curricular advantages have been many, including:

- Linear algebraic concepts, required by ABET program-specific requirements for Mechanical Engineering Programs and once nearly absent from the curriculum, are now present both at the Freshman and Senior levels (in the computer applications and finite element analysis courses).
- Students are now introduced not only to modern programming tools, but also versatile mathematical analysis software.

- Students are formally introduced to solid modeling concepts at the freshman level.
- A suite of professional engineering tools, available to all students throughout the curriculum on notebook computers, is available for ready integration into upper-division courses.

The highlight of the new notebook computer-based curriculum is the new *Computer Applications in Engineering* course. During the initial year of implementation, this new course was taught by four instructors, and was taken by approximately 130 students. Student feedback measured at the conclusion of the course can be summarized as follows:

- Students felt a higher degree of confidence in their choice of major.
- Students perceived a greater understanding of the curriculum.
- Students exhibited increased confidence in using their notebook computers and the computing infrastructure at MSOE.
- Students felt that the number of computer tools addressed in a single two-credit course was excessive.

Important instructor feedback includes:

- The most valuable outcome of the course was that students were trained to use a structured approach to engineering problem-solving.
- Small lecture and laboratory sessions (limited to twenty students, and averaging approximately sixteen) allowed for a close interaction between Mechanical Engineering Department faculty and freshman students; this has the useful side-effect of making the freshman students feel more like a part of the department, and should benefit department retention in the long run. Short run retention gains have been seen already.

The new notebook computer-based curriculum is running virtually unchanged for a second academic year. The performance of the original group of student participants in the notebook computer program is being closely tracked; of particular interest will be the level of usage of computer tools of these students in the capstone design course.

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