Cut to the Chase:
Extensive Computer Applications in a First Engineering Course

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Abstract

Freshman engineering students generally have laudable goals. They want to learn how to build quality products and work with appropriate engineering tools. Nonetheless, the typical freshman in many pre-engineering programs is not well prepared for the rigors of study in higher education. Now, much of their learning comes outside the classroom, and often the hands-on, in-class experience they are accustomed to is completely absent. How do you build an introductory engineering course that gives students the flavor of engineering, improves their general pre-requisite engineering knowledge and problem solving skills, motivates them via interesting applications and the use of modern engineering computer tools, helps them learn to use high-level computer software for problem-solving, and gives them the confidence to continue successfully in the engineering field? Part of the answer may be to cut to the chase and get them actively involved while in the classroom with engineering tools they can apply immediately. This paper describes how the extensive use of computers in a freshman level introductory course in engineering gives students the necessary hands-on skills, experience, and motivation to succeed as they continue their engineering education. Approximately one-third to one-half of class time in a three-credit, semester long course is devoted to computer skills essential to engineering success. These skills are introduced using MS-Word, MS-Excel, and MATLAB, and are completely integrated into the course through assignments involving engineering professional knowledge, analytical problem-solving skills, and simple design projects. Significantly, this approach naturally ties into current, student-centered, best practices in engineering education because active learning is automatically incorporated into class activities. The experience gained through the hands-on setting inside the classroom gives students confidence to attack non-trivial problems, solve them with the aid of the computer, and present results professionally. This conclusion is supported by student evaluations ranking the course between 4.0 and 4.75 on a five-point Likert scale over several years and by retention rates near 80%, which well exceed overall college retention rates of below 60%. By organizing much of the material in this course around computer applications, a unique introduction to engineering geared towards helping students with under-prepared backgrounds to succeed has been created.

Introduction

A general introductory engineering course, Fundamentals of Engineering Analysis and Design, has been developed to serve the needs of a broad range of students in the pre-engineering transfer program at Lewis-Clark State College. Generally, the freshman students enrolling in the pre-engineering program have laudable goals. They want to learn how to build quality products that have meaning to them, and they want to work with some of the high-tech tools that got them interested in engineering in the first place. Nonetheless, these students are generally not well prepared for the intensity or level of independence required for study in the world of higher education. Thus, a course has been designed such that students can develop their confidence and skills in a hands-on environment rich in active and cooperative learning opportunities, particularly by centering much of the course activities around the use of computers.

By cutting to the chase and allowing students to develop and utilize computer-based engineering skills directly relevant to their long-term goals of becoming practicing engineers, this course gives students the flavor of engineering by: improving their general pre-requisite engineering knowledge and problem solving skills, motivating them via interesting applications and the use of modern engineering computing tools, helping them learn to use high-level computer software for problem-solving, and giving them the confidence to continue successfully in the engineering field. Approximately one-third to one-half of class time in a three-credit, semester long course is devoted to computer skills essential to engineering success. These skills are introduced using MS-Word, MS-Excel, and MATLAB, and are completely integrated into the course through assignments involving engineering professional knowledge, analytical problem-solving skills, and simple design projects.

By allowing students to practice the skills they are developing on the computer while they are in class, this active learning approach naturally ties into current, student-centered, best practices in engineering education because active learning is automatically incorporated into class activities. Furthermore, specific efforts are made to effectively implement these learning activities via utilizing a cooperative learning team environment. All of these activities are designed around achieving general course outcomes relevant to professional engineers rather than being designed around specific content. This aligns well with the general principles of course design, where content appears naturally as students are led through learning activities centering around more general course goals that are developed first. The experience gained through the hands-on setting inside the classroom gives students confidence that they do indeed possess the necessary skills to attack non-trivial problems, solve them with the aid of the computer, and present their results professionally in an electronic format.

Below, the context of the course within the pre-engineering program is discussed, the philosophy behind the design of the course in terms of how its computer application emphasis benefits underprepared students is discussed, and results in terms of student enjoyment and persistence in engineering are discussed.

Background

The pre-engineering program at Lewis-Clark State College began in 2001 through the Idaho governor's technology initiative. This program is designed to be a transfer program feeding into other, four-year degree granting, state engineering programs. As such, 3/2 articulation agreements have been set up with Boise State University and Idaho State University, and similar efforts are under way with the University of Idaho. Because the pre-engineering program must serve not only multiple institutions, but also multiple engineering fields within those institutions, the nature of the pre-engineering program must be quite broad. Thus, the introductory engineering course – Engineering Fundamentals, Analysis, and Design – cannot be designed to serve any specific program. It must, by nature, aim to build engineering skills essential for any flavor of engineering.

The course has three main goals: 1) introduce engineering as an overall profession involving engineering analysis and design along with describing the various areas of specialization 2) build skills in utilizing general engineering knowledge such as unit systems, mathematical principles, and fundamental physical concepts 3) grow student skills in the use of computers as tools for engineering analysis, design, and presentation of information. The implementation of this third goal turns out to be the glue that holds the entire course together. Students utilize computers throughout the course to apply and present engineering content. The focus on using computers is to learn to perform and present engineering analysis and design work in a professional format. In order to accomplish this, constant feedback is of high importance. Therefore, as skills and course content are introduced, students are given ample opportunity to practice while in the classroom. During these sessions, which last anywhere from 15 minutes to entire class periods, students may work individually or in teams while the instructor constantly circulates to provide assessment of their performance.

In summary, some of the benefits of this active learning approach are

- immediate utilization of new knowledge
- integration of computing skills and engineering content knowledge
- immediate assessment feedback from instructor
- cooperative learning due to team environment
- easy sharing of information due to electronic format

Key analytical and written presentation skills needed by professional engineers are introduced using MS-Word, MS-Excel, and MATLAB. These skills are completely integrated into the course through assignments involving engineering professional knowledge, analytical problem-solving skills, and simple design projects.

First, the problem solving methodology used by Hagen[1] is introduced early in the course. Students learn to present complete solutions using MS-Word. A memo format is required for all homework and students create and apply their own template for presenting solutions. Specific skills introduced are the use of simple drawing tools or insertion of JPEG types of images to create descriptive figures for each problem, the creation and manipulation of tables to present or summarize data, and use of the equation editor to present governing equations and summary calculations. Use of this format is emphasized early in the course such that students can present their work in a completely electronic and professional format.

Next, students learn to use MS-EXCEL as an analytical tool. After a brief description of how to enter data, they are introduced to EXCEL equation and function formats. In the classroom and on homework, they practice entering data and equations such that their work is clearly communicated. Graphical presentation of results is also practiced through the use of problems set up to require parametric analysis. The value of parametric analysis to design and optimization is stressed such that students understand there is no single correct answer in design, but rather a variety of possibilities, most of which are mathematically interrelated. Next, embedding and linking EXCEL data or charts to WORD either statically and dynamically are introduced. In this way students begin to understand the concept of working documents that can evolve over time as further work is completed.

Finally, students are introduced to the basics of a high level programming language through learning to write simple MATLAB programs to solve problems. Initially, students compare results in MATLAB and EXCEL by solving problems that have readily attainable algebraic solutions. These solutions are then presented in a parametric analysis format. In this way students gain confidence in their ability to set up a MATLAB metafile and use it to solve problems. Later, computations for class work and assignments move exclusively to MATLAB. In the last two or three weeks of the course, students learn the real design benefits of a mathematical problem solving package by learning to use symbolic algebra and solve systems of equations. The impact this kind of tool has on design capability and flexibility is stressed.

A number of engineering skills introduced in this course would be either difficult to present or impossible without the extensive integration of computers into the course. In particular, the presentation of work in a completely electronic format including links between WORD, EXCEL and MATLAB would be impossible. Also, the consistent use of parametric analyses to analyze the effects of changing design parameters would be extremely time consuming for students without computer integration into the course. And finally, the introduction of symbolic algebra packages to solve systems of equations would be impossible in a freshman level course without the extensive buildup of computer skills throughout of the course and the application of this tool at the end. Without applying the tool and experiencing the benefits of its use, the concept would have no concrete meaning for students. The table below summarizes many of the skills learned by students from each computer tool:

MS-Word	MS-EXCEL	MATLAB
using professional communication formats such as memos and letters	parametric analysis skills	introduction to mathematical equation solving package capabilities
practice in communicating engineering information via drawing	graphical representation of results	usefulness of variable representation for mathematically related design quantities
practice in entering equations used for professional reports	practice in organizing work for clear and easy understanding	graphical representation of results
using tables to present information	learning to embed and link work between MS-Word and MS-EXCEL	familiarization with formatting requirements for programming languages
creation of templates for presenting work of similar type	familiarization with spreadsheet capabilities	recognition of the value of equation solving packages for complex systems analysis

Because the pre-engineering program at Lewis-Clark State College serves a community college role within the region, in should be noted that students entering the program are typically underprepared and have a wide range of pre-requisite knowledge when they enter the program. About half of all students at LCSC are non-traditional students, with similar numbers in the pre-engineering program. Approximately 70% of students enrolling at LCSC begin in developmental level mathematics courses[2]. This changes the way one must approach the content of a course.

In part because of the large fraction of non-traditional students, it is especially important that coursework be relevant to the long-term goals of the student (becoming a practicing engineer). It has been the author's experience that non-traditional students thrive in an environment where they can work towards results that have meaning to them while in the classroom. The goal oriented approach of these students therefore meshes well with a course that provides them with the opportunity to directly practice the skills they need to grow in order to achieve their goals.

Course Design Philosophy

In designing the Engineering Fundamentals, Analysis, and Design course, care was taken to include many current best practices. First, a focus on outcomes was utilized. This practice is consistent with systematic instructional design principles in the literature, where goal analysis is on of the first steps in the process[3]. The following outcomes are primary to the course:

1. Awareness of differences in the engineering profession and what type of work is involved in each major field.
2. Ability to work effectively in teams
3. Successful experiences with 2 or more design projects of moderate difficulty and 3 or more simple design projects.
4. Achievement of moderate skill in producing solutions to engineering analysis problems and communicating them electronically
5. Proficiency in graphing, data manipulation, and calculations using MS-EXCEL and MATLAB.

The final two outcomes are specific to development of skills that must be practiced with the use of computers and can be easily tied to the first three goals by having all course materials produced by students turned in via electronic formats. Furthermore, these outcome goals are reinforced via a classroom atmosphere where using computers is part of the normal activity.

Second, learning at the keyboard is naturally suited to an active learning environment where students are actively performing and using skills and knowledge rather than passively absorbing information. Thus, a course philosophy dedicated to allowing students to utilize computer tools to process new content as it is introduced can vastly accelerate their rate of learning. This is because the general engineering content knowledge is naturally integrated into the computer applications that students are using to process information and perform analyses. This focus on students performing skills in the area of learning is consistent with the goals of process education[4].

Third, because students are required to perform engineering analyses in basic engineering content that is new to them while simultaneously learning the computer skills necessary to perform the analyses, this process naturally ties into the use of just in time teaching because new content knowledge is continually introduced to the students[5]. Via classroom discussion in both large and small groups, significant effort is made to tie this new information into previous material such that students can link them together as they construct their knowledge base[6]. In this way, students can reach the analysis and synthesis levels of learning from Bloom's taxonomy while in the classroom rather than mostly remaining at the comprehension mode or below as would occur in a traditional lecture[7].

Finally, the author would argue that motivation is a key component to student success. The hands-on approach applied here where students are growing computer application skills through active processing of new engineering content knowledge gives students a feeling of achievement. This, in turn, may be a motivating factor in pursuing their engineering education further because they achieve success in a complex learning environment that integrates computational tools, written presentation skills, and engineering analysis. Below, results from the course are discussed in terms of how well students completing the course enjoyed the course itself and how well they performed as they continued their education.

Student Performance

Students who have completed Engineering Fundamentals, Analysis, and Design have shown a high level of satisfaction with the class. Course ratings based on student evaluation have come in at 4.5, 4.0, and 4.75 over the past three offerings. These results are based on a five point Likert scale where score of 5 is the best possible rating. Thus, the results indicate students enjoyed the class. A few relevant comments about the how students perceived the style of learning or the level to which the course content challenged them follow:

"This should be a six credit class. The workload seems like it. Keep it up."

"Overall, it is very informative. The class was also very conducive to learning."

"Most especially I am grateful that I can use the computer better now."

"Class times are 3hrs long, but time goes by quickly."

The first comment is rather unique in that the student felt challenged well beyond the confines of an average course, yet felt the effort to be valuable enough that he or she felt others should experience it as well. The second comment echoes this sentiment in that the student felt like the level of learning in the course was high. The third comment recognizes the specific value in engaging students at the keyboard as a means to assimilate new engineering knowledge. Finally, the last comment refers to a single weekly lecture format that was only used for one semester, but nonetheless indicates that the active and cooperative learning techniques used in the class worked well in terms of holding the attention of the students over long periods of time. This comment also strongly suggests that the students were fully engaged in the material while in the classroom.

Another indicator of success in a course is the impact it has on persistence in a chosen field of study. From the previous three offerings of the course, 83% of students completing the course are known to have continued with studies in a STEM field for at least one year. Currently, at least 61% of students completing the course are either currently enrolled or have graduated as majors in a STEM field, with several students having unknown status after transferring or dropping out of school at some point. Of those continuing in STEM majors, 73% are continuing in engineering. Although not statistically significant, these persistence rates can at least suggest that the Engineering Fundamentals, Analysis, and Design course is not turning students away from engineering. These numbers may not appear particularly impressive at first glance when compared with a national average for persistence in engineering around 60%[8]. However, the data presented above is quite impressive when compared with the overall college one-year retention rates from the freshman to sophomore years between 52% and 59% in the previous two reporting years[9]. Thus, it would appear that the techniques used in the Engineering Fundamentals, Analysis, and Design course positively impact retention when compared to other programs at the college.

Conclusions

As a first course in engineering, the Engineering Fundamentals, Analysis, and Design course that has been developed and implemented over the past four years at Lewis-Clark State College has effectively engaged students through an approach to classroom learning that focuses on actively engaging students, particularly through the use of computers for engineering computations and analysis using MS-EXCEL and MATLAB along with an electronic format for presentation of results in MS-Word. The course has been designed to focus on a number of professional outcomes essential for an engineer, two of which concentrate on the use of computers in the engineering profession. The focus on outcomes is consistent with instructional design methodologies. Furthermore, by utilizing computers for active and cooperative learning activities in the classroom, a very student-centered learning environment has been created which utilizes many of the current best practices in engineering education and elevates the level of learning of the students. Finally, initial data regarding student perceptions of the class and their persistence in engineering (or other STEM fields) indicate that the course has a positive impact on student learning experiences and their motivation to continue.

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