Engineering Design – On-Line

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Introduction

Transforming engineering curriculum to an on-line asynchronous format presents many challenges and opportunities. Engineering design has typically been taught as a collaborative interactive course at Iowa State University where student involvement and engagement was promoted in face-to-face synchronous learning environments. With the dawn of e-learning, a new opportunity to reach students on-line, faculty at Iowa State University re-examined how engineering design methods and tools might be transformed to the on-line format. On-line learning provides engineers an opportunity to obtain the training they need at the point in projects where they most need it. The power of learning and using information immediately, as it is needed, is a key to the attractiveness of using the Internet as a delivery mode.

Iowa State University has initiated an experimental project with eCollege.com to develop credit and noncredit on-line courses. The Communications and Continuing Education organization and Engineering Distance Education are facilitating the details of the experiment. Two engineering faculty members, a team of graduate students, and specialists in distance education, combined efforts to transform the engineering content and learning from a traditional on-site learning environment to a web-based environment.

As part of this experiment, two of the modules from the design sequence in the Aerospace Engineering and Engineering Mechanics program were converted to web-based delivery. Modules entitled ‘Design Modeling with Parameterization for Optimization’, and ‘Finite Element Analysis for Practicing Engineers’, were selected since they are both important topics for practicing engineers in industry and popular with the students.

Re-thinking the Content for the On-line Environment

The goals for the project were carefully developed prior to delving into the details of the work. The instructors examined the content and reflected on their experiences, both in the academic environment as well as their participation on projects with industry partners. The following list defines the goals outlines by the faculty for the creation of the modules in the on-line environment.

- Each module should be designed to reflect industry needs.
- The project should result in the development of shared engineering course development tools, templates, and resources so that other instructors can easily transform content into on-line environments appropriate for the engineering discipline without the steep learning curve associated with beginning a new course.

- The result should be a consistent, standard, simple, quality-centered approach to on-line delivery of engineering courses.
- The modules should include learner-centered materials that follow pedagogically accepted instructional design.
- Meaningful representations of engineering concepts and theories will be explored and tested.
- The process will avoid the trappings of an ad hoc development effort that cannot be easily captured or repeated due to lack of planning and documentation.

At every step in the development process the instructors were asked to consider the learning objectives and how the material provided will support those objectives. The instructors were also asked to continually think about the student's perspective. The on-line student must take responsibility for the learning experience and brings a unique base of knowledge and experience to the situation. Since the diversity of the target audience is much larger than the traditional classroom, more thought must be given to the support materials and resources provided. The instructors need to carefully consider the different ways of thinking about the material and the misconceptions that the learners may have as they study the material. Additionally, the instructors must give a lot more thought to the organization and presentation of the information. Hierarchy and navigation are paramount concerns in the on-line environment. It is critical to think about how material will build to a desired outcome and what is essential for the student to pay attention to, at any given point in the learning experience.

In addition to thinking about the learning process, it was also necessary to consider how the on-line environment, and specifically the associated technology, might be best used to facilitate learning. The instructor has many options to consider for representing ideas and concepts. The key is to use multimedia to facilitate the learning and effectively communicate the concepts. Multimedia also provides opportunity for the learner to interact or self-discover underlying principles, models, or relationships. The challenges to creating meaningful on-line learning experiences can be divided into two steps: (a) selecting meaningful activities to enrich learning and (b) managing those experiences effectively. The instructor always has to keep in mind the implications of being separated from the learner in space and time.

On-line instruction requires a great deal of thought, planning, and effort up-front. Thus, the following systematic approach to development was followed.

First, the instructors planned their instruction in a manner similar to a storyboard. The focus was to determine innovative ways to make the instruction visual and move away from text and verbiage. Both the order of instruction and the time allotted for various activities need to be considered relative to the learning outcomes and their relative importance. Throughout the entire on-line learning experience, the student needs to be engaged and involved. Thus, instructors needed to look for ways to make the material interactive in meaningful ways. Interactivity can take on different approaches[1]: it can be *exploratory* where the learner is allowed to explore the content, *navigational* where the learner chooses the order of the activity, *presentational* where the learner is presented with dynamic materials, *involved* where the learner is purposefully involved in achieving a goal or assessing content, *manipulative* where the learner must manipulate information or objects, *reflective* where the learner must consider the content in light of personal experience, or *accidental* where the learner initiates an interaction for which there is no predetermined response. When the instruction is interactive, feedback should be immediate and accurate and user control must be maintained so that the user can easily navigate through the content. Interactive learning should also focus on allowing the learner to use the information rather than just learning it. Case studies and problem-based learning are two effective means to engage the student. Each activity needs to include appropriate questions to enhance the learning process, and ample opportunity for reflection. The rule of thumb to keep in mind when planning the instruction is that interactive exercises tend to take longer than expected and lecturing tends to take less.

Second, the instructors were asked to consider their intended audience including their level of experience and knowledge as well as how they will use the knowledge they have.

Third, the instructors explicitly defined their learning outcomes and mapped different teaching strategies to each outcome. This included identifying the content and its scope, the concepts, knowledge and specific skills that must be attained, the supporting information the students will need and how it will be provided. The faculty decided that the best approach was to reduce the amount of information delivered and increase the interactive value of the planned activities. Thus, the emphasis would be on discovery learning.

Fourth, the instructors considered the types of media and technology available to them and mapped these to the learning outcomes and content requirements. The emphasis was on visuals and simulations since these tend to simplify the information. Templates were developed that may be re-used for other on-line engineering courses. These templates integrated simulation and modeling tools, embedded resource materials, and provided alternative delivery strategies that meet learner needs. The idea behind creating a uniform template was to promote consistency and facilitate development of other modules.

Fifth, the instructors considered how the learning and the quality of the experience would be assessed. Evaluation of the modules and assessment of the learning opportunities is important. The nature of the on-line environment is different from the typical synchronous team atmospheres typical of engineering design. Thus, the modules will be tested in an industrial environment with practicing engineers' participation using a model similar to the MERLOT project[2], where discipline experts and users evaluate the on-line modules. Evaluation will also include a component that provides feedback regarding potential performance outcomes that are important to the careers of the practicing engineers. (add industry-centered approach) Results of the evaluation will be available during the spring of 2001 and presented subsequently.

Course Module Scope

Course modules developed within the pedagogical arena described above are generally subsets of complete college courses in engineering design and various disciplinary areas normally encountered in engineering design. As an example, one might consider breaking a 3 credit-hour finite element analysis course into 4 course modules that combine to form the total course. The motivation for a modular structure resides in the fact that students who enroll in off-campus courses cannot always schedule sufficient contiguous uninterrupted time to allow completion of the full 3-hour course. Modular segments, on the other hand, are much more likely to be completed. Students earn credits for the 3-hour course by completing all modules contained in the course makeup.

Target Audience for Course Modules

Course modules are designed to service working engineers that must learn new technologies necessary for more competitive product research and development. Included in this set of potential participants are many engineering college students working in the field on cooperative or internship programs. On-the-job training in the area of engineering design and computational analysis can be very effective in the development of young engineering trainees.

Design Modeling with Parameterization for Optimization

The ‘Design Modeling with Parameterization for Optimization’ module included approximately eight hours of on-line instruction that will guide the learner through the thought processes involved in system mathematical modeling, determining design parameters and constraints, objective functions, and optimization procedures. Course module delivery methodology centers on the interactive design of small engineering systems by students using the module This minimizes the background knowledge requirement in the engineering disciplinary areas that are incorporated in the course thus allowing the student to concentrate on the design optimization study. Sample problems are provided to illustrate the concepts and demonstrate the process. Interactive problems are given to help the learner incorporate the process into his or her own mental framework. The module also guides the learner through various design optimization methods including the limits and benefits of some of the more popular methods. The learner is provided with the opportunity to apply some of the methods to simple example problems. The objective of this module is to introduce the learner to basic engineering design thinking and solutions.

Factual information, techniques, and processes pertinent to the overall design modeling, parameterization, optimization procedures, and design problems are provided the student through many templates made available by eCollege and Macromedia's Authorware. The Authorware software provides a complete set of tools for developing multimedia, interactive modules that allow generation of self-learning environments in which students are challenged to learn. The software provides a series of system and custom variables and functions that allow the course developer to generate sophisticated interactive applications for students as they learn. This is especially important in the teaching of design methodologies in that student have many options in the process of modeling and optimizing an engineering system. Course module software must be capable of assessing student responses and providing feedback over a wide range of outcomes. In essence, the software must provide a simulated synchronous learning environment in an asynchronous form. The speed at which the student moves through the various components of the module is governed by quality of response by the student to queries by the system. Remedial information and learning exercises in the disciplinary areas used in the module are provided as needed.

Upon completion of the module a students will have a much better understanding of analysis, synthesis, and design. They will have the ability to model and parameterize simple engineering systems, enumerate the design variables available within the system, undertake sensitivity studies on design variables and constraint boundaries, proceed with an optimization process, and provide an assessment of the quality of their final solution. Overall, the student will be much better at the process of formulating and solving design problems.

Finite Element Analysis for Practicing Engineers

The 'Finite Element Analysis for Practicing Engineers' module focuses on the analysis aspects of engineering design. Industry has been using finite element analysis extensively for decades. However, most large finite element packages are created based on certain assumptions and constraints that are not always obvious to the users. Additionally, many design problems must be simplified to enable practical analysis. The combination of these two factors can render finite element analysis solutions questionable. It is not difficult to significantly alter the results by slight variations in loading or boundary conditions. Thus, it is critical that engineers understand the practical issues associated with correct use of finite element codes. The purpose of this module is to introduce practicing engineers to the practical aspects of finite element analysis to ensure that they use the software effectively and appropriately.

This short course module is a transformed version of a credit course that provides coverage of the following topics: finite element analysis fundamentals including an overview of the assumptions and elements built into most commercial codes, two- and three-dimensional modeling strategies including boundary conditions and loading, element selection, steady-state and transient analysis, and model analysis. This module will also introduce some basic optimization and sub-structuring fundamentals. Finally, the issues of verification and validation of the analytical results are addressed. In all there is approximately twelve hours of on-line instruction provided.

Finite Element Analysis is a well-developed industrial tool. As a user, the designer has to understand

- How to break down a real problem so that it can be solved by FE
- What types of elements to be used understanding their advantages and limitations
- How the proper physical properties of the elements are to be simulated so as to mimic the nature
- How the real life constraints have to be simulated in the form of boundary conditions and forces
- How to intelligently interpret results obtained from the solution.

Modules are being developed to emphasize on each of the above aspects of the FE process. In this process the important thing to remember is that the audience would not have a theoretical understanding of the FE process. Today, FE has become an industry standard tool. Our goal is to give the students enough background that they can use this tool intelligently. Simple solved examples are developed which emphasize these aspects of FE. Some of the examples are:

- 3-D Truss analysis using bars and beams: here the students learn how the choice of elements effects the results
- Study stress concentration in fillets and cutouts: here the study of mesh size is incorporated.
- Elastic – Plastic material behavior; material's non-linear properties are simulated for the study of high stress loading
- Axi-symmetric symmetric problems: to show how the symmetry can reduce the problem size significantly
- Impact loading problem: here we see how time varying load are handled
- How to set up the FE problem in parameter form for design optimization

Finally, this whole process was incorporated in a design cycle so that a team of a designer and an analyst can use this powerful tool to further their design efforts.

Evaluation of the Modules

Both the design optimization and finite element analysis modules will be evaluated by practicing engineers in industry once they are released. The engineers will be asked to provide feedback on issues related to educational richness, presentation format and utility, navigation, and organization. Results of the evaluation will be discussed subsequently.

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