

AC 2007-360: DEVELOPMENT OF A MULTI-LEVEL MECHANICAL ENGINEERING EDUCATION TOOL

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Development of a Multi-level Mechanical Engineering Education Tool

1 Abstract

The design and structure of a student-based learning portal is presented. Progress through the program is determined by the particular user. No “right” way through the material is presupposed; one can move in a linear progression from low to high levels of information along a particular thread, move laterally across threads, and so on. The targeted audience are mechanical engineering students and undeclared students who may be thinking of entering mechanical engineering.

2 Introduction

A common presumption is that a student majoring in mechanical engineering knows that he or she needs particular courses for graduation, they take those courses, and they (hopefully) absorb the material. What has just been described is the hope. The reality is that, more and more frequently, students are expressing a distressingly high degree of confusion and uncertainty with regard to their education. In the “old days” one presumes it was somewhat different. Students had some experience with mechanical systems and realized on their own that this was the area they wished to pursue and had a sense as to what aspect of mechanical engineering most intrigued them.

As is by now well understood, however, the modern situation is different. All a student needs to do is demonstrate skills in math and physics in high school and they will immediately be told by their counsellors that engineering is a good fit. And the students, by and large, accept this and apply to college as prospective engineering majors. It is only after arriving at college that they begin to wonder exactly why they said they wished to be engineers - whether it really is the right avenue for them.

The intent of our work is to support the education of mechanical engineers in a way that complements traditional engineering education, as reflected in courses such as dynamics, vibrations, and so on. In such courses, the aim is to transmit a well defined body of knowledge to the enrolled students. Our concern here is rather different. Our aim is to address a broader and more diffuse set of needs. We address the question of ‘why’ and to a large degree leave the engineering classes to provide the ‘how.’ “What is the point of taking a particular class and how does it fit into a larger picture?” “Why will I need to know what a coefficient of friction is?” “I really enjoyed my first course in dynamics - so what does that mean in terms of further courses and career paths?” These are the class of inquiries we address.

These questions are typical of students who already, for one reason or another, have entered the mechanical engineering program. A different question, one which will likely become

more widespread as the practice of entering college as an undeclared major becomes more commonplace is “What do mechanical engineers *do*?” This sort of enquiry is far more diffuse but critically important to answer. An undeclared student is choosing among competing majors and it seems reasonable to assume that having a complete answer, one that indicates not only what mechanical engineers do but why it’s often fun and interesting, can only serve a positive role in maintaining a healthy and well-enrolled program.

These sorts of questions simply aren’t going away - if anything they’re going to become more widespread. And, in the current climate of reduced resources and support infrastructure, where will students find their answers? Advising by faculty advisors is a catch as catch can proposition and is notorious for its uneven level of quality. Beyond the simple question of expertise, there is the problem of actually finding an advisor when needed.

Our solution to this problem is an electronically available resource that’s accessible 24 hours a day (assuming no network server failures, of course). Electronic learning has been an object of steadily growing interest [1], [2], [3], [11], [12], and the present project falls within this general area - an expandable program that enables learning to progress at the user’s pace and convenience.

The concern over education of this sort isn’t limited to college-level engineering. A national program, called Engineering Pathway [10], is being built with support by NSF through the National Science Digital Library. This structure aims at supporting K-12 education, helping prepare students for college. Our program complements Engineering Pathway, picking up the thread after high school and continuing it through to graduation.

3 AWESOME: Structure and Contents

Our program is named AWESOME: **A Web Enabled Study Of Mechanical Engineering**. Because of its design as a web-based portal, it is available to any student with access to a web-connected computer. As its name indicates, the program has been constructed for mechanical engineering concerns and, more precisely at this point, mechanical engineering at the University of XYZ. The underlying structure, though, can serve as a template that can be modified in two ways.

Most obviously, it can be reworked with relatively small effort to address students at different universities. Many of the links will remain unchanged – namely those dealing with general questions of mechanical engineering. The pages dealing with courses specific to a particular school will need changing, of course, as will informational links local to the particular institution. A distribution of the final program to different schools is, in fact, a primary goal of the effort. The University of XYZ does not have a monopoly on confused students – they appear in similar quantities throughout the US. If the use of AWESOME can help support mechanical engineering outside the bounds of its originating institution, then the time constructing it will have been well spent.

Moving beyond mechanical engineering, the basic framework of a student-directed advising program could also be retained but the entire content revised in order to apply to different disciplines – electrical engineering, nuclear engineering, and so forth.

The design of a web resource so that it is easy to use and provides the expected learning benefits is a non-trivial task [4], [5]. One has to be concerned with technical issues linked to the web technology as well as be cognizant of learning behaviors – how they differ and how to best accommodate them. Students in general display a range of motivations, [6], [13] and an effective web portal will be designed such that users displaying a wide range of internal motivations will be able to extract useful data. One way in which an information rich portal can actually help in the case of particular classes is by reinforcing and supporting different goal types. As a particular example, consider the three commonly agreed upon types of goal setting [8]. Level 1, or task completion goals, are what students who simply work to finish an assigned project display. This would be equivalent to students who simply want a framework from the book that allows them to solve the assigned homework. Level 2, or instructional goals, imply that the student actually spends some time thinking about what the answer means and perhaps generalizes it a bit. Level 3, or knowledge building goals, refer to a student who actually gets fired up and wants to go deeply into the material and see how it fits into a larger structure.

Consider the case of a Level 3 student in a class for which the professor aims his or her presentation at Level 1 students. The result can be disengagement by the student who wants more but lacks a directed means of acquiring the information. AWESOME would work as a complement to such a class. The student could find out what the larger structure is and also find links to further related material.

With this as background, we now consider the structure of the program. Users enter AWESOME through a home page that combines graphic images and text. Graphics are used in multiple ways within the program. Descriptive icons serve as quick visual identifiers that delineate a subfield within mechanical engineering (a smiling drop of water indicates fluid mechanics, for instance) and by this means the student will know when he or she sees the water drop that the material will be fluid related.

The next use of graphics comes from pictures of large-scale mechanical systems that are familiar to students, systems such as cars, planes and so on. These pictures are rollover enabled and the presence of the cursor over particular hot-linked areas will bring up a small Java animation that dynamically illustrates an aspect of the overall system. Clicking will then direct the user to a new page, one that gives more information/details about the illustrated sub-system. Graphic images are also used as static imagery to support the written material and, finally, are present as video clips for topics in which seeing a dynamic representation of some engineering system is helpful.

The program is *not* organized in a linear fashion, as a textbook or course would be. Pages are cross-linked so that the user can move through the information in an individually determined manner. No two students will navigate through the material in the same way. The program is also designed to be open-ended so that material can be added at any point. Thus,

depending upon how much work has been done in entering data, a student may ask what is covered in ME 123 and get an answer. They may then go further and ask what topics are generally covered in the 10th week. They can then ask for clarification as to what these topics mean in physical terms and what other materials they relate to. Live links will allow the student to jump into a course's individual webpage, assuming it is active during the given semester/quarter.

By making the portal detailed in information and easy to navigate, the student can get the answers to quick, general questions as well as in-depth enquiries. Proper data structuring allows the program to be updated in a relatively easy manner, allowing information on multiple pages to change simultaneously so as to reflect changes in the courses, requirements, and so on. The program serves as an unbiased advisor, giving the answers to questions across the entire field of mechanical engineering and with great specificity. This contrasts with the limitations of the usual academic advisor, someone who by definition has a research specialty and who can often only answer questions pertaining to that specialty. A further advantage of this program is that fact that a student's common fear of appearing ignorant in front of a professor will not be present when interacting with a web resource.

4 AWESOME: Home Page

A student's interactions with AWESOME begins at the AWESOME homepage, a schematic of which is shown in Figure 1.

Four questions lead to the primary discovery threads that encompass the basic classes of questions students will ask. Each of the four questions directs the user to an answer page designed to address its respective question. These are:

- **What is AWESOME?**
- **What is Mechanical Engineering?**
- **Why am I taking this class?**
- **I like [a particular subject or activity]. What should I do now?**

What is AWESOME?, as its title implies, sends the new user to an answer page that describes the explains what AWESOME is and how it is used.

Clicking on **What is Mechanical Engineering?** sends the user to a page that gives a reasonably broad overview of the mechanical engineering field. This link, one of the most important for potential mechanical engineers who have, as yet, no clear idea as to what mechanical engineering comprises, provides a variety of visually compelling images that serve to help instruct the user. An image marquee scrolls through a set of familiar systems that

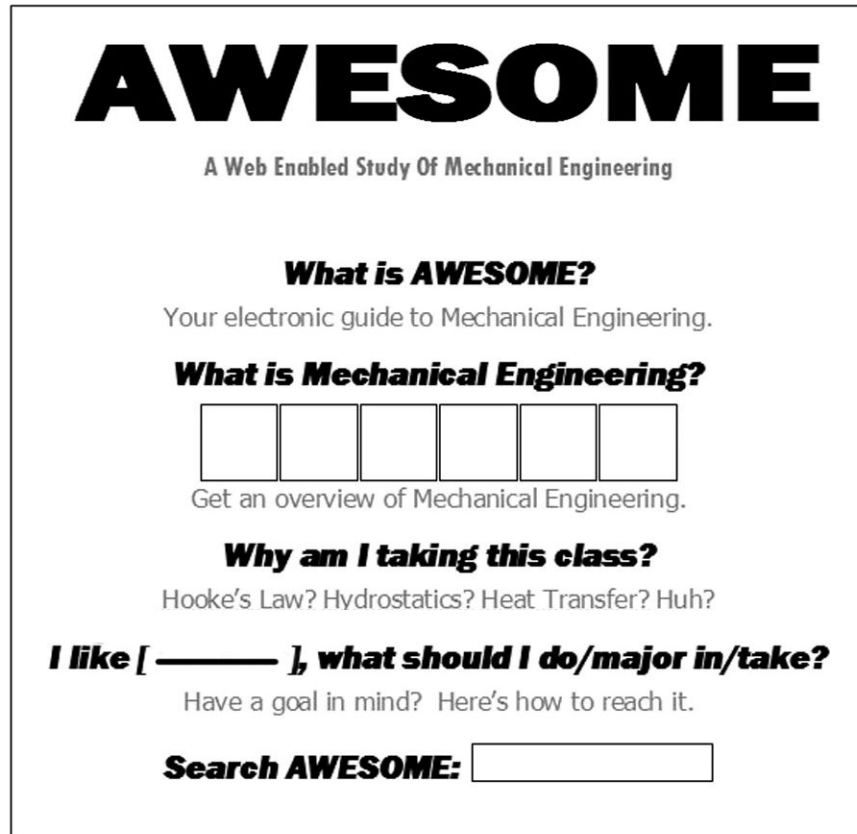


Figure 1: Schematic of AWESOME home page

encompass a wide range of mechanical engineering disciplines. These images are carefully chosen so as to cover all of the major fields contained within mechanical engineering.

The **Why am I taking this class?** link brings the user to a page which describes, in easy to understand terms, what the “point” is of all the mechanical engineering courses offered in the department. These explanations link as well to the particular homepages of the courses (when active) and to pages that cover the professions that utilize the course material.

The final category of general question is **I like [a particular subject or activity]. What should I do?** A click on this link brings the user to an answer page that offers brief descriptions of the various fields in mechanical engineering, what they deal with and in which sectors of industry they would be found and matches it to widely understood systems, such as cars, planes, computers, and so on. In this way a student who, say, enjoys working on engines, would find out what jobs are out there for him and what courses will best prepare him for them.

Figure 2 illustrates the logical structure of the program. For clarity, only the most important links between pages are shown.

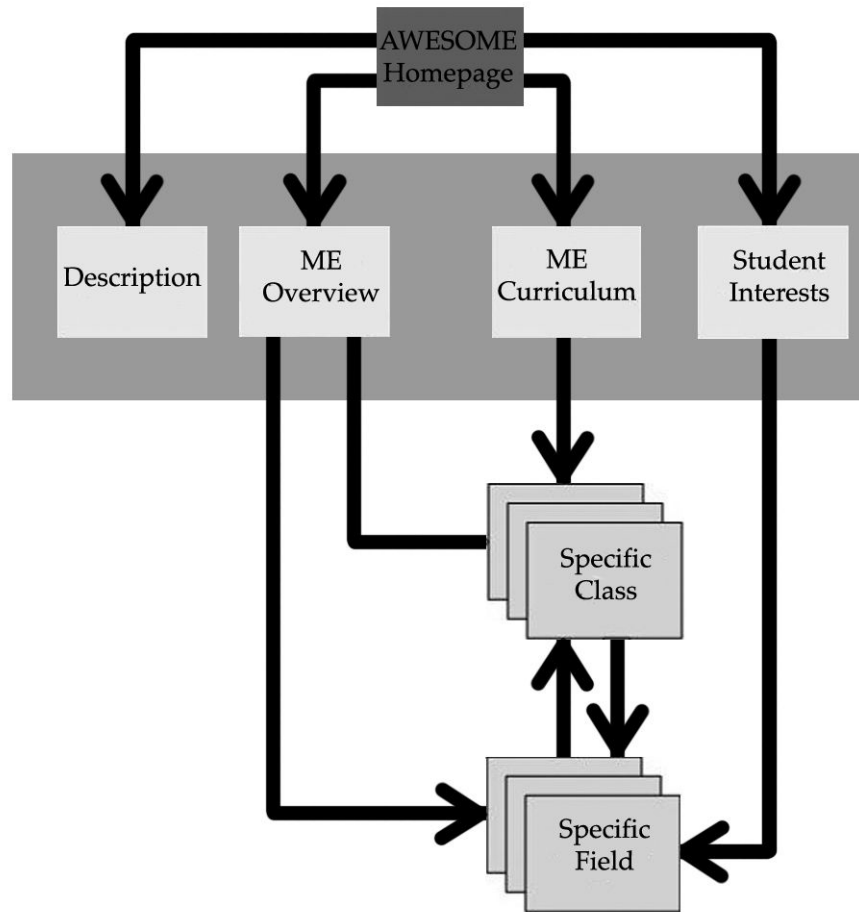


Figure 2: AWESOME's primary relational structure

Structure of Overview Page

In addition to the text, the Overview Page contains a variety of Visual PathFinder (VPF) images. These images represent common devices that encompass several areas of ME specialization and contain dynamic video and text to help orient students as to what aspects of ME correspond to what real-world systems.

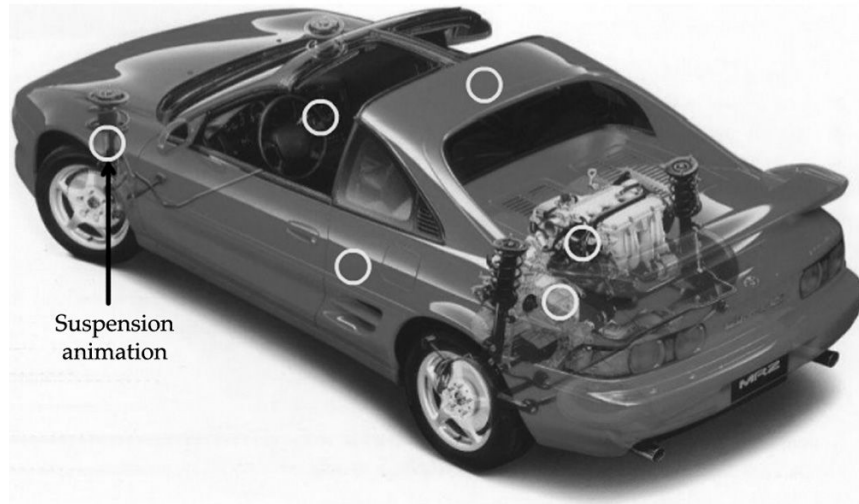


Figure 3: PathFinder

A specific example is shown in Figure 3, which contains a static image of an automobile with superimposed circles. These circles are chosen to correspond to particular ME themes and are rollover enabled. When the user moves her mouse over these circles the VPF activates a Java animation that illustrates an underlying mechanical engineering concept related to that portion of the larger picture.

The front-left suspension of the car is indicated. When a user moves the mouse across this circle, the picture enlarges and shows the car's suspension moving up and down as it would over a rough road. Clicking on this circle brings the user to a page that explains how the motion of the car's suspension falls under vibrations theory and, more generally, the field of dynamics. Further links would then bring the user to applications of dynamics, courses that cover dynamics, and so forth.

Other links in the car would target aerodynamics, heat transfer, kinematic mechanisms, and so forth.

Structure of the Curriculum Page

The curriculum page (shown in Figure 4) summarizes, not surprisingly, the mechanical engineering curriculum for the University of XYZ. Links to class-specific pages allow the student to easily peruse all of the department's offerings. Each of the classes listed in the page actively link to pages about that class as well as to the current class webpage (if an individual page exists on the departmental server).

The Mechanical Engineering Curriculum

Introduction

The ME curriculum at Cal is divided into three segments: fundamentals, core mechanical engineering classes, and technical electives.

Fundamentals

These classes are to ensure that mechanical engineers graduate with a strong foundation in the fundamentals science and math. Upper division mechanical engineering courses often build on or use concepts learned in these classes. Students are expected to have a basic understanding of these courses

Math 1a Math 1b Math 53 Math 54
Physics 7a Physics 7b Physics 7c
Chemistry 1a
Biology 1a

Engineering Fundamentals

These classes teach concepts useful for multiple engineering majors.

E28 E36 E45 E77
CE130
EE100

Core ME classes

These classes will teach you the core body of knowledge fundamental to mechanical engineering.

ME102 ME104 ME105 ME106 ME107a ME107b
ME124

Technical Electives

These classes cover specific topics in greater depth allowing students to focus their degree on a particular area within ME.

Design and Manufacturing Classes

ME101 ME110 ME119 ME128 ME130

Controls Classes

ME132 ME133 ME134 ME135

Combustion and Thermodynamics Classes

ME140 ME142 ME145

Dynamics Classes

ME170 ME175

Figure 4: Curriculum Page

E28 – Basic Engineering Design Graphics

Overview

E28 covers basic graphical design, engineering drawings and documentation, and introduces the programs AutoCAD® and SolidWorks®.

What Will You Learn

You will learn to create engineering drawings in both AutoCAD® and SolidWorks®, as well as tolerances, 3-Dimensional visualization, and basic descriptive geometry. At the end of the class you will complete a simple design project in which you will make a complete set of engineering drawings for your design.

E28 is the most hands-on class in the lower division ME curriculum. You learn to use AutoCAD® and SolidWorks® through tutorials in lab, and the final project requires you to combine many of the skills you've learned throughout the semester.

Example – throughout the class you might be asked to make an engineering drawing of a simple mechanical part (a bracket or a lamp stand), or draw an object from the top view, given the front and side views.

Why is this useful?

Engineering drawings are the primary method by which engineers communicate design ideas. Standardization of these drawings ensures that they can be unambiguously understood by all engineers. In E28 you will learn these engineering standards, as well as the computer-aided-drafting software to make engineering drawings.

The skills you will learn in E28 will be applicable in any engineering course or job that involves design.

Other classes you might like if you liked this class

If you liked E28, you might like E128, which teaches computer aided design using ProEngineer® and other CAD software.

If you liked the hands-on design portion of the final project, then you should look forward to lab classes like ME102, ME110, ME128, and ME130.

Subjects you might like if you liked this class

Drafting software is used in all fields of mechanical engineering.

Figure 5: Specific Class Page

In Figure 5 we see what a student would see if he or she clicked on a particular course. The course is described in an informal manner and from here the student can view prereqs, follow-on courses and so on. Individual class-specific pages provide comprehensive guides to each class offered by the department. Examples, pictures, and student comments describe in detail the material encompassed by each course. The class pages also detail the significance of the class in real-world engineering (eventually including commentary from professional engineers), as well as the class's relevance with respect to other areas within the mechanical engineering curriculum.

This page can list prerequisites, estimated work load, places to get help, related books and/or

internet sites, and complementary classes the student might find of interest in the event that he or she enjoyed this class.

Interests Page

As the name indicates, the aim of this page is to permit the student to plan their way through mechanical engineering in a way that emphasizes their own particular interests. The page provides information regarding the different fields within mechanical engineering and notes the types of jobs available in each field and the academic subjects that most directly pertain to that field. Students will be able to determine what ME subfield is most suited to their interests, based on their interest match, and can then navigate to the corresponding field page via the links on the interests page.

Note that the interests/fields page and the MEOP are distinct entities, although overlapping in general intent. They both describe mechanical engineering for the student but in very different ways. MEOP is aimed more at students without any significant knowledge of mechanical engineering, students who are starting from the ground floor, as it were. MEOP is more attention grabbing, highlighting why ME itself is an exciting area.

The interests/fields page addresses users who have already experienced enough mechanical engineering related activities so that they have formulated a goal for themselves. The information is more technical and structured, covering the academic subjects and career-related information in each field to a relatively high degree of specificity.

Field Page

The field page gives an in-depth look at the various fields and provides guidance to users who are trying to choose a particular field for use as an emphasis area or as a minor. Included in the coverage are the types of jobs open to people studying within the field as well as presentations of cutting edge research in the field, noting companies and institutions involved in the work. The page lists the classes which are directly relevant to work in that field so that the student can shape his or her schedule appropriately.

Crosslinking of AWESOME

An important functionality of AWESOME is to provide users with easy navigation from one part of the site to the next via a high degree of page cross-linking. Such links are critical if students are to be able to easily move from one area to the next as their interests dictate. As an example, a student with an interest in aerodynamics might start off in the interests page. There, the student might see an unfamiliar term, such as boundary layer. These words are clickable as hyper-links. Clicking on it will direct the student to the class page for ME XXY, a class covering fluid dynamics. In the ME XXY page there will also be links to prerequisite and follow-on courses. Students entering the site with the idea of investigating a particular area may easily end up in an entirely different area, having learned something about mechanical engineering along the way.

5 Conclusions

What has been created is an evolving, multi-media, web-based portal that addresses student learning within the field of mechanical engineering. Text, graphics and video are combined to create a rich environment that allows students to actively guide their own education with regard to elective course material and to understand the real-world applications of their course material, both required and elective. Such an understanding will provide a better motivation both before and during the course.

This portal has been designed to allow expansion and refinement and is envisioned as very much an on-going project. Faculty interested in possible applications to their own universities should contact the author.

References

- [1] Albright, M.J. and Graf, D.L. (1992), *Teaching in the information age: The role of educational technology*, San Francisco, Jossey-Bass.
- [2] Broadbent, B., (2002), *ABC's of e-learning: reaping the benefits and avoiding the pitfalls*, San Francisco, Jossey Bass/Pfeiffer.
- [3] Brown, D.G. (ed), (2000), *Interactive learning: Vignettes from America's most wired campuses.*, MA, Anker.
- [4] Carter, J., (2000), *A framework for the development of multimedia systems for use in engineering education*, *Computers and Education*, **39**, Pergamon, pp 111-128
- [5] Clark, R., Mayer, R., (2002), *E-learning and the science of instruction: proven guidelines for consumers and designers of multimedia learning*, San Francisco, Jossey-Bass/Pfeiffer.
- [6] Grasha, A.F. and L. Richlin, (1996), *Teaching with style: A practical guide to enhancing learning by understanding teaching and learning styles*, Pittsburgh, Alliance Publishers.
- [7] Ng, E., Bereiter, C., (1991), *Three levels of goal orientation in learning*, *The Journal of the Learning Sciences*, **1**, (3&4), pp 243-271.
- [8] Papanikolaou, K., Grigoriadou, M., Magoulas, G., Kornilakis, H., (2002), *Towards new forms of knowledge communication: the adaptive dimension of a web-based learning environment*, *Computers and Education*, **39**, Pergamon, pp 333-360.
- [9] <http://www.engineeringpathway.org>
- [10] Romiszowsky, A., (2004), *How's the E-learning baby? Factors leading to success or failure of an educational technology innovation*, *Educational Technology*, Jan-Feb, pp 5-27.

- [11] Rosenberg, M. (2000), *E-learning: strategies for delivering knowledge in the digital age*, NY, McGraw Hill.
- [12] Seifert, T. (2004), *Understanding student motivation*, *Educational Research*, **46**, 2, pp 137-149