Interactive Web Examples for Dynamics Developed using DazzlerMax™

Phillip J. Cornwell
Rose-Hulman Institute of Technology

Abstract

Technology and the WWW have tremendous potential to enhance the teaching and learning of dynamics. Course notes, animations, worked out example problems, videos of lectures, etc., can be, and are being, put on the web for student use. Lacking, however, are interactive example problems that require students to not only read a problem but to actively work through the problem. Example problems are key elements in helping students learn the basic principles of dynamics. In this paper, the author will discuss interactive example problems that were developed using DazzlerMax™, an e-learning authoring tool. The examples were developed using the same question and answer paradigm that the author uses when presenting example problems in class. Students are required to pick a strategy and to answer questions that are chosen to help guide them through the example problem’s solution. Since there is rarely a unique path through a solution, the interactive example problems are designed to allow different paths, thus challenging the students’ perception that there is a “right way” to solve a problem. For example, for a problem involving multiple systems, the student decides which system to start with rather than being forced to passively accept one. Assessment of the interactive example problems will also be presented.

I. Introduction

Engineering educators are struggling with the question of how to most effectively utilize technology, multimedia and the WWW to enhance engineering education. In the subject area of dynamics one of the most natural applications of multimedia has been in the use of simulations. Dynamics textbooks often include a CD-ROM with simulations. For example, Engineering Mechanics: Statics and Dynamics by Hibbler has over 120 simulation models. Often these models are of example problems or homework problems and allow students to vary parameters to hopefully explore the problem more fully. In the author’s personal experience, these sorts of simulations are not very useful unless the students are specifically assigned to look at them. The best use of these types of simulations has been in the demonstration mode and to help improve students’ intuition, visualization and to provide some motivation. They do not however, help strengthen students’ problem solving abilities or their ability to apply fundamental principles to solve problems.

A second use of technology that is becoming more popular is the use of web-based homework problems. Homework is critical in helping students acquire a mastery of course material because it is the first situation in which they are required to apply the principles on their own. Every instructor has heard the complaint “I understand the material but I just can’t do the problems!” Homework, quizzes and exams are three primary ways students can demonstrate a
mastery of the course material. Feedback on homework is critical in this process, but unfortunately, for many schools hand grading all the homework is unrealistic due to a lack of time and resources. On-line, web-delivered homework and quizzes can help mitigate this problem. One disadvantage of this approach is that computer graded homework and quizzes generally only evaluate the answer to a problem and not the process by which the student acquired the answer. The author is fortunate enough to have student graders, so all of the homework is graded and the students are marked off not only for wrong answers, but also for not showing all of their work, for being messy, or for not communicating the solution in a clear manner. This has the added benefit of stressing the very important communication aspect of engineering problem solving.

Multimedia materials can be used by students working through the materials on their own or by a professor using the materials as an aid during lecture. Those developed primarily for students to do on their own include interactive tutorials that walk students through the process of drawing shear and bending moment diagrams. Multimedia applications that are being developed for classroom use include computer-based interactive examples for statics instruction. Both of these groups of developers have used Macromedia Flash. Student response to the models for statics instruction was mediocre at best. Hubing’s research group observed that when the switch was made from the blackboard to the computer examples students tended to sit back and relax and were no longer as engaged. They modified the problems to be shorter and more query based.

Clearly a key to the successful implementation of these technologies is the answer to the question of how to engage students in a meaningful way. Asynchronous web models have been developed that ask students questions and then allow them to check their answers with a simulated experiment. The work most similar to that presented below is in Ref. 11. This paper describes a learning experiment that was conducted at the University of Missouri-Rolla. In this study students were randomly assigned into three groups that viewed two example problems either by: 1) video lecture presentation, 2) static HTML webpage delivery, or 3) interactive animated modules featuring high quality, three dimensional graphics created with Macromedia Flash software. Students viewing the animated Flash modules had ratings and scores that were not statistically different from those students viewing the video lectures. Lacking from this study, however, were lectures in which the professor actively engages the students with questions and has them talk themselves through the problem solution. It was this type of engagement that helped motivate the examples discussed below.

The initial motivation for this work on interactive example problems was a survey that was taken at the end of the 1999 academic year. In this survey, students were asked to evaluate a number of proposed elements of a mechanics website on a scale from one to five where one indicated the student would never use this on a website and five indicated the student would use it frequently. The results of this survey are summarized in Table 1. Even though some elements seemed to be more popular with students than others, everything proposed had some students who indicated that they believed they would use it frequently. The items students indicated they would use the most were 1) answers to homework assignments, 2) old exams and 3) interactive example problems. Even though most students had never experienced an interactive example problem posted on the web, they recognized the limitations of just posting examples on the web that are in essence no different than examples in the textbook. Since all of
the example problems that are done in class are very interactive, that is, students solve example problems as a result of responding to questions, I believe students felt that if this same sort of interaction could be captured on the web, it would be advantageous.

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### II. Interactive Example Problems

To develop example problems for the web that have some degree of user interaction, the author chose to use the e-learning authoring tool DazzlerMax™. DazzlerMax™ is a software product for producing e-learning and interactive multimedia presentations, training courses, product catalogs and kiosk systems. This authoring tool was chosen because of its ease of use. DazzlerMax™ also includes a Packaging Wizard enabling the presentation to be published for the Internet as a Java applet.

DazzlerMax™ presentations are composed of individual “Tasks”, or screens, that are linked together. Each Task is composed of “Actions” and “Responses”. Actions are the things that happen in the presentation such as showing a picture, playing sound, running a video clip, etc.,
and Responses tell DazzlerMax™ how the user will interact and navigate through the presentations; for example, by pressing buttons, clicking on hot spots, typing in information, etc. Each Response can link to any other Task in the presentation, other presentations or other applications.

The examples that were developed use the same question and answer paradigm that the author uses when presenting example problems in class. The student is required to pick a strategy and to answer questions that are chosen to help guide the student through the example problem’s solution. Since there is rarely a unique path to a solution, the interactive example problems are designed to allow different paths to the solution, thus challenging the student’s perception that there is a “right way” to solve a problem. For example, for a problem involving multiple systems, the student decides which system to start with rather than being forced to passively accept one. For each wrong answer, an explanation is provided as to why it is wrong. The number of equations and unknowns are listed as the problem is solved, so the student is continually aware of how many additional equations are necessary to complete the solution. The algebra required to solve the problem is not included because it is assumed the student can use some sort of computer algebra program to solve the resulting equations. This can be done at Rose-Hulman since all of our students are required to have laptops with Maple installed and they are experienced users of this software by the time they enter the course.

Several of the interactive examples that have been developed are discussed below.

Example 1:
In this problem students are asked to determine the equations necessary to find the tension in a cable connecting two blocks. The complete problem statement is shown in Figure 1.

For the system shown, the mass of A is $m_A$ and the mass of B is $m_B$ and the applied force is $P$. Assume the friction between all surfaces is negligible. Derive the equations necessary to solve for the tension in the cable and the accelerations of the two blocks.

This interactive example includes the major decision points and steps shown below:
1. Students are asked which kinetics principle to apply.
2. After identifying Newton’s 2nd law, they are asked to identify a system. They can choose block A, block B, or block A and B together.
3. The system chosen is isolated using a system boundary and its free body diagram is drawn and the equations are developed.

4. The unknowns are listed and since there are more unknowns than equations the student is asked where to get more equations. After they identify the need to pick another system, the procedure is repeated.

5. After deriving the equations of motion for two independent systems, there are still too many unknowns, so they are asked how to get more equations. If they try to select another system they are told that they only have two independent systems in this problem, so they need to look some place else for additional equations. Eventually they will choose to look at the kinematics of the problem.

6. For the kinematics aspect of the problem, they can choose to look at dependent motion or relative motion. If they choose dependent motion, they are walked through this aspect of the problem and if they choose relative motion, they are walked through the relative motion aspect of the problem. They need to use both relative motion and dependent motion to solve the problem.

7. Only after they have an equal number of equations and unknowns are the final list of equations and unknowns listed as shown in Figure 2. In Figure 2 the equations shown are for the case where block A and block B are chosen as systems. If the student had chosen to use block A and B together as one of the systems then the equations would obviously be different.

For the system shown, the mass of A is mA and the mass of B is mB and the applied force is P. Assume the friction between all surfaces is negligible. Derive the equations necessary to solve for the tension in the cable and the accelerations of the two blocks.

### Summary of Equations

**Block A:**
\[
\frac{d^2x_A}{dt^2} = \sum F_x \quad \rightarrow \quad m_A a_x = P - 2T + 7\cos(5^\circ) - N_B \sin(5^\circ)
\]
\[
\frac{d^2y_A}{dt^2} = \sum F_y \quad \rightarrow \quad 0 = N_A - m_A g - 7\sin(5^\circ) - N_B \cos(5^\circ)
\]

**Block B:**
\[
\frac{d^2x_B}{dt^2} = \sum F_x \quad \rightarrow \quad m_B a_x = -2T \cos(5^\circ) + N_B \sin(5^\circ)
\]
\[
\frac{d^2y_B}{dt^2} = \sum F_y \quad \rightarrow \quad -m_B g = N_B \cos(5^\circ) - m_B g + 7\sin(5^\circ)
\]

**Relative Motion:**

1. \( a_B = a_A + a_{BA/B} \cos(5^\circ) \)
2. \( -a_B = -a_{BA/A} \sin(5^\circ) \)

**Dependent Motion:**

\( 0 = 2a_A + a_{BA/A} \)

### Figure 2
A snapshot of the final screen of the interactive example problem summarizing the equations necessary to solve the problem.
Example 2:
In this problem students are asked to determine the velocity of two disks that are connected by a bar after one of the disks has rotated through an angle of $90^\circ$. The complete problem statement is shown in Figure 3.

The rod $AB$ is attached to two uniform disks as shown below. A constant force, $F$, is applied to point $B$ causing the disks to roll without slipping on the ground. Knowing that all the objects are initially at rest, determine the equations necessary to find the angular velocities of each of the objects after disk 1 rotates through 90 degrees.

![Diagram of the rod AB attached to two uniform disks with radius $r$, mass $m_1$, length $L$, mass $m_2$, and mass $m_{bar}$, with no slipping](image)

**Figure 3** Problem statement for a problem involving conservation of energy.

This example includes the major conceptual steps shown below:

1. Students are required to choose which principle to apply.
2. After choosing to use conservation of energy, students are required to select a system.
3. If the students choose one of the individual objects as a system, it is explained to them why it is not the best system and they choose again.
4. After choosing all three objects as a system, the system is drawn at the two times of interest and the energy equation is written. Students are required to click on each term in the energy equation as shown in Figure 4. As soon as the student selects the box indicated, the equation for that energy term appears in the workspace below. The intent is to help students gain a better understanding of where each term is coming from in the energy equation.
5. After the full energy equation is developed, the unknown variables are listed and since there are more unknowns than equations, students are asked where to get additional equations.
6. After identifying the need to examine the kinematics of the problem, students are walked through relating the various velocities in the problem.
7. Only when there are the same number of equations and unknowns is the problem considered solved.
Example 3:
In this example students are asked to examine a slider-crank mechanism and to determine the equations necessary to find the forces at two points as a function of the crank angle, $\theta$. A complete statement of the problem is shown in Figure 5.

In the engine system shown $L = 250$ mm and $b = 100$ mm. The connecting rod BD is assumed to be a 1.2 kg uniform slender rod and is attached to the 1.8 kg piston P. During a test of the system, crank AB is made to rotate with a constant angular velocity of 600 rpm clockwise with no force applied to the face of the piston. Determine the forces at B and D on the connecting rod as functions of $\theta$ and make plots of $B_x, B_y, D_x$ and $D_y$. The figure shown is a top view so you will not have the weights on the FBDs.

### Figure 4
A snapshot of one of the steps in the solution to a problem involving conservation of energy.

### Figure 5
The problem statement for a rigid body dynamics problem involving direct application of Newton’s 2nd law.
This example includes the major conceptual steps shown below:

1. Students are asked which kinetics principle to apply.
2. After identifying Newton's 2nd law, they are asked to identify a system. They can choose the piston, the connecting rod or the crank. A system boundary is drawn around the system selected and the system is isolated.
3. For the system they choose, the free body diagram is drawn and the equations are developed.
4. The unknowns are listed and since there are more unknowns than equations, the student is asked how to get more equations. After they identify the need to pick another system, the procedure is repeated.
5. After deriving the equation of motion for all possible systems, there are still too many unknowns so they are asked how to get more equations. Eventually they will choose to look at the kinematics of the problem.
6. At this point students are guided through the kinematics aspect of the problem and the relating of the velocities and accelerations of various points in the problem.
7. Only when there are the same number of equations and unknowns is the problem considered solved.

Each of these example problems took approximately 20-40 hours to develop and they are available for general use at http://www.rose-hulman.edu/~cornwell/courses/es204/other.htm.

III. Assessment

The initial assessment of these examples involved 10 students from the United States Air Force Academy and 43 students from Rose-Hulman. Students were asked to work through one of the interactive example problems and then to fill out a survey. On this survey students were asked to complete two sentences and to make additional comments as shown below:

1) The best thing about the example problem was:
2) If I were to change one thing about the module, it would be:
3) Other comments:

Students were also asked to indicate their agreement or disagreement on a scale from one to five with a number of statements. The scale was:

1 = strongly disagree  2 = disagree  3 = neutral  4 = agree  5 = strongly agree

and the statements were:

Statement 1: The interactive portion of the examples helped me learn the material.
Statement 2: There should be more detailed explanations when I pick the wrong choice.
Statement 3: I actually worked through the problem myself, rather than continuously clicking on the options.
Statement 4: More examples like these on different topics would be helpful.
Statement 5: I was interested enough in this example that I looked at some of the other examples on the web page.
The results of this survey are shown in Figure 6.

![Figure 6](image)

**Figure 6** Assessment results of the interactive example problems.

From Fig. 6 it is clear that in general the examples were received very well. Over 80% of the students agreed or strongly agreed that the interactive portion of the examples helped them learn the material. Unfortunately, this is only their perception and it was not possible to give an exam to compare the knowledge of students who used the interactive examples versus students exposed to the examples in a more traditional way. Therefore, it is not clear if these examples actually enhanced students’ learning of the material. Apparently the explanations were adequate since only 17% of the students felt that more detailed explanations were necessary. Only 47% of the students indicated that they worked through the problem themselves, rather than continuously clicking on the options, but this is not unexpected. I would contend that students who read an example in the textbook rarely work through the problem themselves. The survey indicated that students wanted additional interactive example problems available to them. The primary difficulty in developing more example problems is the time required to generate them and to account for all possible paths through a problem solution.

Selected comments to the three open ended questions are shown below.

1) The best thing about the example problem was:
   - it told me why a choice was correct. I didn't have to take it just as being the right answer, I was given a reason as well.
   - the interactive explanations even when the wrong answer was chosen. I feel that learning why a certain answer is NOT the correct answer helps us to better understand the correct answer. I would even click on the wrong answer after choosing the right, just to read those explanations.
   - Listing the equations and unknowns was also very helpful. Often, I don’t think to do this and then realize later, I still need more equations!
   - it gave the step by step solution process, which would be helpful if a student got stuck on a certain part of the problem.
   - the organization.
it showed a quick way to work through the problems and was interactive.
I liked how the equations were clearly labeled and explained.
it was a step-by-step walkthrough which explained in detail at step why certain choices were correct.

2) If I were to change one thing about the module, it would be:
• If I were to change one thing, it would be ensuring that the guidance always says exactly what the next step is. For example, instead of just “click on the red box”, stating that next we will write the kinetic energy for disk 1 (although an arrow pointed to it stating that)- I didn’t realize it was time for me to try the equation out. It’s hard to ensure that you are writing the equations out on your own and then seeing if they are correct, if you click on something and boom! it’s already there without warning. However, this only happens on a few occasions.
• There ought to be multiple choice questions that are graded so that the student has the motivation to sit down and figure out what is precisely going on in the problem. With no extrinsic motivation, it is highly likely that students will simply click through the problem...Then come test time, they will be suffering.
• There should be more explanations as to why things are wrong. People also learn from their mistakes.
• More examples, and maybe have some with the same terms that we use. It was still good to work with though.
• More explanations as to where you get the equations from. During the interaction, all you need to do is click and you get stuff out. If you were to make the students actually need to add the equations themselves and provide hints along the way, I think that would be a much more useful tool for learning.
• More questions. Make it even more interactive.

3) Other comments:
• Overall, this was very cool! This is much better than book examples and I would prefer to practice problems like this than out of the text. However, I would suggest not using this purely to learn the concepts for the first time.
• I'm not used to learning this way but if I did it more often I'd get better at it. The piston example is cool how it draws the FBD and stuff.
• I think these types of applications could be a useful tool in learning dynamics.
• Very good example and method. I like it.

IV. Conclusions

Interactive web example problems have been developed. These examples have the following features:
• They allow for more than one path through the problem. This capability requires the developer to be able to anticipate all the possible routes a student could take through a problem.
They include explanations on every choice students make, whether right or wrong. Questions guide students through the problem in a manner similar to the way a professor guides students through an example problem in class. They can more clearly emphasize what a system is and its associated free body diagram. A system boundary is drawn around the object and then the student sees the object moved to another part of the paper to draw a free body diagram.

Overall, initial student reactions to the example problems were very positive.

V. Acknowledgment

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VI. References


PHILLIP CORNWELL
Phillip Cornwell is a Professor of Mechanical Engineering at Rose-Hulman Institute of Technology. He received his Ph.D. from Princeton University in 1989 and his present interests include structural dynamics, structural health monitoring, and undergraduate engineering education. Dr. Cornwell has received an SAE Ralph R. Teetor Educational Award in 1992, and the Dean’s Outstanding Teacher award at Rose-Hulman in 2000.