AN INTERDISCIPLINARY, MULTI-SEMESTER PROJECT RELATING DIFFERENTIAL EQUATIONS AND ENGINEERING

\[ m \frac{d^2x}{dt^2} + c \frac{dx}{dt} + kx = f(t) \]

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Outline

• The Problem
• The Project Solution
• UML Mechanical Engineering Curriculum
• Differential Equations Course Content
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The Problem

Engineering students often do not understand the relevance of Differential Equations to courses in their major.

Therefore, there is low motivation to learn essential skills for later coursework.
The Problem

Student Comment:

Professor, why weren't we told that the material covered in Differential Equations was going to be really important for the work in this course?

Professor Thoughts:

Hmmmmm...

Student views material in a disjointed fashion

Professor clearly sees how pieces fit together

An Interdisciplinary, Multi-Semester Project relating Differential Equations and Engineering

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The Problem

When the time comes for students to recall Differential Equations, they have difficulty doing this because so much time has passed.

It can be challenging to teach “engineering” while speaking “mathematics.”
The Proposed Solution

Interdisciplinary, multisemester project designed to lead students to appreciate the relevance and importance of basic STEM (Science, Technology, Engineering and Mathematics) material

Project:

Analysis of 1st- and 2nd-order dynamic systems from various points of view, including mathematical modeling
# UML Mechanical Engineering Curriculum

Courses which will utilize the common project

<table>
<thead>
<tr>
<th>Sophomore Year</th>
<th>Junior Year</th>
<th>Senior Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Semester</strong></td>
<td><strong>1st Semester</strong></td>
<td><strong>1st Semester</strong></td>
</tr>
<tr>
<td></td>
<td>Applied Analysis</td>
<td>Mechanical Engineering Lab II</td>
</tr>
<tr>
<td><strong>2nd Semester</strong></td>
<td><strong>2nd Semester</strong></td>
<td><strong>2nd Semester</strong></td>
</tr>
<tr>
<td>Engineering Differential Equations</td>
<td>Mechanical Engineering Lab I</td>
<td>Dynamic Systems</td>
</tr>
</tbody>
</table>

NOTE: The concepts described here can also be applied to other engineering disciplines and other institutions.
UML Mechanical Engineering Curriculum

**COURSE**

- Engineering Differential Equations
- Applied Analysis
- Mechanical Engineering Lab I
- Mechanical Engineering Lab II
- Dynamic Systems

**FOCUS**

- Mathematical Modeling & Analytical Techniques
- Test & Measurements
- Measurements & Other Modeling Methods
Each semester, students will:

1) be reminded of what they already know about the project material

2) apply newly learned techniques from the current course
Differential Equations:

Course Content
Differential Equations Course

Even in applications,

object of interest = differential equation  
goal = solution formula

Engineering point of view,

object of interest = system being modeled  
goal = understand system  
response to different classes of inputs
Differential Equations Course

With the advent of this project, the Engineering Differential Equations course has been modified to reflect more of the engineering point of view.

Two systems:

- RC Circuit
- Mass-Spring-Dashpot (MCK) System

Students learn how to model these systems using:

- RC Circuit: 1st-order linear differential eq.
- MCK System: 2nd-order linear differential eq.
Traditionally, the students learn how to model each of these systems by a differential equation, and they learn analytical techniques for finding solutions of the model equations.

Now, they also use the solution formulas to investigate the response of the modeled system to different types of input.
Project Modules

Computer-based tools were developed using the MATLAB, Simulink, and LabVIEW software packages.

A graphical user interface (GUI) allows for easy adjustment of system parameters so the student can explore the effects of changing parameter values on system response.
First Order Systems

\[ R \quad \text{\textbullet} \quad C \quad \text{\textbullet} \quad V_{\text{IN}} \quad C \quad V_{\text{OUT}} \]
First Order Low Pass Filter GUI

User enters time constant and sinusoidal frequency.

The Bode plot is displayed with the cutoff frequency and the applied sinusoidal frequency.

The initial sinusoidal signal and “filtered” time signal are also displayed.

\[
\frac{dx}{dt} + \frac{1}{RC} x = f(t)
\]
Second Order Systems

\[ x(t) f(t) \]

\[ m \]

\[ k \]

\[ c \]
Nels Wirkkala, Research Assistant
Mechanical Engineering Department

An Interdisciplinary, Multi-Semester Project relating Differential Equations and Engineering

2nd Order System Initial Condition GUI

User enters $M$, $C$ and $K$: natural frequency, critical damping and damping are reported.

User can vary the physical parameters with slide bars.

The frequency response function magnitude is displayed along with root locus and time response.

$$m \frac{d^2 x}{dt^2} + c \frac{dx}{dt} + kx = f(t)$$
Preliminary Assessment
The project is only in its 2nd year, so complete data on the program's effectiveness are not yet available.

However, there are preliminary indications that the project has positive effects on students' learning.

Students in the Fall 2004 Engineering Differential Equations course were surveyed before and after this project.
Preliminary Assessment

The students were asked to respond to 17 statements, indicating whether they:

1) strongly agreed,
2) somewhat agreed,
3) had no opinion,
4) somewhat disagreed, or
5) strongly disagreed.
Preliminary Assessment

<table>
<thead>
<tr>
<th>Percentage of students who strongly agreed or somewhat agreed to the first four statements</th>
<th>BEFORE</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>I understand the need for ordinary differential equations in course work for my major.</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>I understand the need for ordinary differential equations in solving practical problems in engineering and science.</td>
<td>79%</td>
<td>100%</td>
</tr>
<tr>
<td>The material from this course will be useful to me in courses in my major.</td>
<td>79%</td>
<td>100%</td>
</tr>
<tr>
<td>The material from this course will be useful to me in my career.</td>
<td>54%</td>
<td>78%</td>
</tr>
</tbody>
</table>
## Preliminary Assessment

Percentage of students who **strongly agreed** to the first four statements

<table>
<thead>
<tr>
<th>Statement</th>
<th>BEFORE</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>I understand the need for ordinary differential equations in course work for my major.</td>
<td>29%</td>
<td>56%</td>
</tr>
<tr>
<td>I understand the need for ordinary differential equations in solving practical problems in engineering and science.</td>
<td>38%</td>
<td>56%</td>
</tr>
<tr>
<td>The material from this course will be useful to me in courses in my major.</td>
<td>25%</td>
<td>67%</td>
</tr>
<tr>
<td>The material from this course will be useful to me in my career.</td>
<td>21%</td>
<td>28%</td>
</tr>
</tbody>
</table>
Summary
Integration of engineering concepts into Differential Equations course has been accepted favorably by students.

The students tend to better understand the material as evidenced from overall capabilities and student comments regarding how they feel with respect to their overall understanding of the material.

Data indicate an increase in student awareness of the need for differential equations during the course of the semester.
Project Overview
Technical Papers
Tutorials
Online Acquisition
Downloads
Acknowledgements
People
Feedback

Tutorials cover a wide assortment of integrated material
Matlab GUIs are available for download

Multi-Semester Intertwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems

Tutorials & GUIs

Material is available on several different topics:
MATLAB & Simulink
First Order Systems
Second Order Systems
Integration and Differentiation
Regression Analysis
Fourier Series
Virtual Measurement System

We would greatly appreciate any feedback you can provide to us about whether you have found this material useful.

Webpage  http://dynsys.uml.edu
Acknowledgements

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