Teaching Critical, Creative, and Practical Thinking with MATLAB Symbolic Math

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Background and Objective:

This paper is one of seven poster papers that cover specific aspects of goal directed course design[1]. The course design process was applied to Engineering 1221, a two credit hour, sophomore level course at The Ohio State University on engineering problem solving using software tools. In this paper, we present the part of the course design that creates a successful learning environment for understanding the *underlying thought processes* supporting these learning objectives.

In goal directed course design, statements of what students should know and care about upon successful completion of the course, are articulated first. Next, observable and measurable learning objectives were identified, which were aligned with the course goals. The course goals were derived from a given subset of ABET student outcomes.

The objective of this poster paper[2] is demonstration of the capabilities of MATLAB as a symbolic math equation solver and as a graphical communications tool; and demonstration of their support of the learning objectives of Engineering 1221.

Method:

The MATLAB Symbolic Math Toolbox[3] provides functions for solving and manipulating symbolic math expressions. Using symbolic math permits solution of equations in symbolic form first. Next, the expressions are evaluated using variable-precision arithmetic. The MATLAB Symbolic Math Toolbox can perform many types of calculations, including differentiation, integration, simplification, transforms, and equation solving.

Students first become familiar with symbolic math by using it in the interactive, iterative design method[4]. Starting with an initial design, the interactive design method repeats the following cycle until the desired level of performance is achieved: Observe, define the problems, develop the solutions, test and evaluate the design, and implement the solutions. After familiarizing themselves with the basics, students use symbolic math on the Wind Farm term project to perform calculations and display results. These results can be shared with other team members as part of the interactive design process using the communications tools that are part of the MATLAB Symbolic Math Toolbox.

Results:

The figures on this poster paper illustrate how Symbolic Math can solve math and engineering problems. Each figure is framed in the color associate with its primary learning objective as follows:

1. THINK (coral)**:** *Demonstrate ability in critical, creative and practical thinking through algorithm design, MATLAB software design and evaluation.* **For example**: Application of symbolic math in simulation, optimization, and data analysis; and, Understanding the use of symbolic approaches in solving complex problems at the forefront of science and engineering.

2. USE TOOLS (purple)**:** *Utilize MATLAB software tools to solve engineering problems.* **For example**: Exploring the capabilities of the MATLAB Symbolic Math Toolbox.

3. COMMUNICATE (orange)**:** *Demonstrate skill in technical communication related to engineering and software development.* **For example**: Developing expertise in using the symbolic math plotting function ezplot to communicate the problem solving results.

Symbolic math is introduced early in the semester to solve for the roots of a quadratic equation representing the trajectory of an ice ball that is hurled from the blade of a wind turbine. Students are asked to compare solutions to the equation using both symbolic math and the quadratic formula.

Later in the course symbolic math is addressed specifically. Students solve a series of problems, each focusing on a different aspect of symbolic math, developed from examples given by the textbook used for this course[5]. Figures 1 and 2 illustrate how MATLAB symbolic math is used to integrate and differentiate equations. Students learn the fundamental concept of symbolic math: The result of processing a symbolic expression is another symbolic expression instead of a numerical result as it is in conventional computing. Figures 3and 4 demonstrate how symbolic math is used to solve systems of equations. These systems of equations represent 'real world' engineering problems. Figures 5 and 6 show how the results of MATLAB symbolic math displayed as two-dimensional plots are used to communicate solutions graphically.

As the course continues, the capabilities of the MATLAB Symbolic Math Toolbox to support analysis and communications using ezplot are demonstrated. The examples in Figures 7 and 8 illustrate the expanded communications capabilities of MATLAB using the specialized symbolic math plotting function ezplot. Figures 9, 10 and 11 show how the results of MATLAB symbolic math computations can be displayed as three-dimensional surface plots.

Conclusions:

Symbolic math supports our primary course goal of teaching students to think. Student labs, as well as, the "technical challenge" problems, provide opportunities for students to develop fluency in engineering thought processes including critical, creative, practical thinking. The course learning objective: *Demonstrate ability in critical, creative and practical thinking* *through algorithm design and evaluation,* is achieved through the student labs and "technical challenge" problems associate with the MATLAB Symbolic Math Toolbox.

In addition, the skills developed using the MATLAB Symbolic Math Toolbox are directly related to two additional course learning objectives: *Utilize MATLAB software tools to solve engineering problems;* and, *Demonstrate skill in technical communication related to engineering.* The MATLAB ezplot function is exceptionally well suited to communicating symbolic math solutions. It can be used to view results of changes in initial conditions on the final outcome of engineering problems, facilitating "what if" investigations of the effect of design modifications.

MATLAB symbolic math solves engineering problems that can be represented as equations or sets of equations, including differential and integral equations. It is one of the most versatile tools in MATLAB. It can be used to replace many specialized MATLAB Toolboxes with a single Toolbox applicable across multiple engineering disciplines. The advantage is that skill developed in using a single MATLAB Toolbox can be applies across multiple engineering disciplines. The disadvantage if using the MATLAB Symbolic Math Toolbox stems from the requirement for a deeper and more fundamental understanding of the engineering principles underlying the problem solution than is required for using other MATLAB toolboxes.

In summary, the MATLAB Symbolic Math Toolbox creates a successful learning environment for assimilating the *underlying thought processes* supporting engineering design and analysis. This, in turn, supports three of the primary course leaning objectives: THINK, USE TOOLS and COMMUNICATE.

References:

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