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Online Matlab/Octave tutorial to help non-computer science engineering students improve programming skills

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Abstract

The goal of the project is to integrate interactive tutorials into engineering classes to support students' knowledge, facility, and prior experience with programming. Research[1] has shown benefits in using tutorials via mobile and web applications to better engage students and help them learn at their own pace and level. The programming platform will be Matlab/Octave[2] which is a programming language initially developed for numerical computations. It is widely used across industry and academia and research institutions. Knowledge in Matlab/Octave is required in many of the engineering job openings, which makes it a very important technical skill that our students have to master for a successful career as engineers.

Knowledge of programming and specifically Matlab is a prerequisite for several classes taught at the Schools of Engineering around the country and a Matlab course or equivalent is mandatory for many mechanical and bioengineering students. Just one course (10 weeks, in a quarter system) is clearly not enough to learn to program effectively. To achieve true proficiency, subsequent classes should routinely exercise prior programming skills and techniques. This is especially difficult since the current Matlab course is taken by most students in their freshman/sophomore year, while the required classes using Matlab are usually taken in later years. Students typically remember very little of Matlab and this leads to difficulties on homework and class projects and necessitates significant amount of class time and office hours for reviewing programming concepts. The challenge is to maintain the curriculum for the later classes -what is being learned- while enhancing the learning experience through on-line support of programming concepts. Use of the proposed tool will encourage active participation, provide prompt feedback, and pose challenging but achievable goals.

This project will allow students who need review or develop proficiency to work on their own time and at their own pace by following our on-line tutorial. The tutorial will cover the most important programming concepts needed for the later classes. Therefore, the tutorial, while reviewing general programming concepts, will also be targeted to the specific class, and the instructor in charge of the class will be able to create his own content.

Paper Body

This paper is based in Digital Game Based Learning (DGBL) pedagogical theory[3], a constructivist theory of education. Digital game-based learning (DGBL) is an instructional method that incorporates educational content or learning principles into web content and video games to actively engage learners in a more relaxed environment to which millennial students are nowadays more used to. Research[4,5] has shown benefits in using mobile applications to better engage students and help them learn at their own pace and level, learning has the potential to engage and motivate students and offer custom learning experiences while promoting long-term memory and providing practical experience.

In his article M. Pensky[3] states that recent generations of students, the so called Millennials, have lived their entire lives with access to technology — not only computers, but also digital music and video players, cell phones, video games, and a host of other gizmos that require technology. Because of this access to technology, Pensky argues that today's students "think and process information fundamentally differently than their predecessors." And teachers now have to adapt to the language and learning styles of "digital natives".

A.1 Project Goals.

First, integrate interactive tutorials into engineering classrooms that require previous programming knowledge of Matlab/Octave. To achieve true proficiency in Matlab, subsequent classes should routinely make use of it. Students typically remember very little of Matlab when they take these upper divisions classes. This makes it difficult for students to do the homework and class projects and also creates difficulties for the faculty who, after requiring students to take anything from 3 to 5 units class (depending on the intitution) in Matlab, find themselves dedicating significant amounts of class time and office hours to reviewing Matlab programming concepts. Second, to encourage collaboration without "cheating".

This project includes a second component that works more like a forum for questions and answers related to Matlab. Students will post a question or problem that he/she is having with Matlab and the rest of the class or the TA can answer. The forum will be monitored by the instructor to avoid inappropriate questions but will not require intervention. The main problem with forums of QA is that students do not participate in them. To encourage students, we want to implement a kind of "stackoverflow.com" system where participants can vote for the best answer and students with best answer selected receive a star.

This project enhances student learning since it blends a 21st century fundamental engineering skill, programming, with the theory and skill development of the existing engineering curriculum. It enhances teaching because it will provide a shared and consistent resource for multiple instructors and in multiple subjects. It will free more instructor time to cover the key topics for the subject, and it will fundamentally enable more sophisticated applications to be

addressed in class. We envision this technology enhancing the class environment in two ways: first, to review main programming concepts in a more dynamic way than just a lecture; second, by interacting with the QA repository, not only asking questions but also posting answers. This is a way to develop the crucial skill of "debugging" a program, i.e., the detective work necessary to ferret out coding errors, both by analysis and by searching in the aforementioned QA repository. This also enhances peer-to-peer collaboration among students. There are other universities implementing similar concepts as proposed in this paper, for example Stanford[7] and Berkeley[8] , have as part of different engineering classes an online discussion forum, where students can ask questions and suggest answers to those questions, both of which can be voted up or down by their peers.

A.2 Project Method and Outcome

The project has two main outcomes. First, an online Interactive tutorial integrated with the Resource Management Class Tool used at our institution (canvas). Second, a forum with ranking system to enhance responses. Both tools are implemented in a way that can be reused for different classes and easily adapted to their content.

We integrated as much as possible all tools created for the project into Canvas/Camino minimizing the number of platforms students needed to use. In the first week of classes, students of the numerical analysis class where instructed to take an online interactive tutorial (Figure 1), to check student Matlab preparation. As can be seen in Fig 2 students can directly enter Matlab code on the quiz question answer space and get the result executed from inside canvas, without the need to install a compiler or go to a different program.

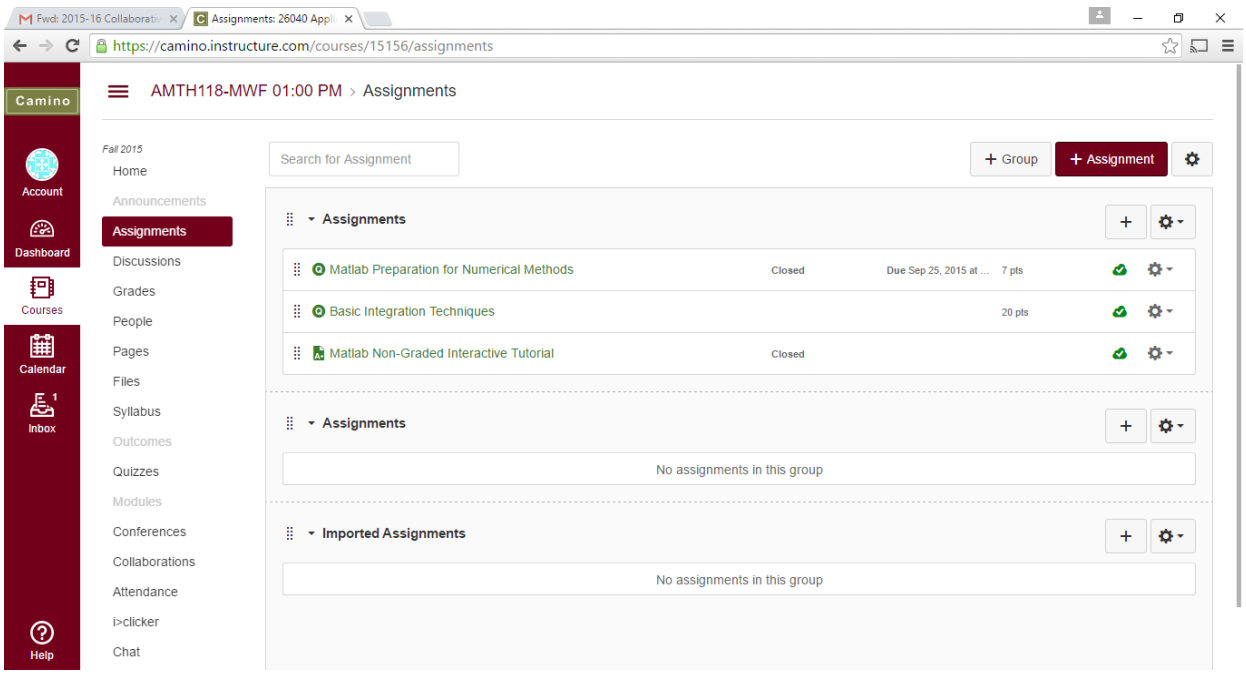

Fig 1. Extra Iterative tutorials to Prepare students for Numerical Analysis

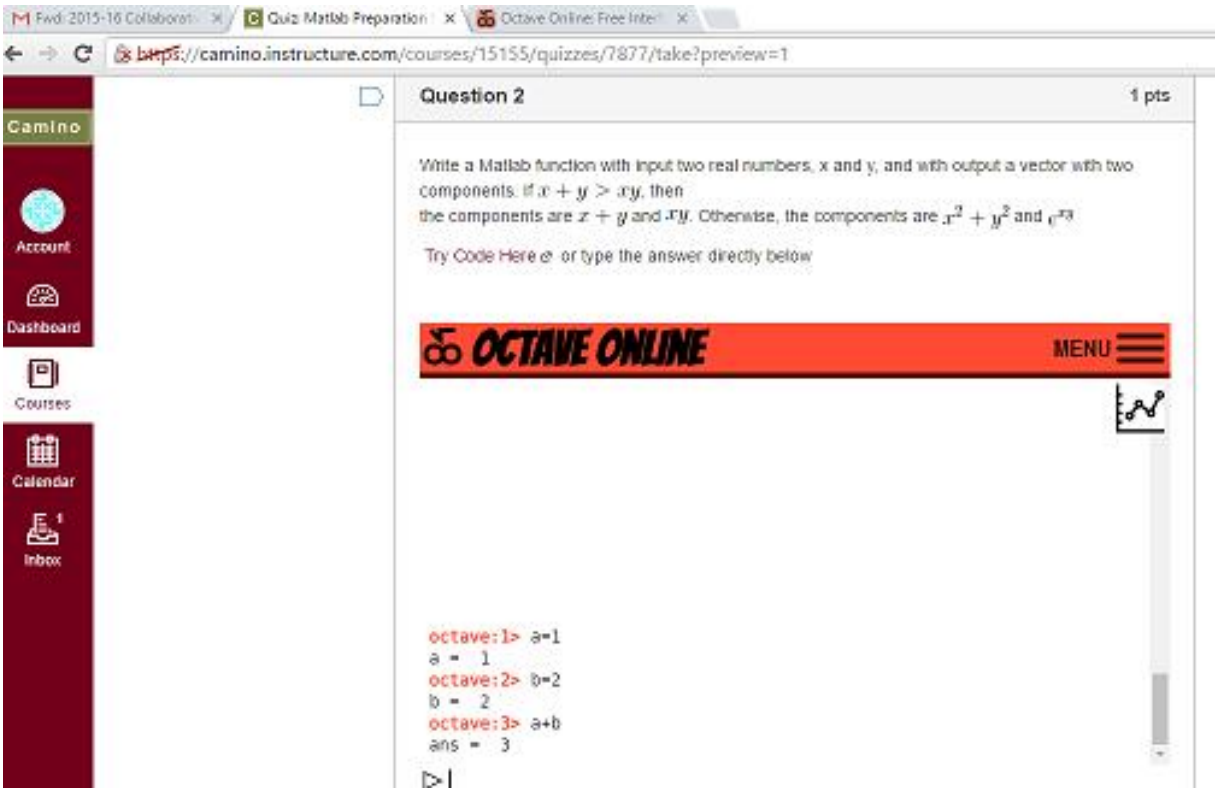

Fig 2. Sample Question of Tutorial

After taking the non-graded quiz, the TA, and the instructor for the class review the results to check for areas that need improvements. Students were then assigned tutorials to address areas of weakness. The following is a sample of the instructions sent to students.

"Over the years, I noticed that the students' main problem to succeed in taking this class is lack of programming knowledge, to solve this problem I suggest students take the following tutorial. If you feel confident in your Matlab skills, you can skip this tutorial and try directly the graded **online** Matlab Quiz 1 (X% of your grade). There will be an i**n-Class** Quiz (X% of your grade) based on the previous one. You should be able to finish the entire tutorial in the first two/three days of the quarter. Necessary for this class are the following modules: Syntax, variables, commands, M-Files, Data Types, Operators, Decision, Loops, Vectors, Matrix, Array, Colon Notation, Number, Functions, Data Import/Export and Plotting. Clink on the next link to start the self-paced tutorial. **Note:** the tutorial is interactive, you can click on Try-It button and change values and then click on Execute to see the result"

To achieve the second goal, we implemented a Q&A forum inside canvas and used Pizza features to manage it (Fig. 3). Students are encouraging to participate in the forum, but no grade is assign to this to avoid competitiveness. All participants can vote for the best answer and the highest-ranking answer will show always on top. We create a forum for each one of the main labs/assignments on the course, this way student can quickly find help on the project they are

working on.

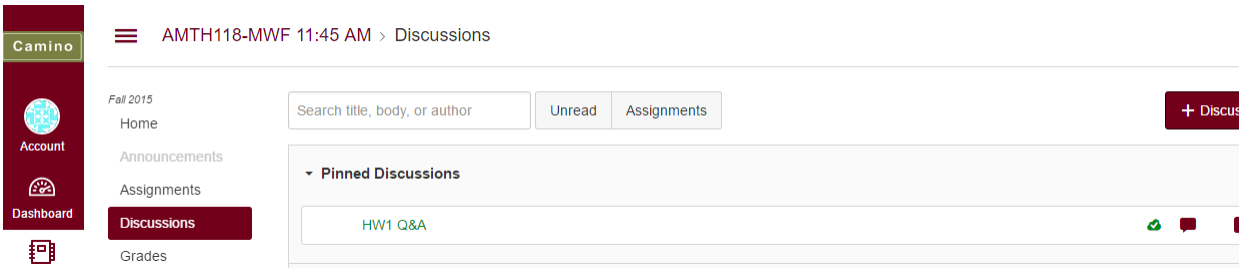

Fig 3 Q&A Forum

Results

To evaluate the benefits of this project we used some of these educational technologies in different classes. Introduction to Programming in the Computer Engineering Department, a Numerical Analysis class in the Applied Math Department, and Introduction to Programming for Engineers in the Mechanical Engineering Department. This project allowed us to gather information about what programming concepts students struggle the most with, which is important information directly applicable to the teaching of introduction to programming, an important prerequisite course for many engineering classes. A summary of the average time students spend on each of the tutorial topics is presented in Table I. We can conclude from this table that students have the most trouble with iterative approximations and functions, this result was expected since those concepts are more difficult to understand in general

Since we are able to time how long students spend on the tutorial, we get a better idea of how much time students should spend to satisfactorily complete class assignments, and provide this information to the students to give them an idea of what is expected of them.

Table I. Time Spent per Topic

Topic	Average % of Time Spent
Syntax Variables	5%
M-Files	5%
Decision	5%
Loops	15%
Iterative Approximation	30%
Functions	25%

Data In/Out	15%

As part of the tutorial students also have to take an online quiz, which is open book, open notes and students can retake it three times, the main purpose is to self asses the student assimilation of the tutorial. We measured the influence of this tutorial on the students grades by comparing results to prior years (before taking the tutorial) with this year (after taking tutorial) and measure the influence of on-line quizzes on improved performance in the classroom. A summary of these findings can be seen in table II. Fundamentally we studied if online quizzes and interactive tutorials makes students like programming more. Very often student enjoyment and motivation is an important factor on performance in the classroom and afterwards.

Table II Average class grade

Year	Grade Average (for the class)
2013	2.85
2014	2.75
2015 (tutorial introduced)	2.92

We also evaluated and measured student acceptance using the course evaluation comments related to overall improvement in the learning experience. In Table III we present a summary of this data , still we get some comments that are related to being expected to know more about how to program than what they actually learned but the students do better in the class and we are improving the tutorials according to this feedback

Table III Summary of Students Evaluations Comments

Students comments before tutorial introduction	Students comments after tutorial introduction
Instructor expects us to know how to program	The tutorial was nice but more time should be used explaining how to use it and more exercises should be added
Impossible projects that require tons of time doing very little numerical methods	Tutorial helps with initial fear for this class
Tough class not the instructor fault but lack of previous preparation	Tutorial should be expanded

Instructor expects us to program like pros	Tutorial did help

Conclusion

We want to evaluate long-term effects of the project, and to compare the test results of upper division classes that require programming skills before and after the introduction of the tutorial/forum. We need to gather more data about this but results from the last two year seem to confirm the value of using the tutorial.

To encourage students, use of the tutorial for longer periods instructors need to spend more time explaining the new tools at the beginning of the quarter. We also want to explore the possibility of doing this tutorial as a one day seminar, this way no class time needs to be compromised. We are also planning on improving the forum for Q&A to allow students to add pictures (so they can meet each other) and make it easier to search.

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