

Work in Progress: Development of MATLAB Instructional Modules for Engineering Students

Dr. Sergey Nersesov, Villanova University

Sergey G. Nersesov received the B.S. and M.S. degrees in aerospace engineering from the Moscow Institute of Physics and Technology, Zhukovsky, Russia, in 1997 and 1999, respectively, with specialization in dynamics and control of aerospace vehicles. From 1998 to 1999 he served as a researcher in the Dynamics and Control Systems Division of the Central Aero-Hydrodynamic Institute (TsAGI), Zhukovsky, Russia. In 2003 he received the M.S. degree in applied mathematics and in 2005 he received the Ph.D. degree in aerospace engineering both from the Georgia Institute of Technology, Atlanta, GA. Currently, he is an Associate Professor in the Department of Mechanical Engineering at Villanova University, Villanova, PA. His research interests include nonlinear robust and adaptive control, nonlinear dynamical system theory, large-scale systems, cooperative control for multi-agent systems, hierarchical nonlinear switching control, hybrid and impulsive control for nonlinear systems, system thermodynamics, thermodynamic modeling of mechanical and aerospace systems, and nonlinear analysis and control of biological and physiological systems. Dr. Nersesov is a coauthor of the books *Thermodynamics. A Dynamical Systems Approach* (Princeton University Press, 2005), *Impulsive and Hybrid Dynamical Systems. Stability, Dissipativity, and Control* (Princeton University Press, 2006), and *Large-Scale Dynamical Systems. A Vector Dissipative Systems Approach* (Princeton University Press, 2011).

Zuyi Huang, Villanova University

Zuyi (Jacky) Huang is an Associate Professor in the Department of Chemical Engineering at Villanova University. He teaches Chemical Process Control (for senior students) and Systems Biology (for graduate students) at Villanova. He is enthusiastic in applying innovative teaching methods in class to educate students with modeling and control skills. His research is focused on developing advanced modeling and systems analysis techniques to manipulate microbial biological systems for generating biofuels from wastewater and for combating biofilm-associated pathogens. His BESEL group developed the first model for microbial desalination cells and the first metabolic modeling approach for quantifying the biofilm formation of pathogens.

Work in Progress: Development of MATLAB Instructional Modules for Engineering Students

Sergey Nersesov¹, Dr. Zuyi (Jacky) Huang^{2*}

1. Department of Mechanical Engineering, Villanova University, Villanova, PA, USA
2. Department of Chemical Engineering, Villanova University, Villanova, PA, USA

* Corresponding author: zuyi.huang@villanova.edu

Abstract: As an engineering technical software, MATLAB has become an immensely popular tool in both academia and industry. It is widely used as a software supplement to many courses in the College of Engineering at Villanova University. On the other hand, instructors of different courses have to spend time introducing MATLAB repeatedly. And instructors are usually left to a very fragmental teaching of MATLAB tools needed for a specific project in a course. Moreover, being focused on the fundamentals of the course, the instructors usually do not have much time to explain the details of MATLAB. This leaves students frustrated and unaware where to seek the information needed. In order to address these issues, we developed 17 video-based instructional modules that systematically introduced fundamental MATLAB skills that are related to the curricula offered in engineering, especially in the Mechanical and Chemical Engineering departments. With these modules available online for students, instructors don't need to repeatedly introduce MATLAB in their courses. These modules were widely implemented in courses in the departments of mechanical engineering and chemical engineering in the 2017-2018 academic year at Villanova University. The students can either systematically learn MATLAB or just study the modules that are related to their courses. In order to evaluate the effectiveness of the developed modules in facilitating students' learning, an anonymous college-wide survey was conducted via Survey Monkey in May 2018. The survey included five general questions that were focused on evaluating the improvement of student's overall learning, student's conceptual understanding of principles and courses, students' ability to apply knowledge in solving real-world problems. The effectiveness of the videos in motivating student's learning and conveying the materials was also evaluated in the survey. The results show that the hands-on experience with MATLAB improved students' overall learning and conceptual understanding of principles and courses they took in engineering. Students also agreed that the training videos were effective in conveying the training materials. Open-ended comments indicate that students need more incentive to motivate them to watch the training modules. Most of them would not watch the modules if not required.

I. Introduction

MATLAB is one of the most commonly-used programming software in engineering [1]. It is widely used as a software supplement to many courses in the Departments of Mechanical Engineering (ME) and Chemical Engineering (ChE) at Villanova University. The Department of Electrical and Computer Engineering (ECE) has a separate course on MATLAB fundamentals. MATLAB also serves as a convenient platform for learning programming skills as well as logical/critical thinking. However, the teaching of MATLAB in the ME and ChE departments is not centralized and is somewhat sporadic. Neither department has a designated course and instructors are usually left to a very fragmental teaching of MATLAB tools needed for a specific project in a course. Moreover, being focused on the fundamentals of the course, the instructors usually do not have much time to explain the details of MATLAB. This leaves students frustrated and unaware where to seek the information needed.

Instructors from different courses repeatedly introduce similar MATLAB tools. This wastes the time of both students and instructors. This motivates us to provide training modules that cover the most commonly used MATLAB toolboxes and to take the burden of explaining MATLAB off the shoulders of instructors by allowing them to simply refer the students to specific modules pertaining to the assignments in the course. We developed video-based teaching modules to educate students with basic biochemical lab skills [2] and ODE solving skills in MATLAB [3, 4]. Feedbacks from students on video-based training modules indicate that those videos can not only provide students with flexibility in their learning schedule but also reduce instructors' time in covering the same topics in their courses. This motivated us to design video-based modules that cover the basics of MATLAB use and implementation and, with the significant overlap of MATLAB topics used in various ME and ChE courses at Villanova University. In particular, seventeen video-based modules were developed in Summer 2017, which were then delivered to students in the entire College of Engineering in Fall 2017. An online anonymous survey was conducted and analyzed at the end of the spring semester of 2018 by students in the entire College of Engineering. While video-based training modules of MATLAB were presented before [5-7], this work presents the first one that targets a broader student audience with multiple disciplines in the entire college.

II. Materials and Methods

Seventeen video-based modules were developed in this project to introduce MATLAB and provide application examples of MATLAB to solve problems in data process and display, curve fitting, basic statistics, linear algebra, linear and nonlinear algebraic equations, integration and differentiation, ordinary differential equations (solved in both command window and Simulink format), partial differential equations, process control (including transfer function, Laplace transfer, and PID controller design), and animation. Each module was designed to include a 15-20-minute video recording of a short lecture in which the instructor discussed a particular MATLAB feature augmented by several related examples detailing the development and implementation of the particular MATLAB script. Several videos were longer than 30 minutes as the instructors included more examples to illustrate the selected math topics. In addition, the instructors wanted to obtain feedback from students' comments on the video durations in the survey. In particular, the instructors liked to know whether a 40-minute video was too long for students to follow. The detail of each developed video-based module is listed in Table 1 below.

Table 1, Detail of the seventeen modules developed in this work.

Module Index	Module Name	Video Duration
1	Introduction of MATLAB installation, user interface, help and plot functions	28 minutes
2	Data format, operation, import and export	56 minutes
3	Data display-multiple curves, error bars, 3D plotting	42 minutes
4	Data iterative processing - function, looping and logic operation	52 minutes
5	Interpolation and Curve Fitting	25 minutes
6	Basics of Statistics	11 minutes
7	Basics of Linear Algebra	26 minutes
8	Systems of Linear Algebraic Equations	15 minutes
9	Systems of Nonlinear Algebraic Equations	23 minutes

2019 ASEE Annual Conference

10	Symbolic Integration & Differentiation	24 minutes
11	Solving ODE in MATLAB and plotting phase portrait	49 minutes
12	Introduction of Simulink and solving ODE in Simulink	43 minutes
13	Solving Linear ODE via Laplace Transform and via State Space Representation	21 minutes
14	Transfer Function and System Response Prediction	45 minutes
15	Control System Design - Root locus and PID controllers	36 minutes
16	Animation	15 minutes
17	Solving Partial Differential Equations (PDE) in MATLAB	49 minutes

The seventeenth videos, along with the handouts, were posted onto a sever in the College of Engineering at Villanova. Links for these modules were also listed in the co-authors' lab webpage. They can be accessed by any Villanova students. The links to access the module handouts and videos were sent to all faculty members and students in the college so that students can always refer to these modules when needed. It also takes the burden of explaining MATLAB off the shoulders of instructors by allowing them to simply refer the students to specific modules pertaining to the assignments in the course. Since the short lectures/modules were created to detailing various MATLAB capabilities mainly pertaining to the ME and ChE curriculum, they were mainly recommended by the faculty of both departments as well as the chairs to students taking their courses. In particular, instructors for 20 ME courses, 9 ChE courses, two college-wide courses, and some graduate courses showed interest in using the developed modules in their courses.

In order to evaluate the effectiveness of the developed modules in facilitating students' learning, an anonymous college-wide survey was conducted via Survey Monkey in May 2018. The survey included two sections. Section 1 contained five general questions that were focused on evaluating the improvement of student's overall learning, student's conceptual understanding of principles and courses, students' ability to apply knowledge in solving real-world problems. The effectiveness of the videos in motivating student's learning and conveying the materials was also evaluated in the survey. The five questions contained in Section 1 were listed in Table 2. Students' responses for each question was quantified with a score ranging from 0 to 5, with 0 representing totally disagreement and 5 representing 100% agreement. Section 2 of the survey provided open-ended questions that allowed students to provide comments on what they liked or disliked the modules and what they suggested to improve the modules.

Table 2, Survey questions to evaluate the effectiveness of the developed modules in facilitating students' learning

One of the major goals of the MATLAB videos is to make you more competent in solving ordinary differential equations (ODEs) of microbial fuel cells using MATLAB.	Disagree	Agree
(1) The hands-on experience with MATLAB improved your overall learning in the College of Engineering	①	② ③ ④ ⑤
(2) The MATLAB modules improved your conceptual understanding of principles and courses you took in the College of Engineering	①	② ③ ④ ⑤
(3) The MATLAB modules improved your ability to apply knowledge in solving real-world problems over the classical in-class lecture format	①	② ③ ④ ⑤

(4) The MATLAB modules motivated you in your learning	①	②	③	④	⑤
(5) The training videos were easy to follow and they effectively conveyed the materials	①	②	③	④	⑤

III. Results and Discussion

Students’ responses to the five questions listed in Table 2 were shown in Figure 1. As for Question 1, more than 80% of students agreed or strongly agreed that the hands-on experience with MATLAB improved their overall learning in the College of Engineering. More than 60% of students agreed or strongly agreed in Problem 2 that the MATLAB modules improved their conceptual understanding of principles and courses they took in the College of Engineering. Similar results were obtained in Questions 3 and 5, i.e., “The MATLAB modules improved your ability to apply knowledge in solving real-world problems over the classical in-class lecture format” and “The training videos were easy to follow and they effectively conveyed the materials”. The distribution of students’ opinions in Question 4 was different from those of other questions. In this question, 40% of students neither agreed or disagreed with that the MATLAB modules motivated them in their learning. One potential reason for this is that these MATLAB modules were supplemental materials in the courses students took. They mainly provided introduction of MATLAB functions/commands that were helpful for students to solve course problems. Students might not have to use MATLAB toolboxes if the instructors didn’t require them to do so. Students might focus on those course topics that were tested in exams, instead of MATLAB modules.

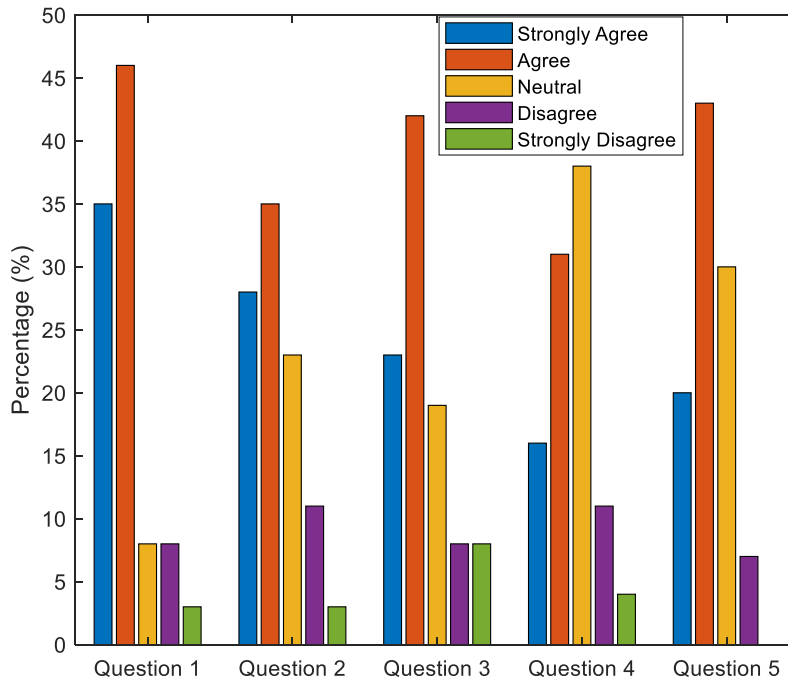


Figure 1, Survey results of the five questions shown in Table 2.

Students’ answers to the open-ended questions show the following positive comments on the designed web-based MATLAB modules: 1) the module videos were easy to follow and very useful; 2) the videos were helpful for learning distinct concepts (perhaps those not even covered in

lectures); 3) these modules can be used as a reference later in life; 4) videos were a good way to lecture MATLAB functions/commands. The major negative comments from students include: 1) certain lectures were too condensed for a completely effective learning experience; 2) students didn't have motivation to finish all the modules (as supplemental materials of their courses); 3) instructors should give more directions to students on when and which modules students should finish. The positive comments are in line with the survey results for Questions 1-3 and 5, while the negative feedbacks are reflected in the survey result for Question 4. In the future implementation of the MATLAB modules, instructors may need to offer more incentives to motivate students to apply the MATLAB functions/commands they learned from the modules. Students didn't have negative comments on certain long videos. This implies that longer duration to cover more materials may be a solution to attract more students to use the developed MATLAB video modules.

IV. Conclusion

We developed 17 video-based modules to offer MATLAB training for engineering students at Villanova University. These modules covered the commonly used MATLAB techniques used in engineering so that instructors of various courses don't have to repeatedly train students with MATLAB. Anonymous surveys were conducted to obtain students' feedback on the developed video-based modules. The results turn out that students were generally positive with the developed modules in motivating and facilitating them in their learning. As for the future implementation, students need more incentives to finish all the modules. It would be helpful if instructors could incorporate the modules in their homework assignments.

V. Bibliography

1. Berens, P., *CircStat: A MATLAB Toolbox for Circular Statistics*. Journal of Statistical Software, 2009. **31**(10): p. 1-21.
2. Elmer, J.J., et al. *Preparation of biology review and virtual experiment/training videos to enhance learning in biochemical engineering courses*. in *ASEE Annual Conference & Exposition 2015*. Seattle, WA, June, 2015.
3. Guo, P., K. Yuan, and Z. Huang, *Develop Web-based Modules to Educate High-School Students in Studying Microbial Fuel Cell Dynamics*, in *2017 ASEE Mid Atlantic Section Spring Conference*. 2017: Baltimore, Maryland.
4. Geng, J., et al., *Comparison of R and MATLAB Simulink in Educating High School Students with ODE Modeling Skills* Chemical Engineering Education 2018. **in press**.