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Work In Progress: Improving Mechanical Engineering Students' Programming Skills Through Hands-On Learning Activities Designed in MATLAB Live Editor

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Abstract

With the advances and rapid improvements in technology, engineering students are expected to have programming skills to keep up with the evolving demands in their fields. However, among the various engineering programs including mechatronics and robotics, computer, and electrical, mechanical engineering students face the biggest challenge. While they are known to be good problem solvers, they often encounter struggles in programming. This challenge primarily stems from the limited programming courses offered in the curriculum and a lack of exposure to low-cost data acquisition systems like Arduino within their laboratory environments. To give an example, the educational laboratory equipment favorably utilized in mechanical vibrations and control theory courses is tailored with custom software and data acquisition systems to implement inputs and record output data. This inhibits students' understanding of signal flow and data recording. Consequently, students struggle to replicate similar tasks using low-cost alternatives to actuate the mechanisms or design a controller to accomplish desired tasks. To address this problem, we collected feedback from undergraduate mechanical engineering students enrolled in mechanical vibrations (junior level) and control theory courses (senior level) to assess their confidence levels and proficiency in programming, identifying areas where improvement is needed. We created a series of in-class and out-of-class learning activities designed in MATLAB Live editor for students taking mechanical vibrations and vibrations and control labs courses that incorporate programming. These activities are specifically designed to encourage and support students taking the mechanical vibrations course to serve as a candidate. Our continuous work involves iterative development and refinement of these activities based on ongoing feedback and assessment. Through these activities, we aim to bridge the programming gap and empower our students to excel in the increasingly technology-driven field of mechanical engineering.

Keywords

Mechanical vibrations; control theory; MATLAB Live Editor

Introduction

The transition into university, especially for incoming first-year students, has always been marked by a confluence of emotions, challenges, and newfound experiences[1]. Many external and internal factors have complicated this journey recently, reshaping students' fundamental understanding and approach to their education. The profound influence of the COVID-19 pandemic, which introduced unprecedented disruptions, leading to isolation and limited access to traditional educational environments, cannot be overlooked[2]. This isolation, while protective, inadvertently shifted the learning paradigm for many, challenging conventional pedagogy and student interaction, further widening the educational disparity among different student groups and dramatically altering the learning environment.

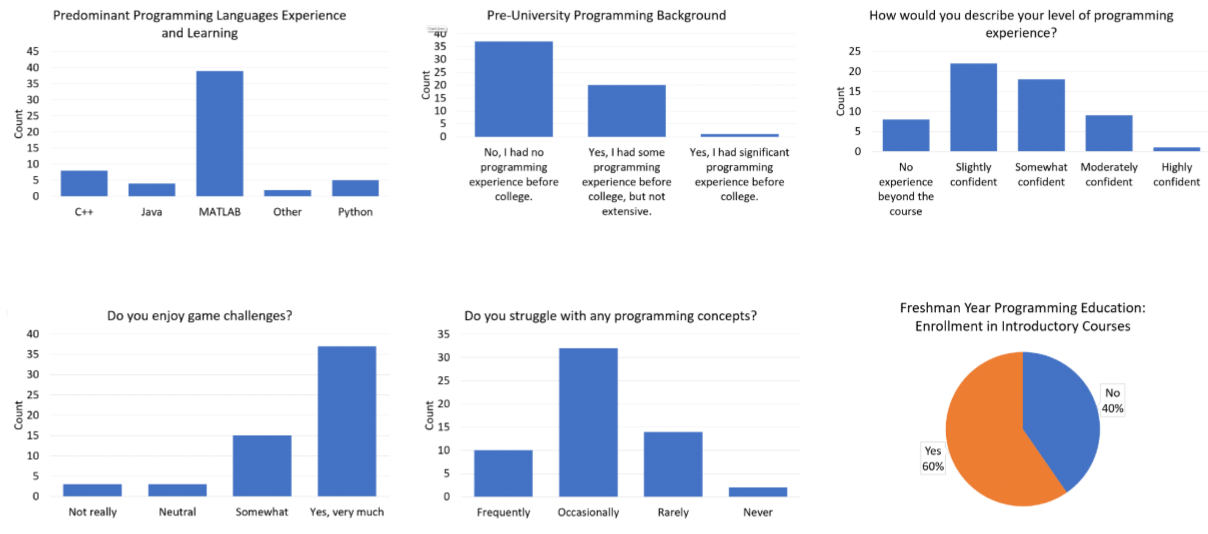

Figure 1. Fall 2023 Junior & Senior Survey Results

But even as the world grappled with the pandemic, another transformation was silently but steadily changing the educational landscape: the digital revolution[3]. In an era of ubiquitous internet access and the proliferation of smartphones, tablets, and other electronic devices, information has never been more accessible. While this surge in easy accessibility can be seen as a boon, facilitating instant knowledge acquisition also has drawbacks. The immediacy of information has often curtailed students' intrinsic drive to delve deep into subjects, grapple with challenges, or even commit to the rigorous problem-solving process. Rather than immersing themselves in the struggle to understand, many opt for the path of least resistance, sourcing ready-made answers without genuinely comprehending the underlying concepts. Furthermore, the swift growth of our educational frameworks demands interdisciplinary expertise, even from first-year students. For instance, a biology student today needs to comprehend computational thinking and programming to process extensive data sets for visualization. Similarly, modern mechanical engineering curricula often mandate programming to navigate intricate design computations. Such a dual-pronged challenge – nurturing the motivation to learn interdisciplinary skills and the temptations of readily available information – places students, especially those in mechanical engineering, in a precarious position as they commence their university journey.

An alarming manifestation of these shifts is evident in the diminished foundational knowledge many students possess as they enter higher education. A deficit in basic mathematical principles, a shortage of computational thinking, and underdeveloped problem-solving abilities contribute to a formidable uphill battle during their initial university years. During the Fall 2023 semester, a survey was conducted targeting mainly junior students from mechanical, mechatronics, and computer engineering programs—who had completed introductory programming courses in their freshman year—to evaluate their proficiency with programming and frequency of usage in other courses. While a significant number of participants were from the mechanical engineering program enrolled in vibrations and control theory courses, the survey included students from the mechatronics and computer engineering programs. The issue's core, as highlighted in Figure 1, is especially concerning for mechanical engineering: many first-year students are grappling with programming. Figure 1 depicts a survey that illustrates the wide range of programming experience among incoming students, with a notable majority entering without prior knowledge. The figure further reveals a lack of experience in programming throughout the "university experience, continuing even upon graduation. It also points out that while students are getting exposure to MATLAB, they lack experience in other programming languages that are popular in the industry. However, the survey also shows that many students enjoy game challenges and problem-solving, suggesting an untapped opportunity to leverage these interests to foster a more engaging and effective programming education. This engagement could provide a critical medium for applying programming concepts to areas that students find enjoyable and relevant.

Literature Review

The realm of education has undergone profound transformations in recent years, significantly altering the learning landscape for students[4,5,6]. Technological advancements and shifting pedagogical strategies have been at the forefront of these changes. This article delves into the evolving educational dynamics, with a particular focus on students' experiences in the digital era, the implications of these changes on their academic and professional trajectory, especially within the domain of Mechanical Engineering. In bygone eras, the educational journey was notably defined by a rigorous engagement with problem-solving tasks, primarily attributed to the scarcity of readily available solutions[7]. The endeavor to grapple with complex problems fostered a depth of understanding and a refined analytical prowess among learners. Fast forward to the present day, the advent of sophisticated digital tools like Generative Pre-Trained (GPT) AI models and a plethora of online resources have significantly eased the acquisition of solutions[8,9,10,11]. This shift has served as a double-edged sword[12]. On the one hand, motivated learners find themselves in a golden age of accelerated learning, with around-the-clock access to virtual tutors and a vast reservoir of knowledge, enabling them to delve deeply into their areas of interest[13,14,15]. On the contrary, this ease of access may inadvertently nurture a shallow engagement with the learning material, especially among less motivated learners, potentially undermining the depth of understanding[16]. The COVID-19 pandemic further complicated the educational landscape, as many students found their academic pursuits sidelined by pressing concerns engendered by the global health crisis[17,18,19,20,21,22,23].

The evolving dynamics of the job market increasingly underscore the necessity for an interdisciplinary approach in academic and professional endeavors. This is particularly salient in mechanical engineering, where a strong foundation in programming has become indispensable [24]. Recognizing these educational challenges has spurred a myriad of innovative solutions to enhance motivation and deepen the learning experience[25]. These include engaging workshops and tutorials, gamification in programming courses, preparatory classes for those needing a stronger foundation, and a wealth of self-learning opportunities through online courses and tutorials on platforms like YouTube[26]. A promising approach is the interactive integration of programming into coursework through live editor environments.

Learning Activities Developed in MATLAB Live Editor

Developing engaging learning materials is critical to active learning. However, faculty, especially those early in their careers, often face the challenge of dedicating sufficient time to course preparation, considering their heavy workload. Therefore, instructors highly appreciate open-source materials for classroom implementation. Mechanical Vibrations, a 3-credit engineering course, and Vibrations and Control Laboratory, a 1-credit lab, are integral to the mechanical engineering program at Kennesaw State University. Both courses are deeply mathematical, and students frequently struggle to solve differential equations and visualize output motion. These courses also offer an excellent opportunity to enhance mechanical engineering students' programming skills. To address this, we are actively creating learning activities through homework and lab handouts using MATLAB Live Editor, which we share on our project website[27]. With its interactive and intuitive interface, the MATLAB Live Editor plays a crucial role in enhancing the learning experience, especially in courses like mechanical vibrations and the vibrations and control Laboratory where one can incorporate programming, visualization, and documentation in a single environment. This integration allows students to see the impact of their code immediately, assisting in understanding complex mathematical concepts like differential equation solutions. The Live Editor's ability to display outputs, graphs, and equations alongside the code promotes a deeper comprehension of the material, making abstract concepts more tangible.

Moreover, the MATLAB Live Editor is a soft introduction to coding for mechanical engineering students, who are often new to programming. Its user-friendly interface, with features like syntax highlighting and automatic code formatting, reduces the initial intimidation factor associated with learning a new programming language. This environment encourages experimentation, where students can modify and execute code in real-time, seeing immediate results. This trial-and-error approach is instrumental in developing problem-solving skills and computational thinking, essential competencies in engineering education.

The implementation phase of our project revolved around two key courses: ENGR 3125 and ME 4501. We created in-class and out-off-class learning activities in the form of lab handouts in MATLAB Live Editor in ME 4501, and out-off-class activities as homework assignments in ENGR 3125 in which students were expected to upload their work in Live Editor format. All learning activities are shared publicly in our project's GitHub website[27]. To ensure a foundational understanding of the required tools, both courses began with an ungraded homework assignment focused on completing MATLAB and Simulink Onramp interactive courses as more information can be found in [25]. An example learning activity in ENGR 3125, as shown in Figure 2, tasked students with designing a Grashoff double-crank four-bar mechanism, formulating vector-closure loop equations, solving them symbolically, plotting the results, and validating solutions through a virtual lab in MATLAB Simscape. This integrated approach aimed to reinforce theoretical concepts and empower students to apply their knowledge in simulated real-world scenarios.

Figure 3 displays the sections of a lab handout created in MATLAB Live Editor. This instructional document includes information on the deadline, task completion instructions, learning objectives, hands-on data recording procedures, theoretical modeling guidance, detailed calculations, and the use of MATLAB Simulink for model validation.

Previously, students were primarily accustomed to using MATLAB solely for data recording and plotting. However, with the transition to lab handouts created in MATLAB Live Editor, students initially faced challenges during the first three weeks, a period that could be characterized as a transitional phase. However, as the semester progressed, students gradually became more at ease with this new approach. Feedback obtained from course evaluations in the Spring 2023 semester reflected this evolution, with students expressing comments such as: "*I enjoyed learning how MATLAB can be used in control theory and vibrations and for writing very excellent and effective*

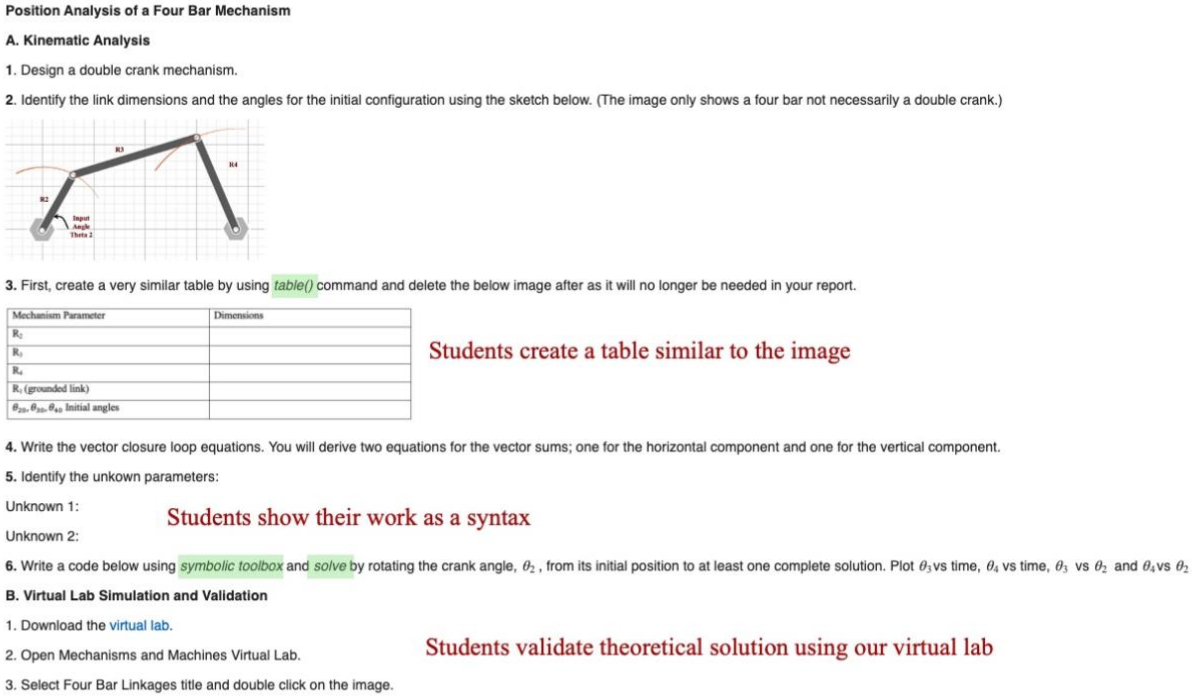

Figure 2. Learning activity for machine dynamics and vibrations course (ENGR 3125)

lab reports./ I hated MATLAB so much but this course helped me understand how to use the program a lot more./ It was a bunch of fun experiments and we really got a chance to practice using our MATLAB skills./ I liked the individual MATLAB and Simulink labs during class./ How much I learned about MATLAB./ The application of MATLAB and how it was utilized in this course was very interesting./ This course features virtual labs created by research students, and the potential for others to contribute to the lab is fascinating./ It also helped reinforce our understanding of vibrations and MATLAB. / I enjoyed how Dr. Tekes pushed us to use MATLAB for writing lab reports. I feel much stronger in my MATLAB ability. / I enjoyed learning about MATLAB and the different ways it can be used like Simulink simulations."

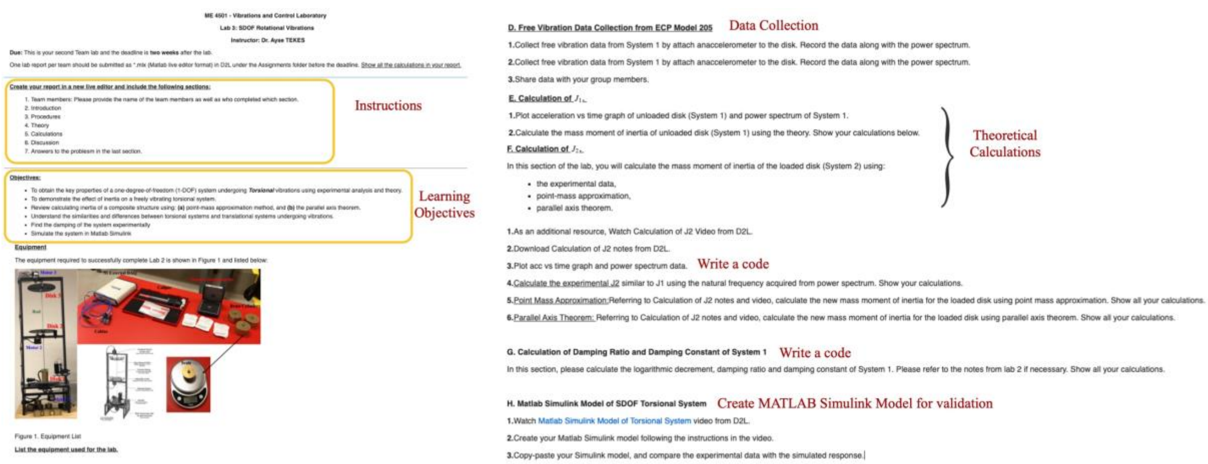

Figure 3. Learning activity for vibrations and control laboratory course (ME 4501)

Conclusion

The integration of MATLAB Live Editor in the selected courses has shown promising results, particularly in improving students' understanding of mechanical vibrations and control theory. The Live Editor's interactive tools have positively impacted student engagement and their ability to program. Students showed resistance to MATLAB at the beginning of the semester, especially when writing lab reports in the Live Editor. However, over time, they became more comfortable with the programming and data analysis tasks required. Future surveying will be crucial in evaluating the long-term benefits of incorporating interactive tools like MATLAB Live Editor into coursework and lab activities. These surveys will provide insights into how such tools influence learning outcomes and student perceptions, guiding further curriculum enhancements. Expanding diverse programming tools and languages should also be explored, aligning to keep pace with the rapidly evolving technological demands in engineering education. The continuous assessment and adaptation of interactive learning methods are essential in preparing students for the complex challenges of their professional careers.

References

[1] Clinciu, Aurel Ion. "Adaptation and stress for the first year university students." Procedia-social and behavioral sciences 78 (2013): 718-722.

[2] Tsolou, Olympia, Thomas Babalis, and Konstantina Tsoli. "The impact of COVID-19 pandemic on education: social exclusion and dropping out of school." Creative Education 12, no. 03 (2021): 529.

[3] Broo, Didem Gürdür, Okyay Kaynak, and Sadiq M. Sait. "Rethinking engineering education at the age of industry 5.0." Journal of Industrial Information Integration 25 (2022): 100311.

[4] Michael J Haslip and Dominic F Gullo. The changing landscape of early childhood education: Implications for policy and practice. Early Childhood Education Journal, 46:249–264, 2018.

[5] Peter Teo. Teaching for the 21st century: A case for dialogic pedagogy. Learning, Culture and Social Interaction, 21:170–178, 2019.

[6] Abdullah Saykili. Higher education in the digital age: The impact of digital connective technologies. Journal of Educational Technology and Online Learning, 2(1):1–15, 2019.

[7] Anealka Aziz Hussin. Education 4.0 made simple: Ideas for teaching. International Journal of Education and Literacy Studies, 6(3):92–98, 2018.

[8] Ashraf Alam. Possibilities and apprehensions in the landscape of artificial intelligence in education. In 2021 International Conference on Computational Intelligence and Computing Applications (ICCICA), pages 1–8. IEEE, 2021.

[9] Michael Carmichael, A Reid, and Jeffrey D Karpicke. Assessing the impact of educational video on student engagement, critical thinking and learning. A SAGE white paper, 2018.

[10] Kevin Fuchs. Exploring the opportunities and challenges of nlp models in higher education: is chat gpt a blessing or a curse? In Frontiers in Education, volume 8, page 1166682. Frontiers, 2023.

[11] Brady D Lund and Ting Wang. Chatting about chatgpt: how may ai and gpt impact academia and libraries? Library Hi Tech News, 40(3):26–29, 2023.

[12] Margaret Bearman, Juliana Ryan, and Rola Ajjawi. Discourses of artificial intelligence in higher education: A critical literature review. Higher Education, 86(2):369–385, 2023.

[13] Aida Aryani Shahroom and Norhayati Hussin. Industrial revolution 4.0 and education. International Journal of Academic Research in Business and Social Sciences, 8(9):314–319, 2018."

[14] Chung Kwan Lo. What is the impact of chatgpt on education? a rapid review of the literature. Education Sciences, 13(4):410, 2023.

[15] Tareq Rasul, Sumesh Nair, Diane Kalendra, Mulyadi Robin, Fernando de Oliveira Santini, Wagner Junior Ladeira, Mingwei Sun, Ingrid Day, Raouf Ahmad Rather, and Liz Heathcote. The role of chatgpt in higher education: Benefits, challenges, and future research directions. Journal of Applied Learning and Teaching, 6 (1), 2023.

[16] Rongrong Yu and Kusum Singh. Teacher support, instructional practices, student motivation, and mathematics achievement in high school. The Journal of Educational Research, 111(1):81–94, 2018.
[17] Pradeep Sahu. Closure of universities due to coronavirus disease 2019 (covid-19): impact on education and mental health of students and academic staff. Cureus, 12(4), 2020.
[18] Kunal Chaturvedi, Dinesh Kumar Vishwakarma, and Nidhi Singh. Covid-19 and its impact on education, social life and mental health of students: A survey. Children and youth services review, 121:105866, 2021.
[19] Ryan Michael Oducado. Faculty perception toward online education in a state college in the philippines during the coronavirus disease 19 (covid-19) pandemic. Universal Journal of Educational Research, 8(10):4736–4742, 2020.
[20] Aras Bozkurt and Ramesh C Sharma. Education in normal, new normal, and next normal: Observations from the past, insights from the present and projections for the future. Asian Journal of Distance Education, 15(2): i–x, 2020.
[21] Lokanath Mishra, Tushar Gupta, and Abha Shree. Online teaching-learning in higher education during lockdown period of covid-19 pandemic. International journal of educational research open, 1:100012, 2020.
[22] Yong Zhao and Jim Watterston. The changes we need: Education post covid-19. Journal of Educational Change, 22(1):3–12, 2021.
[23] Alison Clabaugh, Juan F Duque, and Logan J Fields. Academic stress and emotional well-being in united states college students following onset of the covid-19 pandemic. Frontiers in psychology, page 765, 2021.
[24] Stamatios Papadakis and Michail Kalogiannakis. Evaluating the effectiveness of a game-based learning approach in modifying students' behavioural outcomes and competence, in an introductory programming course. a case study in greece. International Journal of Teaching and Case Studies, 10(3):235–250, 2019.
[25] Burak Sisman, Sevda Kucuk, and Yavuz Yaman. The effects of robotics training on children's spatial ability and attitude toward stem. International Journal of Social Robotics, 13:379–389, 2021.
[26] Beatriz Mar´ın, Jonathan Frez, J Cruz-Lemus, and Marcela Genero. An empirical investigation on the benefits of gamification in programming courses. ACM Transactions on Computing Education (TOCE), 19(1):1–22, 2018.
[27] Ayse Tekes and Kennesaw State University. Ayse-tekes-kennesaw-state-university repository, 2023. URL https://github.com/Ayse-Tekes-Kennesaw-State-University. Accessed: November 27, 2023.
[25] MathWorks. Matlab onramp getting started, 2023. URL https://matlabacademy.mathworks.com/details/matlab-onramp/gettingstarted. Accessed: November 27, 2023.