Teaching Control Systems with Interactive MATLAB Live Scripts

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Abstract

Control engineering, as with many other engineering courses, are commonly taught using static course notes and lecture slides. These methods, however, often fail to elicit adequate student interest and understanding of the advanced mathematical and theoretical concepts fundamental to the subject. As a result, many students experience a disconnect with the content early in the course, leading to disinterest and poor academic performance. This paper presents the development of an interactive "live" textbook using MATLAB Live Scripts, providing a dynamic and engaging learning experience. This resource allows students to interact with the theoretical material in real-time, run simulations, adjust parameters, and immediately visualise the impact of their changes — all in a single, unified environment. The integration of LaTeX typeset equations and text, code blocks, dynamic diagrams, and high-level controls such as sliders and buttons empowers students to explore the subject matter deeply at their own pace, fostering a stronger connection and understanding of the material. The effectiveness of the interactive course material is evaluated using anonymous course evaluations, which assess key performance indicators such as understanding of course material and overall course satisfaction. Furthermore, key course statistics, such as pass rate and average mark, are compared over the past four years, showing significant improvements across all areas following the intervention of the developed interactive textbook.

Keywords: MATLAB Live Scripts, interactive learning, engineering education, control systems education

1 Introduction

1.1 Background and problem statement

Modern control engineering is a field of engineering that encompasses a range of science, technology, engineering, and mathematics (STEM) sub-disciplines, which includes engineering sciences and programming. This subject is commonly found in several engineering programmes, such as mechanical engineering, electrical engineering, mechatronic engineering, and chemical engineering. Although control engineering is rooted in practicality, it is often received by students as being highly abstract and mathematically rigorous. The prevailing approach to teaching control engineering at university level is to make use of static course notes, in the form of a textbook, and/or lecture slides. Studies suggest that this non-dynamic approach fosters antiquated memorisation-and-regurgitation type learning in students, which leads to student disengagement in the course (Rossiter, 2020). The net result is commonly that lecture attendance drops significantly over time because of student detachment, leading to poorer academic performance. To remedy the stagnant nature of the learning material, zyBooks was investigated in 2022 as a non-static online learning resource. The service offers digitised online versions of popular textbooks, referred to as zyVersions, which include interactive tools, animations, and embedded learning questions (zyBooks, 2025). However, zyVersions offer moderate interactivity and limited customisation. Additionally, the service is charged based on a semester-based subscription per student, which meant that the cumulative cost over time was not financially viable.

1.2 Objective

The aim of this study is to showcase the development and application of interactive course notes in the context of a 3rd-year control engineering course. The interactive course notes take the form of multiple MATLAB Live Scripts, separated by chapter, with the intention of creating a dynamic and engaging learning environment for the students. This resource allows students to interact with the material in real-time, run simulations, adjust parameters, and instantaneously visualise the impact of their changes — all within a single, unified environment. The Live Script resources can facilitate a combination of typeset LaTeX equations, regular text, imagery, easily adjustable code blocks, and triggered visualisations of the code implementation, as shown in Figure 1. This experiential learning environment is intended to allow students to explore the subject matter deeply at their own pace, fostering a stronger connection and understanding of the material.

1.3 Outcome and contributions

The effectiveness of the interactive course notes was evaluated through anonymous course evaluations, assessing student understanding and overall satisfaction of the course. Additionally, key course metrics of student pass rate and average mark were analysed over four years, demonstrating significant improvements in student performance and engagement. This study suggests that interactive course material enhance student understanding and satisfaction, as shown by course evaluations and performance data. While this study and teaching approach is applied to a particular course, the material preparation and presentation can be adopted by a wide range of STEM-based courses, both at high school and university level. The developed interactive textbook is freely available on MATLAB File Exchange and GitHub, and can be copied, modified, and repurposed without limitation. This allows for adoption and adaptation by educators globally. Literature review

1.4 Current teaching methods

Common pedagogical interventions in historically challenging STEM courses include project-based learning, lecture flipping, computer-aided assessment, and virtual laboratories. Project-based learning involves groups of students solving a complex, open-ended problem that aims to solidify understanding of the course content (Fernández-Samacá, Ramírez, & Orozco-Gutiérrez, 2012). Lecture flipping encourages students to cover the relevant course content prior to engaging in in-person activities with staff. The subsequent in-person activities are then used for more experiential activities, with the aim of facilitating a deeper understanding of the material (Seery, 2015). Computer-aided assessment and virtual laboratories work on the premise that interactive, multimedia environments that can offer instantaneous feedback on student understanding are essential for content assimilation (Rossiter, 2018).

1.5 Interactive learning tools

zyBooks offers digitised online versions of popular textbooks, referred to as zyVersions, which include interactive tools, animations, and embedded learning questions (zyBooks, 2025). The zyVersion most applicable to the field of control engineering is Control Systems Engineering, based on the static textbook by Norman Nise (Nise, 2020). The zyVersion offers moderate interactivity and limited customisation. The service is notably charged based on a time-limited subscription per student of $20, which means that the cumulative cost over time will grow approximately linearly, depending on the number of students in the class.

MATLAB Live Scripts provide an interactive and fully customisable environment for combining formatted text, equations, code, and visualizations in a single document. Unlike traditional scripts, they allow users to run code in sections, modify parameters dynamically, and instantly see results through embedded plots and simulations (MathWorks, 2025). Features such as LaTeX-rendered equations, sliders, buttons, and interactive figures make them particularly useful for educational purposes, enabling hands-on learning and real-time experimentation. Live Scripts are widely used in engineering and scientific fields to create self-contained, shareable documents that enhance engagement and understanding.

2 Methodology

2.1 Study design

This study made use of a quasi-experimental, retrospective analysis. There was no assignment of students to control and experimental groups, with data coming from real classroom settings, over multiple semesters. Past student data, including course evaluations and pass rates, were used to measure the impact of the intervention.

2.2 Participants

This study was applied to a 3rd-year control engineering course, named Control Systems (MEC3079S), in the Department of Mechanical Engineering at the University of Cape Town. The course has 12 NQF Level 8 credits, with three lectures a week. The entire course spans approximately 13 weeks and makes use of a combination of virtual labs, quizzes, a project, and a closed-book pen-on-paper test and exam. Data for the study was obtained and compared for the years 2021 to 2024, inclusive, with the introduction of the interactive course notes into MEC3079S taking place from 2023. No selection bias was present, as all students in each semester were exposed to the same teaching methods.

2.3 Intervention

The developed interactive course notes were used as the primary learning resource of the course and incorporated into certain lectures as a visual aid. Students had access to the interactive course notes chapter at the beginning of the relevant week and were encouraged to read through the notes prior to the associated lectures. The course notes were organised so that convenient sliders and buttons were present in the code blocks, allowing for easy adjustment of key system parameters that were highlighted as important for the particular section of work. The code blocks were configured so that any change in the slider or button state would automatically compile and run the code, and thereby instantaneously generate an associated visualisation of the code, such as a time-domain plot of a system's step response.

2.4 Data collection and analysis methods

Data collection comprised quantitative information, including pass rate and Likert-scale course evaluation questions, as well as qualitative information, such as student responses to open-ended questions and instructor observations on student engagement. The collected data was quantitatively compared over the years of 2021-2024 and considered the primary learning resource used for each year. A thematic analysis was performed to identify common themes in the student feedback.

2.5 Study limitations

No randomisation was included in this study. As a result, external factors, such as different instructors or exam difficulty changes may influence the results. Self-reported student feedback presented in the course evaluations can be subjective. The study was limited to a single control engineering course, and the results cannot be generalised to other control courses or institutions without appropriate adaptation. Data available for evaluation was limited for the years of interest and constrained the scope of evaluation methods that could be applied in this study.

3 Results and discussion

3.1 Quantitative metrics

Using student pass rates as a high level indicator of student understanding, we observed a clear upward trajectory over the past four years (2021-2024), as detailed in Table 1.

Table 1: MEC3079S pass rate and primary learning resource used for the period 2021 to 2024

	2021	**2022**	**2023**	**2024**
Pass rate (%)	73	80	92	91
Average mark (%)	55	64	84	72
Number of students	143	151	109	150
Primary learning resource	Textbook	zyBooks	Live Scripts	Live Scripts

In 2022, coinciding with the introduction of zyBooks as the primary learning resource, an increase of 7% in student pass rate was observed, elevating the pass rate to 80%. An even larger improvement in student pass rate was observed in 2023, where an impressive 92% pass rate was achieved — the average pass rate for all courses in the Mechanical Engineering department in 2023 was 85%, for reference. This 12% increase in pass rate notably coincides with the initial implementation of the MATLAB Live Scripts as a primary learning resource. The same MATLAB Live Scripts were used in 2024 by a new lecturer, and a similarly high level of student success was maintained, with 91% of students passing the course (the average pass rate of all Mechanical Engineering courses in 2024 was 84%). While these results cannot be directly attributed to the change in course material, the coincidence of such a marked improvement in student pass rate in 2023 with the debut of the MATLAB Live Script notes potentially hints at a positive correlation. The sustained success of students in 2024 under a new, and notably inexperienced lecturer, not only potentially supports the aforementioned correlation, but also suggests that the effectiveness of the developed course notes is not solely dependent on the original lecturer’s teaching ability, and thereby underscores the potential for the interactive material to be adopted widely and successfully by other instructors.

We see a similar positive trend in grade average (Table 1, row 2) over the four year period under consideration. With the introduction of zyBooks in 2022, the grade average increased by 9% to reach 64%. In 2023, when Live Scripts were introduced, the grade average increased significantly by 20% to 84%. In 2024, the second year of using Live Scripts, the average grade was 72%. Although this was lower than in 2023, it coincided with the introduction of a new lecturer, and remained considerably higher than grade averages recorded in the years prior to the implementation of Live Scripts.

3.2 Qualitative student feedback

Student feedback, gathered through course evaluations between 2021 and 2024, reveals a largely positive trend in overall student satisfaction with the MEC3079S course and its content. This positive trajectory is particularly noticeable in the responses to the 'live' elements of the course, which students frequently highlighted as beneficial to their learning experience — see Figure 2.

In 2022, course evaluations were notably favourable, with 82% of students indicating 'Excellent' or 'Good' satisfaction with the course overall. This marked a substantial increase from the 67% positive response rate to the same question in the previous year — see Table 2.

Table 2: Overall level of student satisfaction (2021-2024)

	2021	**2022**	**2023**	**2024**
Excellent (%)	35	40	65	38
Good (%)	32	42.5	30	42
Average (%)	30	15	4.7	4
Below average (%)	3	2.5	0	4
Very poor (%)	0	0	2.3	8
Response rate (%)	37	40	43	24

The qualitative feedback also supported this positive trend. In 2022, when asked, "What aspect(s) of the course have you enjoyed?", 17 out of 40 students explicitly mentioned the interactive content, such as zyBooks and virtual labs, as being advantageous to their learning. Additionally, many students suggested that zyBooks, in particular, was a valuable tool in aiding their understanding of the course material.

The positive feedback continued into 2023, with an impressive 95% of students rating their satisfaction with the course as 'Excellent' or 'Good'. The qualitative comments in 2023 were overwhelmingly positive and focused on the interactive textbook used in the course. Students described the course notes as "exceptional", "extremely useful for understanding", and "too good".

In 2024, there was a slight decrease in student satisfaction, coinciding with the introduction of a new and inexperienced lecturer for MEC3079S. Despite this dip, the overall feedback remained positive, with 80% of students expressing satisfaction with the course. In response to the question about enjoyable aspects of the course, 3 out of 4 respondents specifically mentioned the MATLAB-based course notes as being particularly helpful.

Overall, student feedback from 2021-2024 shows that students were highly satisfied with the course. Interactive elements like zyBooks, virtual labs, and MATLAB course notes were repeatedly highlighted by students as valuable components that improved their learning. We note, however, that student participation in the course evaluations is entirely voluntary, and that the qualitative data obtained here only represents 36% of students on average (see Table 2, row 6). The quantitative data from the past four years, however, is available for all students, and shows a promising improvement in student performance. Key factors identified as potential drivers of this success were the temporary introduction of zyBooks in 2022, and the implementation of MATLAB Live Scripts course notes from 2023 and onwards.

4 Conclusion & future work

4.1 Summary of key findings

The above-mentioned results infer that the positive levels of student satisfaction are likely attributed to the implementation of interactive learning material. The interactive elements of the course notes were repeatedly highlighted within the course evaluations as components that improved student learning. Furthermore, data from 2021 to 2023 exhibit a monotonic improvement in student performance, with 2024 closely matching that of 2023, which coincides with when the course intervention took place. These findings emphasize the importance of continuing to explore and adopt innovative teaching methods and resources to enhance student learning outcomes. All content developed is freely available on MATLAB File Exchange and GitHub, with the invitation for other educators to copy, modify, and repurpose the content as required.

4.2 Implications for education

This teaching pedagogy has been applied to a particular control engineering course. However, the concepts can be abstracted to other STEM-based courses. MATLAB has an extensive list of well-written toolboxes, ranging from engineering and computer science to finance, which can be incorporated into bespoke teaching material for the course in mind.

4.3 Future work

The impact of the interactive course notes was evaluated using easily accessible quantitative data such as pass rates and student feedback from course evaluations that served as broad indicators of the effectiveness of the developed interactive notes. However, to gain a more nuanced and precise understanding of the developed material's utility, we propose the development of assessment indicators specifically tailored for this purpose. This may involve the creation of questionnaires designed to elicit detailed student opinions on how effectively the live script material supports their learning and comprehension. The next phase of this study is to strategically assess the 2025 course offering against an improved evaluation framework. In particular, the upcoming investigations, based on data from 2025, will seek to establish a robust evaluation design and assess causality between the intervention and performance improvements.

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6 Appendix

6.1 Interactive course notes

With reference to Figure 1, the developed MATLAB Live Script course notes contain a collection of sectioned text, LaTeX-rendered equations, customisable code blocks with convenient sliders, and associated information-rich visualisations. Adjusting one of the sliders automatically recompiles the code block and instantaneously generates the updated figure (see on the right). The interactive course notes can be accessed online using MATLAB Online here.

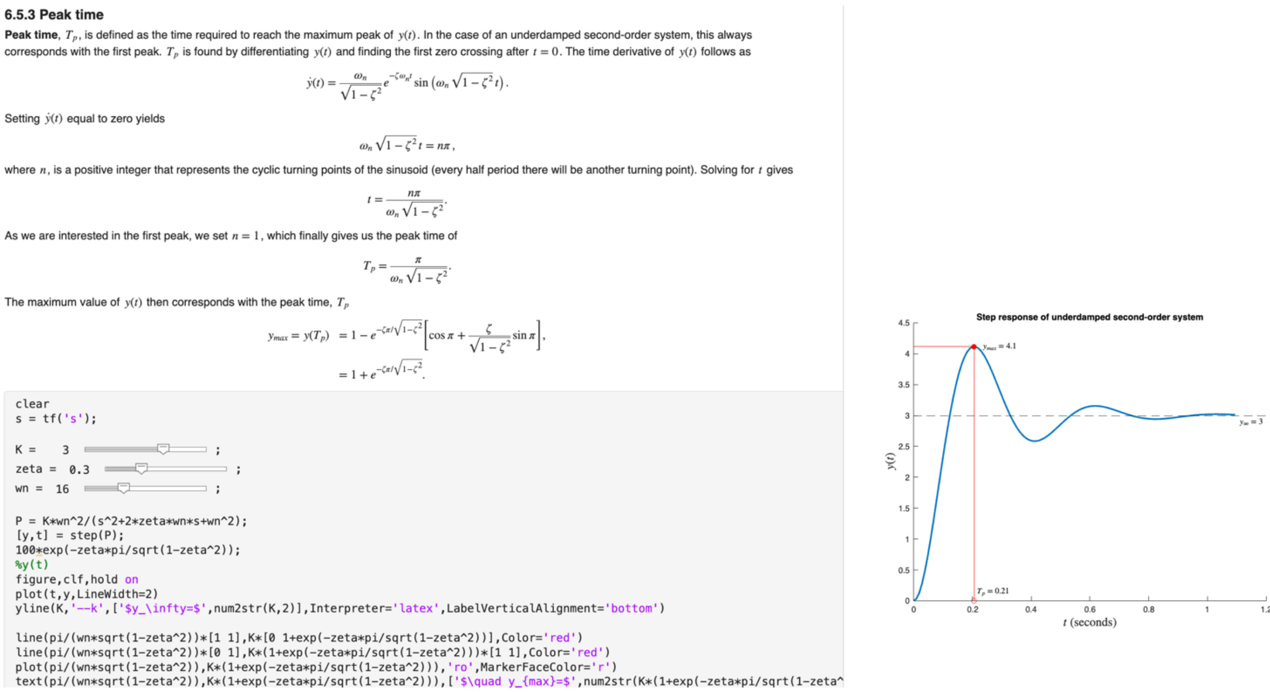

Figure 1: Example of information present in the developed MATLAB Live Script course notes

6.2 Word cloud of student responses

The word cloud shown in Figure 2 was generated from qualitative data obtained in the anonymous course evaluations. Students were asked to comment on elements of the course that they particularly enjoyed, and/or found useful.

Figure 2: Word cloud of free-written student responses