Motivating diverse student cohorts with targeted learning material in control engineering

Felix H. Kong, Brian K.M. Lee, Ian R. Manchester

SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

Our introductory control engineering course is found to be difficult by many of our third-year students who come from various engineering streams (e.g. biomedical, aeronautical). To ensure that students come away with a working knowledge of control engineering relevant to their field, it is important to keep this diverse cohort of students motivated. In addition, our course relies on knowledge from prerequisite courses; incoming students may have gaps in this knowledge. Also, some topics may need more clarification outside of lectures throughout the semester.

PURPOSE

The purpose of this project was to better motivate students from multiple streams to engage with course material, and to give students additional help on specific topics that students were unclear about.

APPROACH

We conducted weekly post-lecture surveys, and based on these surveys, produced post-lecture follow-up videos addressing topics that students indicated difficulty with. Additionally, we attempted to motivate our diverse group of students using a stream-specific design project (e.g. a simplified rocket landing problem for aeronautical students, closed-loop insulin control for biomedical students).

RESULTS

Two sources were used for results: the Unit of Study Survey (USS), which obtained general feedback regarding the course, and a Follow Up Survey (FUS) run by the authors. The FUS asked questions specifically about the two new teaching methods mentioned in the Approach. Roughly 60% of the class responded to the USS, while about 10% responded to the FUS.

CONCLUSIONS

Based on student feedback and the authors' own reflections, the videos were well received, and were helpful to students to follow the course and during revision at the end of semester. The stream-specific design projects did appear to motivate students better, but could be improved by a better balance in difficulty and guidance from instructors.

KEYWORDS

Control engineering, Problem-Based Learning

Motivating diverse student cohorts with targeted learning material in control engineering

Felix H. Kong, Brian K.M. Lee, Ian R. Manchester

Introduction

Upper level undergraduate courses and masters level courses in STEM (science, technology, engineering, and mathematics) are often highly technical, and rely heavily on rigorous theoretical concepts. In engineering, it is often difficult to connect to physical intuition and practical insight, which can impede student motivation and interest.

Our introductory control engineering course AMME3500 at the University of Sydney has about 300 undergraduate and postgraduate students from varying streams, including aeronautical, mechanical, mechatronic, and biomedical engineering. In such a large and diverse class, the standard practice of lecturing and giving assignments may not be the best way to keep students motivated. Mills & Treagust (2003), for example, suggest that the conventional ‘chalk-and-talk’ engineering curricula are overly focused on the technical aspects, providing limited relevance to industrial practice and insufficient design experience. This may prevent students from engaging with the course material. In particular, it may reduce motivation.

As an effort to counteract this, we targeted student motivation in two ways: firstly, by producing videos targeting topics they have identified as being confused about, and secondly, by giving a stream-specific assignment to target students based on interest.

As an upper-level course, our course content builds upon materials covered in prerequisites; if a student fails to understand a basic topic, s/he will struggle to learn topics dependent on it. In order for students to learn effectively, especially in a problem-based learning environment, basic concepts from prerequisite courses must be understood, which in our experience has not always been the case.

Blended learning provides a good avenue for this, in particular online videos, which are available at any time. This facilitates revision at the student's own pace, which can increase student ownership of their own learning (Urdan & Schoenfelder, 2006). Online pre-lecture lesson modules are increasingly popular for teaching STEM related courses, (e.g. Docktor & Mestre, 2014; Chen, Stelzer & Gladding, 2010). However, without student feedback, the topics of such videos must be selected by the teaching staff, which may or may not align with the topics that students need most; we created follow-up videos informed by post-lecture surveys that target specific areas that students have indicated difficulty with.

This is a natural extension of the “flipped” classroom, where content delivery is given during non-contact hours. It reserves contact hours for more interactive work, which can increase the students' sense of ownership towards their own learning (Abeysekera & Dawson, 2015). The sense of ownership is increased by allowing students to participate in post-lecture surveys, to ask for help on particular topics, and to receive additional support on those topics.

Recently, there has been interest in making assignments more relevant to practical engineering problems by making them more realistic, complex, and open-ended; e.g. (Verbič, Keerthisinghe, Chapman, 2017). Our course already makes use of a problem-based learning component in the form of a design project, which can enhance intrinsic student motivation (Norman & Schmidt, 1992). But in such a large cohort, assigning just one problem to all students may leave some students uninterested. For example, a closed-loop insulin pump controller design would be more easily recognized as applicable to a biomedical student than an aeronautical one; vice versa for a longitudinal autopilot controller for an aircraft. As student interest motivates students (Pintrich, 2003), course content is more effective when students are interested, and is better able to relate it to prior knowledge that they may have acquired from other courses in their stream. One way to do this is to put course content into the context of their degree; we created stream-specific assignments to motivate the diverse cohort, one design project for each stream: biomedical, mechanical, mechatronic, and aeronautical.

In this paper we describe the implementation of the stream-specific assignments, the post-lecture surveys, and their corresponding online follow-up videos. We describe and comment on some results about the reception of these new teaching methods, and give a few concluding remarks.

Method

We separate our approach to the stream-specific assignments from the follow-up videos into two sections, below.

Follow-up videos from post lecture surveys

Our approach to video content outside of contact hours was to use them as targeted feedback on specific issues that students struggled with. Through weekly post-lecture surveys on the class forum, we identified topics that students wanted more clarification on. Based on this information, follow-up videos were produced by the lecturer, and were videos addressing topics such as linearization, the Laplace transform, and sketching a Bode plot. Each video was hosted on YouTube, with an announcement containing the links to the videos posted on the class forum. Figure 1 shows the follow-up video for Taylor series, which was a result of students expressing interest in revising the topic of linearization and Taylor series.

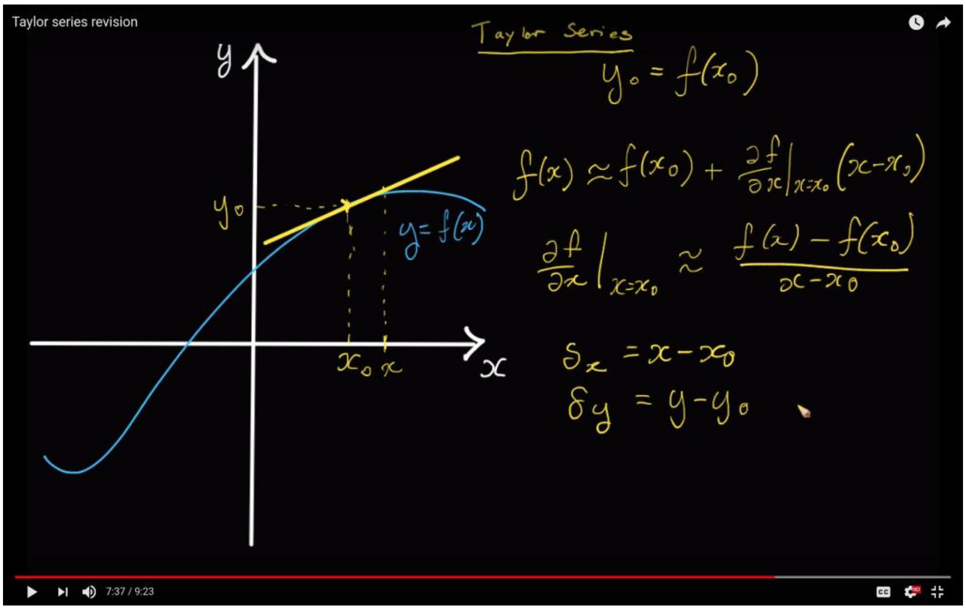

Figure 1: A follow-up video on Taylor Series

Stream-specific assignments

Our approach was to assign a stream-specific design project (e.g. a simplified rocket landing problem for aeronautical students, closed-loop insulin control for biomedical students), and to develop post-lecture videos for specific topics that students have indicated difficulty with.

The design projects, assigned in the second half of semester, were designed as an interesting example of control engineering applied to the context of each stream, shown in Table 1. The assessable material within the design projects was kept the same across all streams, despite the differences in topic. For example, while each stream was given a different nonlinear system, all students were required to produce a linearized model about some operating point. Similarly, while the control design objectives were different between streams, the design methods covered in the course are applicable to any stream. Also, a small stream-specific ‘bonus’ question was given to each stream, which encouraged deeper thought on the application of the controller design in a practical scenario.

Table 1: Stream-specific assignment topics

Stream	Design Project topic
Biomedical	Control of closed-loop insulin pump
Mechanical	Steering control of autonomous vehicle
Mechatronic	Motion control of 2-link robotic arm
Aeronautical	Rocket first-stage re-entry and landing control

To ensure that the students work on the same model, a Simulink template was provided with MATLAB source code. To prevent any potential discrepancy in workload between different streams, the following structure was used in all questions.

Design project fairness guidelines

1. In the Simulink template is a block for an actuator (e.g. a motor for mechatronics students) with unknown dynamics; all students were required to identify a model of the actuator. The actuator code was obfuscated to prevent modification or easy discovery of model parameters. The actuator model for each stream is second order, stable, and has poles sufficiently far away that there is minimal impact on the plant dynamics, even if the student fails to accurately identify the dynamics of the actuator.
2. The model of the system (e.g. the robot arm for mechatronics students) is given to students, but is nonlinear. All students must linearize this model about an operating condition. The models for each stream have either three or four states.
3. All students must design a controller for the linearized model.
4. All students are encouraged to attempt the 'bonus' question. In bonus questions, the student must conduct additional research to develop a more advanced model (e.g. glucose-insulin kinetics with additional compartmental dynamics), and repeat 2. and 3. on the model. Bonus questions are not necessary to achieve full marks.

To support the integration of numerical calculations into practical intuition, we developed visualizers for aeronautical, mechanical, and mechatronic streams. These simple visualizers helped students understand how the graphs they obtain from simulations relate to real-life engineering problem (e.g. how the graph of yaw angle of a car relate to actual driving). No visualizers were provided for the biomedical stream due to the inherent difficulty of visualizing chemical concentrations within a pancreas.

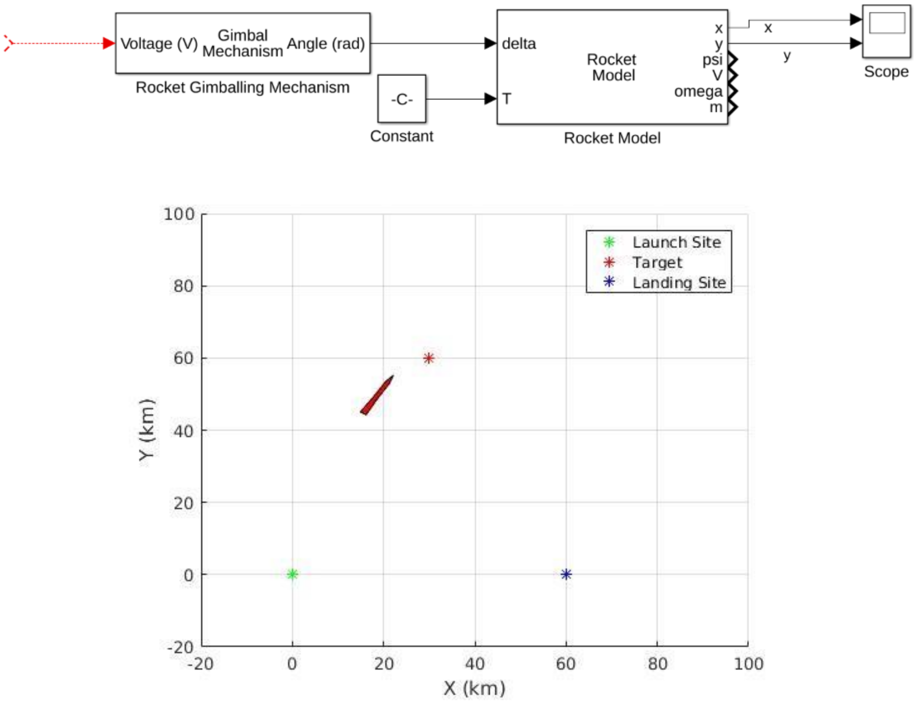

Figure 2: Simulink template from aeronautical stream design project (top) and simple visualization of rocket (bottom).

Results and discussion

To evaluate the effectiveness of these new teaching methods, results were obtained from the Unit of Study Surveys (USS's), and also a Follow-Up Survey (FUS) designed to evaluate the follow-up videos and the stream-specific assignments in particular. The USS run by the university had 190 respondents, while the FUS had 33. As the USS was not designed to evaluate these new teaching practices, for the USS we have restricted ourselves to using only the comments that specifically mention the new teaching practices. On the FUS, students were asked to respond to a number of questions on a Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"); these results are shown in Table 2 (see Appendix).

On follow-up videos

The follow-up videos were evidently very popular, some of them being viewed over 300 times, according to their YouTube viewer counts. When asked what “the best aspects of this Unit of Study” were, many responded on the USS saying follow-up videos were the best aspects. The following are typical comments:

Youtube videos were highly informative and helpful

The small videos on [the class forum] for topics we were struggling for [sic] were very good and helpful and good to refer back to, maybe more of them would be helpful.

I really liked the videos. I feel like those kind of Khan Academy style videos are a lot more effective at teaching concepts. Perhaps you could expand on those and make it a weekly thing which students should watch before the lecture, then use the lecture time more to go through examples and answer student questions rather than go through lecture slides in the traditional format.

I really appreciated the extra videos posted on [the class forum].

... great online content videos posted by [the lecturer].

The suggestion in the third comment is exactly the flipped classroom according to Abeysekera & Dawson (2015), Hereid & Schiller (2013), among others. This suggestion, and related ones, are seen repeatedly throughout the Unit of Study feedback. The feedback closely aligns with the course coordinator's own thoughts on improvements to make to the course next year; next year we plan to utilize out-of-class videos more heavily for information transmission, including some pre-lecture videos that introduce some of the content. Interestingly, while 48% of FUS respondents said that they "strongly preferred" or "preferred" pre-lecture videos over post-lecture follow-up videos, 31% were neutral, suggesting that many were unsure (see Table 2). Based on this information, we may implement both pre- and post-lecture videos in the coming year.

In addition, 82% of FUS respondents (see Table 2) "agreed" or "strongly agreed" that the "post-lecture videos helped [them] improve [their] understanding of concepts in this subject", and 86% "agreed" or "strongly agreed" that the "the videos specifically targeted the areas [they were] confused about". These results suggest that the videos served their intended purpose of targeting areas where students were confused, within the FUS respondents, at least. Hence we will continue to produce these videos in future iterations of the course.

Many comments were also made about changing the role of lectures to being more interactive, such as:

I strongly suppose [sic] that the lecture should involve more practical projects...

I strongly believe the Unit of Study should transition to teaching concepts through the short, concept focused videos and leave lectures to … see[ing] the lecturer's approach to problems.

[the] lectures could be more engaging.

This is further support for the "flipped classroom" approach, in which content delivery is done at home instead of in the classroom. We are interested in moving in this direction, that is, to have short videos focusing on the technical concept, and using class time to show simple and more in-depth uses of the concept. Encouragingly, one lecture was delivered entirely by video, and a separate survey (with about 10% response rate) showed that students overwhelmingly preferred content delivery by online video, with about 70% considering it more useful than an in-person lecture.

On stream-specific assignments (DP2)

The stream-specific assignment was the second design project (DP2) given to students, in the second half of semester. When asked what "the best aspects of this unit of study" were, students responded on the USS:

Interesting problems to solve.

The assignments are giving lot of knowledges [sic] and application skills

Relevant, interesting content

… the variety of design projects is great, allows everyone to look into something relevant

… assignments are engaging.

In the FUS, 72% of respondents "agreed" or "strongly agreed" that "because the [stream-specific assignment] was specific to [their] stream, [they] were better able to understand the relevance of the content in this subject to [their] degrees" (see Table 2). Of the students that responded "agree" or "strongly agree", 82% of those "agreed" or "strongly agreed" that because the assignments were stream-specific, they "[were] more motivated to learn how to solve it". This connection suggests that presenting the assignment in a relevant context does in fact result in increased student interest and motivation, at least in the FUS population.

However, delivery of such an assignment must be carefully organized; opinions on the difficulty of the assignments was mixed, with only 38% "agreeing" or "strongly agreeing" that "the relative difficulty of [the assignments] between different streams was well balanced" (see Table 2). Several comments voiced this view, for example:

"The difficulty between streams seemed pretty uneven, which was a little frustrating. I understand that there were complications for some of the streams' tasks which definitely influenced this."

While we believe the assignments were approximately equal in difficulty, as described in the Methods section, communicating this to the students clearly could have been improved. We will attempt to make this clearer in future years. One way to do this might be to release the "fairness" guidelines used to design the assignments to the students, which was kept confidential. We are also considering tightening the relationship between different assignments by making them more uniform.

Another consideration for any assignment is the amount of guidance that instructors can give. 83% of FUS respondents "agreed" or "strongly agreed" that "[they] felt that [they] needed more guidance from teaching staff on how to approach [the design project]" (see Table 2). Too much guidance may result in students submitting seemingly good assignments despite inadequate understanding of the concepts, while too little guidance may result in students feeling helpless and unmotivated. Getting this balance right is difficult with open-ended projects; we are still considering what kinds of guidance would be best. Next year, we are considering sorting students into classes based on stream, which may allow more within-discipline discussion, but reduces the interdisciplinary nature of this course.

Conclusions

Overall, it seems that the follow-up videos were successful in addressing specific topics students were confused about, and allowing for a reusable revision resource as semester continued. While the stream-specific assignments were received with mixed opinions, our core objective of motivating students better seems to have been achieved according to our FUS sample. In future iterations of the course, we will continue to seek feedback from students to evaluate the effectiveness of this targeted approach to teaching an upper level STEM class.

Appendix

Table 2: FUS survey results

	1	2	3	4	5
The post-lecture videos helped me improve my understanding of concepts in this subject	0%	10%	7%	21%	62%
The videos specifically targeted the areas I was confused about	3%	3%	7%	41%	45%
I would prefer pre-lecture videos that give a preview of the content and concepts, rather than post-lecture follow-up videos	10%	10%	31%	10%	38%
I would prefer that the videos cover theoretical concepts rather than worked examples.	28%	28%	21%	3%	21%
DP2 challenged me to learn the content of the subject at a very high level	0%	3%	17%	28%	52%
Because DP2 was specific to my stream, I was better able to understand the relevance of content in this subject to my degree	7%	0%	21%	24%	48%
Because DP2 was specific to my discipline, I enjoyed it more and was more motivated to learn how to solve it.	3%	10%	10%	17%	59%
I felt that I needed more guidance from teaching staff on how to approach DP2.	0%	14%	3%	34%	48%
From what I know from talking to other students, the relative difficulty of DP2 between different streams was well balanced.	14%	21%	28%	14%	24%

References

Chen, Z., Stelzer T., Gladding G. (2010). Using multimedia modules to better prepare students for introductory physics lectures. *Physical Review Special Topics- Physics Education Research,* 6(1), 010108.

Docktor, J.L., Mestre J.P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics – Physics Education Research* 10, 020119.

Herreid, C.F., Schiller, N.A. (2013). Case Studies and the Flipped Classroom. *Journal of College Science Teaching* 42(5), 62-66.

L. Abeysekera, P. Dawson. (2015). Motivation and cognitive load in the flipped classroom: definition, rationale and call for research. *Higher Education Research & Development*, 34(1),1-14.

Mills, J. & Treagust, D. (2003). Engineering Education, Is Problem-Based or Project-Based Learning the Answer? *Australasian Journal of Engineering Education.*

Norman, G.R., Schmidt, H.G. (1992). The Psychological Basis of Problem-based Learning: A Review of the Evidence. *Academic Medicine,* 67(9), 557-564.

Pintrich, P.R. (2003). A motivational Science Perspective on the Role of Student Motivation in Learning and Teaching Contexts. *Journal of Educational Psychology,* 95(5), 667-686.

Urdan, T. & Schoenfelder, E. (2006). Classroom effects on student motivation: Goal structures, social relationships and competence beliefs. *Journal of School Psychology*, 44, 331-349.

Verbič, G., Keerthisinghe, C., Chapman, A.C. (2017). A Project-Based Cooperative Approach to Teaching Sustainable Energy Systems. *IEEE Transactions on Education,* 60(3), 221-228