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Applications Monday: Students Bring Real-Life Control System Experiences into the Classroom

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Introduction

Control systems courses are often highly theoretical and focused on mathematical derivations. Some students express difficulty connecting the theories to practice due to this emphasis. By the time students reach their senior year of undergraduate studies in the United States, they have inevitably encountered a control system in their daily lives (e.g. kitchen appliance, automobile, house HVAC system) or in an internship or co-op job. Yet, many students do not readily recognize these connections. In previous terms, students have said it was difficult for them to understand how to apply control systems topics in their field. Based on this feedback, I considered course improvements to address this deficiency. I identified two possible causes for learning difficulties: lack of connections to prior knowledge and lack of motivation for the topic. According to Ambrose, Bridges, DiPietro, Lovett, and Norman [1], sufficient and accurate connections to prior knowledge can support learning. Therefore, helping students accurately identify interactions with courses topics in everyday life should aid learning. Additionally, based on the expectancy-value theory of achievement motivation, it follows that a student will likely be less motivated to learn a topic that they cannot identify as being useful in achieving a future goal [1]. Therefore, it is important to show how course topics are applied to designs and projects in the industry. Before finalizing a new assignment, I explored connections to prior knowledge, student motivation, and various types of assessment.

In this paper, I describe the background research that went into the design of a new assignment, the specifics of the implementation of the new assignment, results from using the assignment in four terms during 2016 and 2017, and discuss the possibility of introducing this assignment in another course. The learning objective of the new assignment is to help students connect topics from a required, senior-level, control systems course for mechanical engineers to real-world examples of control systems and modeling.

Background

Previous research has shown that deep learning happens when students can connect what they are trying to learn with what they already know [2]. There are two ways to draw upon prior knowledge in the classroom: creating direct relationships or analogical relations [3]. Scaffolding and coaching are ways for instructors to help students create relationships to their existing knowledge [2]. These connections to prior experience have also been shown to increase student motivation [1].

There are several theories that describe factors of student motivation in the classroom. Two popular theories are expectancy-value theory and self-determination theory. In expectancy-value theory, students have increased motivation if they can identify an intrinsic or instrumental value

and have a reasonable expectation of success [4]. Some strategies to increase value include connecting the material to students' interests, relevance to current academic lives, and demonstrating relevance to future professional lives [1]. Some strategies for encouraging expectancy include alignment of objectives, assessments, and instructional strategies, and identifying an appropriate level of challenge [1]. Self-determination theory suggests that if a students' basic psychological needs—autonomy, competence, and relatedness—are supported than they will have increased motivation [5]. In the classroom, students demonstrate autonomy when they willingly spend time and energy on their studies [6]. Students feel competence when they believe that they are able to meet the challenges of the assignments [6]. Finally, relatedness in the classroom is fulfilled when the students believe that their teacher likes, respects, and values them [6]. Some of the same strategies that increase expectancy help students fulfill their need for competence. Therefore, course activities can be designed to support parts of both theories of motivation.

Course design should incorporate a variety of assessment types that align with the course goals. Svinicki and McKeachie [3] indicate that assessments should measure attainment of all course objectives (e.g. motivation for learning). Additionally, assessments should also be learning experiences and not increase anxiety and competition [3]. Low-stakes and high-stakes writing are forms of assessment that can provide information about student learning beyond traditional exams [3]. Low-stakes writing is generally informal and likely to be ungraded or informally graded. Examples of low-stakes writing include in-class reflections of reading or homework, journals, or discussion boards. Some benefits of low-stakes writing provide students an opportunity to put topics in their own language, allows students to focus on the content, and provide students the opportunity to practice before a high-stakes writing assignment [3]. High-stakes writing assignments are used for assessment and are a factor into the course grade. Some examples of high-stakes writing include project reports, lab reports, essays, and research papers.

Implementation

To highlight real-world applications of course content, I elected to add a new assignment and short presentation to the course. The learning objective for the assignment is for each student to *investigate and explain one real-world application of a concept in the course*. To demonstrate that they have achieved this objective, each student writes a one-page, double-spaced, summary describing how their real-world application applies to a course topic. Then, to leverage the diverse experiences of students in the course, each student is asked to share their application with everyone in a short TED-style talk on the last day of class. Since the last day of class is usually a Monday, I have called this assignment Applications Monday.

In four academic terms during 2016 and 2017, I have used this assignment as the last assignment in eight sections of a required control systems course for mechanical engineering majors (MECH430: Dynamic Systems II with Controls). The course topics include system modeling and simulation, frequency response and filtering, and control system design. Students generally take this course in their senior year. In addition to coursework, students are also required to complete five terms of co-op employment (industry or research positions) that alternate with their academic terms on-campus.

I assign the task of investigating one application of a course topic, usually one week before the last lecture period (see appendix for assignment instructions). While handing out the assignment, I offer to let them borrow a technical magazine (e.g. ASME, IEEE Control Systems) from my office as a potential source of information. I permit the options of using hobbies and research papers as a source for this assignment so that students can still complete the assignment even if they have not used control systems during their co-op employment or they cannot share an example due to a confidentiality agreement.

To streamline the presentations, if a student would like to use a photo or video during their presentation, they are required to submit it before class starts. If they sent materials, I have them preloaded in a Google Drive folder on the computer in the classroom to make it easy for a student to open the file when it is their turn to present. On the last day of class, students present in the order that they volunteer. All students who want to present are provided the opportunity to share their example with the rest of the class. Since the presentation is only worth three of the ten points, some students elect to forego those points and do not present their topic. The length of the presentation and details about visual aids are provided in the text of the assignment (see appendix) and discussed in class the when the instructions are handed out.

I consider this a low-stakes writing assignment. The emphasis of the assignment is not on the formality of the writing, rather the emphasis is on the content (connection between the real-world example and class content). While I do grade the assignment, it only counts as 2% of the final grade. The written description counts for seven of the ten points and the presentation counts for the other three points. If the student clearly describes a real-world example and the connection to the course in the written description, they will earn all seven points. Additionally, if they clearly share the example and connection to the course with the rest of the class, they also receive the three points for the presentation. In general, students lose points for not following instructions on length of the written description, length of the presentation, significant errors in the description, or missing citations.

Results

Overall, this assignment has been successful in my course. My first measure of success was to determine if each student achieved the learning objective of *investigate and explain a real-world application of a course concept*. Each student who has submitted the written portion of the assignment was able to identify a real-world example and describe how that example uses a course topic in the design. Each student who has submitted the assignment has earned at least 6.5 of the 10 points. The real-world examples and applications that have been shared with the course have covered a wide variety of topics; see Table 1. Across all eight sections, all of the major course topics have been covered with an application; see Table 1. Control systems examples tend to be the easiest to find and therefore are the most popular course topic selected by students, so not all course topics are covered each term.

One student mentioned in the text of his assignment, “There are many examples of dynamic systems at my co-op, albeit I didn’t really realize it until after this course.” It is not clear if all students would have made these connections without the formality of this assignment. Before handing out this assignment, I have had students ask me about applications of course material, so some students make the connections without the formality of this assignment. However, since

Table 1: Course topics and selected topics students have presented for this assignment

Course topics (% of total assignments)	**Selected assignment topics**
System Modeling and Simulation (2%)	Creating vehicle model, electromechanical simulation, graphical simulation software
Frequency Response and Filtering (14%)	Music synthesizer, data filtering of dynamotor data, bandwidth of cassette tapes, filter design to reduce vibration, radio filters, speaker design, anamorphic crash dummy sensor filters
Control System (84%)	Anti-lock brakes (ABS), adaptive cruise control, 6-axis robots, CNC machines, ovens, HVAC, power steering, airbag deployment, seat-belt control, automated welding or cutting, engine or motor control

students in previous terms have indicated that they do not understand how the course will be used after school, not all of the students are able to make the connection to real-world examples on their own. While it is not an exhaustive source of data, since implementing this assignment, I have not received any end-of-term feedback indicating that students could not connect the course topics to real-life. This end-of-term feedback is another indication of the success of this assignment.

To understand which experiences students were drawing upon for this assignment, I categorized the source of each presentation based on the text of the written description; see Figure 1. If the written description mentioned co-op, another course, or that the application was a hobby, that is how it was categorized. Some students did not mention how their application related to their life, so these were categorized by their citation: scholarly source (e.g. publication from a related professional society), internet, or missing citation. Since students are required to complete multiple co-op terms, I expected that to dominate the sources for examples. However, I also wanted to make sure that this was not the only source of information to explore the opportunity to implement this as an assignment in a program that does not require a co-op. Additionally, since about half of the sources are not from co-op, it increases the variety of examples and therefore reduces the probability of redundant examples.

Many students have co-op employment in the automotive industry due to the history of Kettering University. Since there is a dominance of one industry, I was concerned that students might submit duplicate examples in the same section of the course. In the eight sections that I have used this assignment, there has only been one instance of a completely redundant example. In the case of redundant examples, two students selected anti-lock brake systems (ABS) and the second student did not have anything significant to add to what the first student presented. There was also one instance of similar examples: two students selected 6-axis robots, however, they selected different uses for the robot. One student's application was a robot that moved parts in a factory and the other student shared how the robot is used in a paint shop, so there were sufficient differences in their presentations.

An unanticipated benefit of these new activities is that I also have a wider selection of practical control system applications to share in subsequent terms. For example, in one class two students

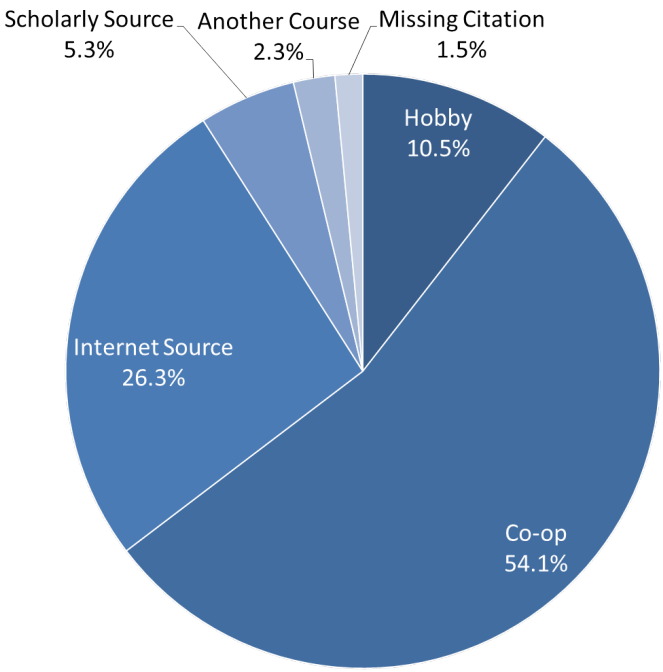

Figure 1: Distribution of the source of the topic presented for the assignment

shared very different oven applications: one a traditional household oven and the other for curing steel. After students presented both of these applications in that class, we were able to compare and contrast the difference in expectations for overshoot and steady-state error between the two applications. I have also been able to share these contrasting strategies with students in later terms.

Since I have designed this assignment to be a low-stakes writing assignment, I have kept the focus on the content rather than the formality of the writing and presentation. The focus on the content is also in line with the learning objective of the assignment. The informal writing expectations have led to a variety of citied sources if sources were cited at all. Some of the sources cited are websites that are not considered scholarly (e.g. Wikipedia, How Stuff Works). While they are referencing what would typically be considered unreliable sources, they are still making the connection to the course topic and using the terminology from the course correctly in their write-up and presentation. As a result, they have demonstrated a connection between the course and the application and therefore achieved the learning objective. Additionally, two of the students who referenced journal articles said the content was too advanced for them to fully understand the work. For that reason, some of the internet resources may seem more approachable to an undergraduate just beginning to learn about control systems.

Within the final grade calculations, I classified this assignment as a quiz, so my policy on dropped quizzes applies to this assignment. Over the four terms, my dropped quiz policy has varied. For the spring 2016 term, I did not drop the lowest quiz score and 97% of the students completed the assignment. For three terms in 2017, I dropped the lowest quiz score of the term, and therefore some students elected not to complete this assignment; see Table 2. At least 70% of the students each term in 2017 have completed the writing part of the assignment. For the remaining students,

Table 2: Percent of students each term who successfully completed the assignment

Term	Completed Assignment
Spring 2016	97%
Winter 2017	78%
Spring 2017	72%
Summer 2017	85%

if they still attended class on the last day (most do) they were still exposed to all of the application shared by their classmates. Therefore, if students turn in a write-up and/or attend the last class, they have probably achieved the learning objective of this assignment. In hindsight, offering to drop this assignment is probably not advantageous for students achieving the learning objective. Going forward, I may reconsider dropping the lowest quiz score. Additionally, instructors who adopt this assignment in their classes might also consider making it a required assignment to achieve the participation levels of spring 2016.

Discussion

This assignment has been successful in my course, but some modifications may be necessary to implement this assignment in another course or university. Due to the small class size (32 students or less per section) and 90-minute lecture length, I have always had time for all of the TED-style presentations. However, for larger or shorter classes, this may not be possible.

Based on a conversation with a colleague at a larger intuition, some possible modifications include video-recorded presentations, having smaller sets of presentations in several class sessions, group presentations, or even shorter presentations from each student while standing at their seat. If video recordings are captured, students could be placed in smaller groups and watch each other's videos to expand the exposure of the examples, however, there would have to be some level of accountability included ensuring the students actually watch each video.

Another option would be to replace the presentation option with another public form of sharing like adding detail to a Wikipedia entry, creating a how-to guide on Hackster.io or Instructables, or an instructional video on YouTube. Extending these ideas further could be to give students the choice (e.g. in a class presentation or one of the internet options) of how they want to share their application publicly. Providing the choice for publishing their example could support the students' sense of autonomy in the classroom.

The presentation portion of this assignment could be eliminated; however, I think the other students gain from hearing the variety of examples. Sharing their example may increase the students' relatedness in the course because the teacher values their application. When other students ask questions or their application generates discussion they may also feel related to their classmates. By focusing this assignment on the content and sharing the variety of applications (low-stakes writing) and setting clear expectations, students feel that this assignment is achievable and therefore increases their sense of competence and expectancy.

Conclusion

Overall, this assignment helped students make a connection between the highly theoretical topics of the course to real-world applications. The assignment is low-stakes and is not intended to take more than an hour to complete. The students in the course have achieved the learning objective of the assignment. With the presentation component, they are exposed to their own application as well as the applications selected by their classmates.

References

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Appendix – Assignment Text

Identify a real application of a concept covered in MECH 430: Dynamic Systems II with Controls. The application could be something you have encountered in a co-op position, hobby, or one found in the literature (e.g. conference or journal papers). If we have already covered the application in class or lab (e.g. DC Motors, cruise control), the description should include more details than what we have covered in class. Write a short description of the application and how it uses the concept from class. The description should be typed, double-spaced, and at least 250 words. Also, include any references that you used. (7 points)

You will also share your application with the class on Monday, September 18. The duration of your presentation should be about 3-5 minutes. The presentation should describe the application and how it specifically relates to the course. These are meant to be quick TED style presentations. Therefore, you should not prepare a formal set of slides. However, if you would like to use a short video or picture that illustrates your application, send it to Dr. Reck before class. Note: the video cannot take up your entire 3-5 minute time unless you are talking over the video. (3 points)