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GIFTS: Exploration Activities for Just-in-Time Learning in a First-Year Engineering Robotics Design-Build Project

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Abstract

This GIFTS paper will provide an example of how Just-in-Time (JIT) learning can be used as a technique in a first-year engineering design-build robotics course to encourage student motivation, learning, and creativity. This paper explores using JIT learning for unique software and hardware skills in a project-based course where students design, build, and program an autonomous robot. Data on student perceptions of the JIT learning activities indicate students find the assignments useful for their learning. This paper will also describe how choice is preserved in student decision-making for an open-ended project while also guaranteeing students learn the desired course learning objectives.

Introduction

Just-in-Time (JIT) learning is an instructional strategy focused on meeting the learner's need only when it arises rather than on a scheduled basis [1]. This strategy is designed to not overwhelm learners with content that does not meet their immediate learning needs [2]. For over 25 years, an honors first-year engineering program has offered a cornerstone robotics design project as the culmination of a two-course sequence on engineering fundamentals [3]. To provide students with the new technical knowledge needed for the robotics project while allowing teams to progress in their own designs, a JIT learning instructional strategy is used for three technical exploration activities. The motivation for this paper is to share a strategy for how JIT learning can be used in a design-build course to motivate student learning and consistently teach important skills while still providing students with choice and flexibility.

Background

Literature

JIT learning is an inductive teaching strategy, which is a class of strategies that helps students perceive real-world applications of the material they are learning [4]. In this way, inductive learning helps students understand why they should care about the material beyond its use later in the curriculum. Inductive approaches normally also involve active and collaborative learning methods, both of which are known to have positive effects on many learning outcomes [5]. JIT learning in this study is also used within the context of many of these other inductive teaching methods, including project- and problem-based learning to more effectively achieve a broad range of learning outcomes [4]. Inductive learning in engineering classrooms is popular and has been shown to improve student motivation and content retention [6, 7, 8].

JIT learning specifically is designed to not overwhelm learners and is highly motivating to students because they clearly perceive the need to know the material [9]. The learner's need is what drives the delivery of information, so it is also more learner-directed than other approaches to education [10]. JIT learning has been studied for undergraduate engineering students pursuing research [11], in engineering capstone courses [12], as a method of teaching engineering students skills related to industry [13], and also broadly in engineering classrooms, which found positive impressions from faculty on improving student energy levels and understanding [14]. This research focuses on JIT learning in first-year engineering project-based classrooms.

Course Description

The honors first-year engineering design-build course at a large Midwestern university consists of over 200 students across several sections of approximately 36 students each. In this course, teams of four students design and build an autonomous robot to perform a series of tasks on a themed interactive robotics course [3]. The robots are programmed using a custom controller [15] and must be designed within a specified size and budget. The robot must navigate the course using input about its location, orientation, and relation to obstacles. The robots can navigate using information given by a custom positioning system [16] and hardware devices such as digital optosensors and microswitches. Example tasks that the robot must complete include flipping the correct lever of a series, determining the color of a light and pushing the corresponding button, and dropping an item in a designated location. During the design project, students must complete three exploration activities that introduce them to important navigation concepts that they can choose to use and adapt for their robot design. To complete these exploration activities, students are provided with a standard prebuilt base robot [17] which was built specifically for the activities and uses the custom controller device provided to students.

Methods

The implementation of JIT learning in a first-year engineering design-build course is outlined here. Additionally, data from an end-of-course survey from the 2022 robot design-build course is analyzed to investigate how students perceive the exploration activities.

Intervention

Throughout the semester, at periodic intervals, students' progress on the robot design project is assessed via four performance tests where their robot must navigate to and complete a set of tasks. The exploration activities and performance tests are interleaved to employ the JIT learning strategy as they expose students to the necessary concepts prior to expecting their robot to complete a performance test where the concept will be useful or required. Table 1 provides a timeline and high-level description for each exploration activity and corresponding performance test.

Survey

As part of normal end-of-course assessment, students are asked to complete a survey that includes prompts for students to select up to three robot project assignments that they found useful and up to three robot project assignments that they found not useful. There were 24 robot project assignments in total, and three of those corresponded to the exploration activities. There are also open-ended question prompts for students to explain their choices.

Table 1: Timeline and Descriptions for Explorations and Performance Tests.

Week Due	Assignment	Description
2	Exploration 1	Motors, navigation with microswitches, soldering a light sensor, and colored light detection
3	Performance Test 1	Navigate to a task, read a colored light, and drive up a ramp
4	Exploration 2	Navigating along a line, navigating using shaft encoding, soldering an optosensor
4	Performance Test 2	Navigating to and completing a different task
5	Performance Test 3	Navigating to and completing a different task
6	Exploration 3	Navigation using custom positioning system, data logging
6	Performance Test 4	Navigating to a task using positioning system and completing a task based on transmitted data

In the most recent offering of this course, 189 students completed the end-of-course survey. As a way to partially assess the utility and effectiveness of the exploration activities, the quantitative survey responses are analyzed to determine what percentage of students found the exploration activities helpful and not helpful, and positive and negative qualitative feedback about the explorations is presented.

Results

Intervention

The implementation of JIT learning for exploration activities in a robotics design-build course enables students to learn a variety of skills while allowing for a choice between options in their designs. Each exploration activity where JIT learning is implemented teaches unique software and hardware skills, outlined in Table 1. This is a large volume of skills, ranging from soldering to writing complex algorithms for driving straight, turning, following lines, and navigating around obstacles. By learning these skills incrementally throughout the semester, students are not overwhelmed by the volume of information and hardware options available to them. In this way, the course is also paced appropriately for students.

Students taking this course often comment that they plan to rely on a single navigation technique, which is most often the positioning system, for their initial design plans. The structure of the activities teaches the most robust navigation techniques first. So, by teaching the positioning system technique last, students are forced to learn all of the other techniques. As a consequence, many students decide to use the navigation systems they have already implemented and tested and build upon them throughout the semester, rather than picking one at the beginning and relying on it alone in their final design. This technique also allows students to make an informed decision about which techniques they want to employ and ultimately choose to use or not use these techniques while still learning the skills associated with using each of them.

Another observed benefit of the JIT learning strategy for these exploration activities is that students incrementally build and test modular software for each activity. For instance, in the first exploration students write software that uses microswitches to straighten out their robot by lining it up against a wall, which students can use in their final software without additional modifications. This also encourages modular software development in general in their software, which is critical in such a large software component.

Survey

Descriptive statistics for the quantitative survey responses are shown in Table 2. Out of the total 24 project assignments, the three exploration activities were the first, second, and fourth most-selected activities for being helpful. They were the second, third, and fifth least-selected activities for being not helpful.

Table 2: Percent of students who found exploration assignments in the course helpful or not helpful compared to other assignments.

Activity	Helpful	Not Helpful
Exploration 1	33.9%	2.6%
Exploration 2	23.8%	3.2%
Exploration 3	40.8%	4.8%
All Assignments (Average)	12.1%	10.8%

Many of the open-ended responses providing explanations for the selections were about the exploration activities. One student noted *"The explorations were comparable to unlocking a new tool."* Another commented that *"Every exploration helped our group excel at performance tasks as we would have had little knowledge of what to do without them."* In contrast, most of the negative comments about the explorations indicate students thought they should have occurred earlier in the project. For instance, one student noted that *"The [positioning system] exploration was helpful but would have been more helpful if it would have happened earlier in the class."*

Discussion and Conclusion

Using JIT learning in a first-year design-build robotics course has a variety of observed benefits including modular software, the use of a wide variety of robust navigation techniques, and the high perceived usefulness of course content. Based on end-of-course feedback, many students report finding the JIT learning-based exploration activities to be useful. Students recognized the value of the exploration activities, especially compared to other assignments, which could have been due to the timing of the activities and the immediate need to use the material in performance tests. This is supported by student comments in the open-ended portion of the survey and the connections between the explorations and performance tests students perceived. A number of students noted in the open-ended response section of the survey that they wished the positioning system navigation strategy had been introduced earlier. However, as the positioning system is the least robust method of navigation, robots that rely on it as the only navigation strategy are prone to failure as they are less consistent than those that use a variety of strategies. Although many students would prefer to learn the skill early, the learning objectives of the course related to teaching a variety of navigation techniques require teaching the positioning system later. Future work in this area could be to compare student motivation, learning, stress, and performance in a project-based course using JIT learning compared to a traditional strategy where students learn all of the needed concepts for the course before the start of the design-build portion of the course.

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