GIFTS: Experiential, Research-Based Learning as part of the First-Year Innovative Research Experience's Bio Inspired Robotics Stream

Introduction

Traditionally, college-level research is conducted by graduate and upper-level undergraduate students. The Bio Inspired Robotics (BR) Stream (a form of lab group), as part of a larger undergraduate research experience, gives first-year, undergraduate students the unique opportunity to conduct authentic, college-level, robotics research within the first few semesters of their academic career. BR stream teaching structure is based upon active, research-based learning methods, tailored to the unique scientific and technical aspects of bio inspired robotics.

Though most stream activities are centered around a collaborative research project, the deployment of which draws from traditional project-based learning foundations, the overarching teaching structure differs in a few ways. Project-based learning seeks to improve student engagement and understanding of class content through active, hands-on product development. [1]. The belief is that students who apply curriculum knowledge through the development of a class-relevant product will gain a more practical mastery of curriculum information [1, 2].

Research-based learning, takes the goal one step further and pushes students to innovate beyond the current class information and technical knowledgebase [3, 4, 5] The hope is that, as students apply research methodology to generate new practical solutions, they will improve in important metrics, such as independent learning capabilities, critical thinking skills and deeper technical insights [3, 5, 6]. In the BR stream, students are first encouraged to develop new methodologies or robotic platforms that can add meaningful solutions to real-world problems and enlarge future curricula. Second, they are mentored in the practical development of hand-on skills through project development.

The unique challenge of this endeavor with BR students is twofold. One, first-year students often lack the technical knowledge required to both create a successful product and do so in a way that contributes meaningfully to the knowledge base. Second, all technical information must be taught as if to a general audience, as the stream welcomes students of all disciplines (STEM engineering, STEM non-engineering, and non-STEM). The purpose of this paper is to discuss the core teaching methods, developed by the BR faculty leader to (1) accelerate the scientific and technical knowledge of first-year students, (2) mentor students as they conduct, college-level research with the goal of innovation beyond current class curricula and (3) ensure students develop real-world technical skills they can deploy after matriculating out of the program.

Program Methods

In the BR Stream, students are guided through a one-year process of designing, developing and building a bio inspired robot to address a specific field application. Class structure is divided into four components: (1) in-person lectures, often with an added activity to reinforce weekly content, (2) in-lab workshops, designed to introduce students to a variety of robot making skills, (3) a parallel, student-driven, maker skills certification system that can be used to further increase technical skills and (4) the summative team project, that gives room for student application of curriculum knowledge and innovation towards real-world solutions. Lectures are designed to introduce technical content in a generalized manner, with the goal of creating an intuitive understanding of concepts that can be reinforced later with deeper theory. During the in-lab workshops, students conduct small, one to two hour projects that provide hands-on interaction with important technical skills that are fundamental to the successful development of robot platforms, such as soldering or power tool usage. The parallel, certification system consists of a series of lessons and projects in different skill sections that students can follow to gain mastery of robot development methods. Students craft their path towards project innovation by choosing which tools or techniques they wish to learn and how far they wish to progress towards mastery in each skill section. They also have the option of adding or suggesting new lesson content for future students. Finally, for their summative project, student teams are given the freedom to determine the project goal, design and biological inspiration of the robot within the three field application categories. Finished robot projects are considered based on their success (design innovation) and completeness (actual functionality).

Conceptual Example

During one semester's project, more than one student team demonstrated innovation by adapting a previously made robot mechanism for new purposes. The mechanism was a z-axis, oscillating shaft with an attached flexible, fish-inspired fin. The starting actuator was a spinning DC motor and through a series of mechanical transitions, the rotational motion was turned into (1) sliding motion, (2) offset rocking motion and (3) flexible oscillation. As the students reverse engineered the original mechanism, they metacognitively applied fundamental engineering principles to the understanding of mechanical transitions, tolerances, internal forces, component spacing and geometry as important factors in the mechanism's proper functioning. Then they created new methods for integrating this design into their robotic platforms, by rotating the axis of oscillation, developing methods of flexible casting, and experimenting with new fin geometries. Looking back at the end of the semester, students documented important lessons learned in the adaptation of the original mechanism and reflected on their improved understanding of mechanical systems.

Introducing students to fundamental aspects of mechanical design and analysis as an early semester, structured lecture became an obvious means of improving project success later on. The innovative results of this semester's project, important lessons learned and the improvement in student critical thinking and understanding of mechanical concepts, informed the development of a new instructional methodology in the next semester. This method was designed to mimic the way in which previous students metacognitively, reverse engineered and adapted the mechanism. The method also took into account the previously mentioned factor that many students were being introduced to these engineering concepts for the first time.

To begin, smaller, deconstructable versions of the fish mechanism were developed and handed out so that, like the previous cohort, the students could physically interact with the mechanism during the lesson. Students were led in a discussion about the mechanism's design that encouraged a "plain-english" description of three important mechanical analysis concepts (1) quantification of motion, (2) motion transitions and connections and (3) forces and moments. Students were asked to consider the intuitive knowledge they already possessed about how mechanisms move about, as a touch base before progressing into deeper understanding. The quantification of motion was described by the "Beginning and Ending Motion" (the general manner of movement and motion transfer) and by "Beginning and Ending Mechanism" (the motor, rocker, slider or other mechanism that generated the motion).

Students were then encouraged to consider more deeply what specific components transferred motion (from beginning to end) and how the geometry of those connections were designed. At this point, more technical concepts, such as tolerances, constraining conditions and degrees of freedom were introduced. Finally, as the process progressed, it became apparent to the students that forces and moments were affecting the magnitude and manner of motion in the mechanism. Students were then reminded of the concept of a Free-Body-Diagram (FBD). However, students were not expected to know precisely what forces/moments would act on the system or where. Rather, they were encouraged to hypothesize what they expected to see, based on the intuitive knowledge they already possessed. Students were motivated to test their hypothesis by finding similar systems in the research literature and exploring which forces/moments were placed on FBDs by researchers and why. In doing this, they both improved their technical understanding of FBDs and procedural understanding of researching engineering concepts.

As a final point, students were asked to replicate the previous semester's process and adapt the fish mechanism into a new application. They had the option of using the entire mechanism or a part of it in their hypothetical design. This reinforced the previous semester's understanding of mechanism adaptation and innovation.

Discussion

This process is now in its third cohort of students. As the methodology has grown, the number of projects demonstrating a level of innovation that can add to the stream's knowledgebase has also grown. Further teaching techniques have been added based on the robotic mechanisms developed by students in previous semesters, prompting improved project success between cohorts. The hope is that, as the research-based model is further refined, students will grow in their ability to independently learn, analyze and contribute scientifically to the robotics community.

References

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