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The implementation of dynamic learning in a project-based introductory engineering course

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The Implementation of Dynamic Learning in a Project-Based Introductory Engineering Course.

New Mexico Institute of Mining and Technology

Introduction

The purpose of this paper is to elaborate on improvements made to the introduction to mechanical engineering courses at New Mexico Institute of Mining and Technology (NMT). Course modifications were tailored to the feedback of last year's report on class success. In addition to new projects, the course has acquired a lab space and new materials to both support and expand student learning outside the classroom.

There are three semester long projects each centered in a different realm of mechanical engineering that students can choose from: Modal Analysis, Rocket Launch, and Bio-mimetic Snake. A description of each project and its tie into broader engineering concepts is outlined as follows.

I. The Modal Analysis project challenges students to build a modal testing device capable of finding the natural frequency of a LEGO model airplane. The project is centered around vibration propagation and control, as well as understanding trends in natural frequency and how to find them in rigid systems.

II. The Rocket Launch requires students to research, design, and launch a model rocket containing an avionics package which records time, altitude, and acceleration. Students are exposed to Open Rocket and Arduino in lab, then encouraged to do independent research to fine-tune their design. The rockets must be designed to adequately secure the avionics package for retrieval after launch.

III. Substituted into the course to replace the transfer case manufacturing project, the Biomimetic Snake project focuses on using soft robotics to generate forward movement. The addition of a project which couples biomimicry and robotics allows students to be introduced to the complex subject of mechatronics in a student friendly and engaging way. Unlike the rocket and modal analysis projects, the manner of movement is entirely in the student's hands, opening the door for innovative means of transport.

Considering the average Intro to Mechanical Engineering class size is 100 students, the course is relatively large when compared to the small overall enrollment at NMT.
This dynamic between large class size and small university size can be relatable to other Universities both small and large alike. The intro course faces issues both with limited resources

such as lab space and funding, as well as lacking interpersonal exchange between TA's and students. Where small universities face limited resources and large universities often have large student-to-faculty ratios, this paper highlights how enhancing student lab experience has boosted retention rates.

The introductory course now has a lab dedicated to providing a workspace for the class' group projects. The workspace is equipped with soldering irons, 3D printers, and a laser cutter. The lab is manned in rotation by eight teaching assistants (3 graduate and 5 undergraduate students) who host various hands-on help sessions throughout the course and are always in the workspace to aid in learning.

The combination of new project integration and an influx of resources has had a positive effect on not only the grades and retention rates of the department, but on the passion new engineering students hold for their work.

Goals of the Course

The Introduction to Mechanical Engineering Course consists of a lab and lecture.
The lecture focuses on preparing students for future classes while also giving them a wide exposure to the various subcategories of Mechanical Engineering. The lab focuses on learning three skills: Solidworks, Arduino, and Engineering Design through a team-oriented design project. The first week of lab students choose their project of interest and form teams accordingly. The lab curriculum then begins with a few weeks of introductory SolidWorks sessions, where the students learn individually. Next, the project design groups are given an Arduino kit to build and code multiple beginner level circuits. The lab ends with the last few weeks solely dedicated to the final projects. These final projects will be described in further detail later. A small midterm project is also implemented to further expose the students to a special research interest of the university and its subsidiaries. Further detail on the structuring of the course can be seen in last year's paper [1]. An important note from last year is the choice of projects and availability of resources compared to this year.

Application of dynamic learning

The type of instruction used in the course can be described as dynamic learning. The introductory course works to make constant changes and progress [2]. One of the ways that we do this is by limiting the static elements of the course. Most of these static elements are the skill outcomes for Solidworks and Arduino while the dynamic elements are the projects and their objectives that return each semester. Students will not want to continue if they are not engaged or interested, meaning it is imperative to get them interested immediately. The implementation of dynamic learning allows us to maintain student engagement by promoting self-inquiry of concepts taught throughout the course. The dynamic learning method used focuses on 4 sections: Beyond the Lab, Beyond the Level, Beyond the University, and Beyond the Tools.

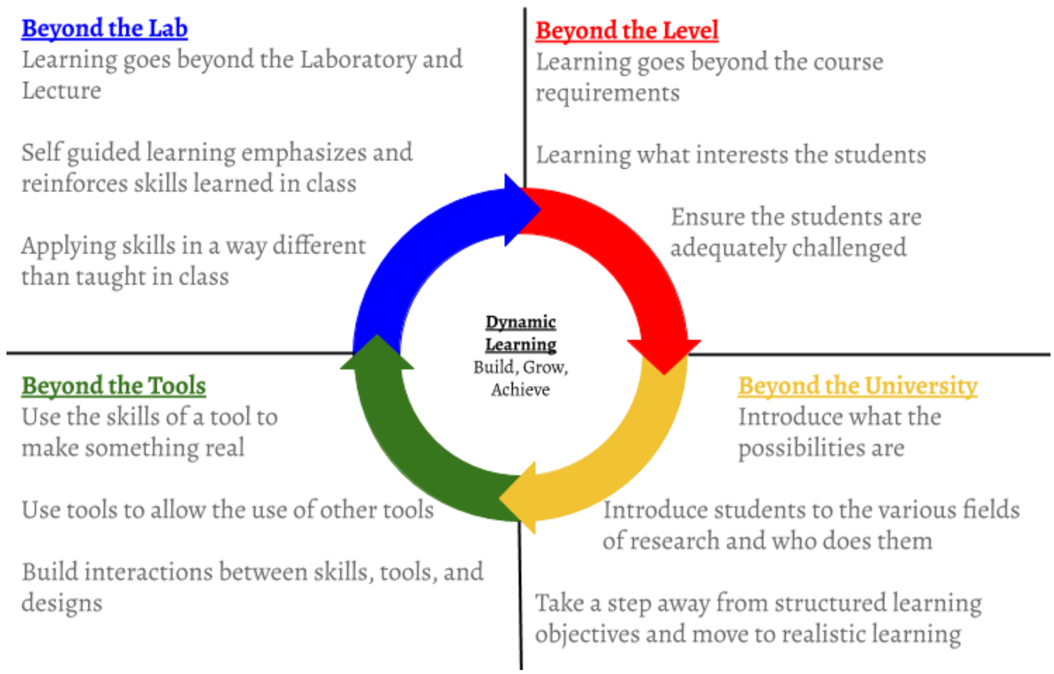

Figure 1: Dynamic Learning Infographic

Beyond the Lab

Beyond the Lab emphasizes the idea that lab assignments are not meant to be done solely during class. All school computers are capable of running the software that students need to complete these assignments. This means that students are expected to complete assignments outside of class, most of which are related to the in-class assignments. This self-guided learning expands upon skills gained in class. The out of class assignments are designed to introduce the students to independent research based on their interests. Finally, the assignments have students connect previously learned skills with their industry applications. The concept of homework is nothing new, but the out-of-class assignments are meant to promote the idea that learning is not restrained to the classroom. An additional way the course goes beyond the lab is with the use of out of class workshops that are available. These will be discussed further later.

Beyond the Level

The level of instruction can drastically change the way students want to continue. The scale is not linear from Not Challenging to Very Challenging, whilst a second axis ranges from Boring to Interesting. With this two-axis scale, there is a balanced region that retains students. Retention comes from project success versus interest. A project needs to be both interesting and challenging enough to keep students engaged. Due to this we focus on student interest but ensure the projects are still challenging such that the students can continue to grow. A graphic is presented below in figure 2. This graphic is derived from our observations and some of the feedback we get from students. However, it is only a representation and not a definitive graph of how to ensure student retention.

Figure 2: Retention of students

Beyond the University

Ironically, a main goal of Universities is to help students exit through graduation. With an end goal in sight, students want an exit strategy that prepares them for their emerging careers. This is the reason for the lecture part of the course. There are many guest speakers from both industry and other academic institutions, often NMT alumni themselves, who help expose students to how Mechanical Engineering applies to their related industry.

Beyond the Tools

There are a lot of tools out there, but none of them are useful unless you know how to properly utilize them. A couple of ways we develop student experience is through the use of digital fabrication tools such as 3D printers and laser cutters. Both require specific design considerations, but also have an incredible number of applications. These considerations apply to the design projects as parts require a doable and efficient means of fabrication. The balance between design and manufacturing is a process that is unfamiliar to most students. A modeling software like SolidWorks (a tool) allows students to make modifications to parts based on feedback for fabrication feasibility.

The goal of dynamic learning is to challenge the student through the use of changing applications and assignments. These changes occur primarily with the way we try to cover the core curriculum. The core curriculum is the same each year, but the way this curriculum is taught is different. One way we achieve this is by changing assignments and projects. The key milestones: research, producing a CAD model, and building have always been there. However, these changes keep the course up to date academically and in the field of mechanical engineering. The concept of changing parts of the course each year is not a new concept, but the difference is the outcome of these changes. Other courses change to fit the book's newest edition or to limit copying from previous years. However, with our open-ended course structure these changes do not affect the course and are not driven by external factors like in other courses. The changes that occur to this course and its projects stem from the idea of furthering the student's education by accommodating their interests, and ensuring a constant stream of growth.

Course Projects

Midterm Project

The aforementioned midterm project, a meteorite shield, serves a similar purpose as the final project. Though this project also requires design, teamwork, and manufacturing, this project focuses more on student interest and engagement. A part of our unique department curriculum is our involvement and availability to work with and study energetic systems and high velocity, dynamic impacts. This field often excites many of our students, and drives many of them to pursue education at NMT for the availability of these classes. As a result, the course is able to smoothly implement a project requiring students to design a space vehicle shield capable of protecting critical components behind it from simulated meteorites. Teams of 6-10 design a shield capable of withstanding shrapnel, approximately 0.375in and spherical in diameter, traveling at ~3000 ft/s. Like the other projects in this course the solution is open-ended yet has some guiding parameters, namely the shrapnel characteristics. A limiting factor of size, weight, and cost are also used. In figure 3 below is an example of all the projects set up prior to the test. Figure 4 shows one of the shields after the test.

This project differs from many of the other projects since there is not a report at the end as the short duration of the project and lack of understanding in shock physics makes a well written report difficult to obtain at this level. An additional reason for neglecting a report is the specialization of this topic. The goal of our course is not to specialize in any one topic but rather a multitude so that students can be exposed to many of the aspects prevalent in Mechanical Engineering. This project not only provides the students exposure to another field of Mechanical Engineering, but it also helps to make their degree more unique since not many people get the opportunity to study energetic materials.

Figure 3: All Meteorite shields set up prior to test

Figure 4: One of the shields after testing

Final Projects

The lab portion is built around 3 projects: Rocket, Modal, and Snake. These three projects are chosen to encompass a wide range of fields in mechanical engineering. The chosen topics are meant to be interesting yet sufficiently challenging enough to where the students meet the objectives of the course. The Rocket and Modal projects are the same as previous years. The Rocket teams are required to build a rocket that has laser cut and 3D printed parts that were modeled in SolidWorks. The rocket must also have a sensor package that tracks the altitude of the rocket. The Modal teams are required to build a modal shaker that can determine the harmonic frequency of a Lego airplane. The team is also responsible for designing a sensor package that determines the displacement and acceleration of the wing tips at the harmonic frequency. With rocket and modal being similar as last year they are described in further detail in last year's paper [1].

The newest project incorporated into the course is the biomimetic snake project, an example can be seen in figure 5. The objective is to make a biomimetic snake capable of generating some form of forward movement while collecting data about the snake's surroundings. The project was inspired by a summer student's research project that involved characterizing a structure comprised of 3D printed rigid links inside of a semi-elastic matrix, producing a tube of cast silicone with an internal structure much like a snake. The snake project is the most advanced project to complete. Many of its challenges come from the fact that snakes have nonlinear structural mechanics resulting in a nonlinear response. The field of soft robotics is an undoubtedly fresh one, resulting in a lesser amount of usable resources than the other classical mechanics projects. Though this project is challenging, its challenges spark the interest of students to stay with the project and the department.

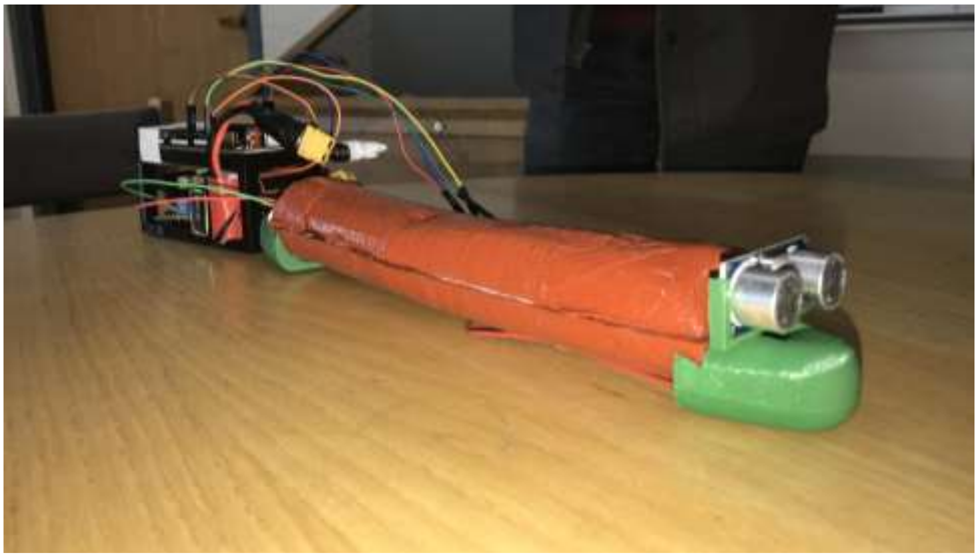

Figure 5: An example of a completed snake

Resources for the course

As this is a continuing paper, one of the things that needs to be addressed is the availability of resources and their improvements from last year. The first change is the number of TAs for the course. This year we had 1 additional graduate and 2 additional undergraduate TAs, bringing our total to 8 TAs. With the increase in TAs there was not a change in the number of classes or a significant change in the number of students in the class, allowing an improvement in the Instructor/Student ratio. This year we had a TA to student ratio of 1:10 and last year we had a ratio of 1:19.

Besides the improvement in TA to student ratio, our TAs work many other positions. One of which is maintaining regular lab hours. Our lab hours are operated by our undergraduate TAs. The implementation of the undergraduate TAs has been seen by other universities to improve the classroom engagement [3]. There were lab hours 2 hours a day, 4 days a week. There were no lab hours on Friday. Along with lab hours and more TAs, a new program was introduced exclusively for this course, our Peer Mentor Program. Unlike other peer mentor programs, the mentors were from within the department at various levels, some being TAs. The Peer Mentor Program was specifically introduced to maintain retention not only within the Mechanical Engineering Department, but retention at NMT overall. They were responsible for planning and orchestrating mentor events and having office hours, both of which allowed students to get extra help with the course, other courses, and becoming acquainted with the department and university.

Beyond the increase in persons, we added a dedicated work space called GROW Lab, pictured below in figure 6. One of the prior bottlenecks was not having sufficient room for the teams to work on their projects. This lab was fitted with a number of power and hand tools to best allow students to work on their projects. The room was also primarily under our use meaning we did not have to coordinate with other departments to allow room access and work time. A similar workspace has been used in the past, but it was under equipped and had insufficient space. The purpose of this room was to provide students an easy place to meet and complete their projects. From our observations we believe the room has helped the students complete their projects. Other institutions have implemented a similar concept and seen similar positive results [4].

Figure 6: Students using the GROW Lab

With the addition of a new lab, we had an increase in manufacturing equipment and workstations. Three new tools were added, two 3D Printers and one Laser Cutter. We added a Markforged Onyx One, Prusa MK3S with MMU2 3D printers, and Muse Laser Cutter. The addition of these tools to the previous Markforged Onyx Pro allowed us to rely solely on our course-dedicated resources for 3D printing and Laser Cutting, thus allowing us to keep the bottlenecks within the instructor’s control.

The additional workspace, TAs, and equipment enable TAs to hold various extracurricular workshops that are supplemental to the skills learned in the lab class. An Arduino workshop has already been implemented and plans for Soldering and 3D Printing workshops are being explored. These workshops are centered around basic skills for true novices who have no previous experience. We have observed a wide range of skill levels from new students, where the novices often lack team participation. The workshops help beginners gain the skill set necessary to participate without saturating experienced students with redundant knowledge. An eventual goal is to provide these workshops year-round, not only in the fall semester when the course is offered. Ideally, the TAs and Peer Mentors will be merged into the same group. This would allow recognizable faces to merge the boundary between in lab class and extracurricular guidance.

Affect to the retention rates or the course evaluations

A very imperative aspect of determining the success of changes in a course comes in a few ways one of which being the retention rates. In this paper we set out to determine the retention rates of this course in the following 2 semesters meaning Fall to Spring and Fall to Fall retention. We believed this to be a good time frame for determining the success of the course because many of the students at our university leave at semester. In fact, only about 75% of entering freshman stay enrolled Fall to Fall [5]. Due to this statistic we wanted to increase the number of students that stayed after the first year with the improvements made to the introductory course. Additionally, because this is the introductory course, we are going to focus on the retention over the first year. As a result, the authors sought help from the institutional research office but ran into an unexpected result. The Institutional Research Office has denied our request for the statistics our class because too few students have dropped as a result, we may be able to identify them which would violate a series of policies on student information. As a result we cannot present data on the specifics results of our modified course but we can say that a very small percentage of students dropped which leads us to believe that our course modifications have had a positive effect on the retention rates of the introductory course in Mechanical Engineering at NMT.

Conclusion

We believe that the incorporation of a dedicated lab space coupled with the introduction of a biomimetics project will increase retention rates in the introduction to mechanical engineering courses benefiting not only the department, but the institution as a whole. Initial course modification ideas were sprung from the feedback received at last year's American Society of Engineering Educators (ASEE) conference.

The GROW Lab has provided students a place to fabricate designs and receive one on one help with course material and projects alike. The addition of two 3D printers and a laser cutter provided for in house fabrication of all student designed project components. The biomimetic snake project has opened the door for an introduction to soft robotics to be highlighted in the introductory course.

The continual incorporation of new ideas into the course structure is allowing the mechanical engineering department to evolve the introduction to mechanical engineering class into a well-established project centered course. The course invigorates students' passion for the different branches of mechanical engineering while providing the basic coding and modeling skills they will need to succeed in future design.

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