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Using a Hyflex Learning Format in a Second-year Mechatronics Course

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Abstract

This evidence-based practice paper details a Hyflex learning format used in a second-year Mechatronics course for Mechanical Engineering majors. At York College of Pennsylvania, Mechatronics introduces second-year Mechanical Engineering students to essential aspects of electronics and instrumentation through experiential hands-on learning. Students regularly conduct laboratory exercises and work on short projects as they learn about common electronic components, basic circuit analysis and sensors, and how these components can be used to create electro-mechanical devices.

The course was modified in Spring 2021 to incorporate aspects of the Hyflex course format necessary to accommodate the ongoing COVID-19 pandemic. The course format enabled students to attend in person or remotely through Zoom video conferencing. The format expanded the use and support of asynchronous learning activities to better enable students quarantined, due to close contacts or positive Covid tests, to keep up or catch up on the course instruction. The goal of the instructors was to enable the same learning outcomes for all students, independent of personal circumstances. Online software tools (Canvas learning management system, Tinkercad and Nearpod) were used to deliver content and engage students. Conceptual topics were introduced followed by hands-on activities from Make: Electronics 2nd edition. Each student was also given a kit of electronic components, wire, a breadboard and a multimeter. Students completed and submitted assignments in a variety of digital formats, such as video reports.

This paper details the Hyflex modifications made to Mechatronics. It also includes student feedback and instructor reflections. Although the Hyflex format required significant new planning and experimentation it provided a means of accommodating a mix of face-to-face and online students and also provided an opportunity to increase the long term effectiveness of the course.

Introduction

At the onset of the Covid-19 pandemic in March 2020, most higher education institutions realized that face-to-face learning was suddenly untenable and unreliable causing them to consider up to fifteen alternative modes of instruction and content delivery for their students over the remainder of the 2020-2021 academic year [1]. One appealing and flexible alternative is known as hybrid flexible, or the Hyflex course format.

Hyflex is an instructional format that combines face-to-face and online learning. This approach was first developed in 2005 at San Francisco State University [2]. In this model of learning, every class session and learning activity that is offered face-to-face in a campus classroom is also offered synchronously for remote online students [2, 3]. Each class session is also recorded so that students can participate asynchronously. An important aspect of the Hyflex course model is equitable participation [3]. Tools and resources are set up in the course so remote online students can fully participate in the activities, discussions and assignments as a face-to-face student would.

At York College of Pennsylvania (YCP), it was mandated that Hyflex learning was to occur synchronously during the 2020-2021 academic year. Class sessions were to accommodate students attending class in-person and remotely through Zoom video conferencing [4]. As a result, instructors redesigned courses to meet the learning needs of students and achieve the course outcomes. One such course that required an extensive redesign was Mechatronics.

Mechatronics is a blend of mechanical, electrical, computer and control engineering [5]. Mechatronics courses are commonly found in undergraduate Mechanical Engineering curricula but the course content can vary widely from one institution to another. Often, Mechatronics is a senior elective course that focuses on a systems approach with topics including PLCs, actuators and automation [6, 7, 8]. Some institutions use the Arduino microcontroller [9] or LEGO Mindstorms [10] to introduce mechatronic concepts into dynamics and kinematics courses. Other Mechatronics courses focus on teaching students electrical and electronics concepts in a manner similar to an undergraduate Electrical Engineering circuits course [11, 12].

Hands-on laboratory experiments and projects are ubiquitous in Mechatronics courses. However, as mentioned in [3], such courses with heavy lab components present challenges to the successful implementation of the Hyflex model. This paper details how an undergraduate Mechatronics course was redesigned using the Hyflex model to create a common learning experience for all students, whether face-to-face, fully online or a mix of the two.

Course Overview

At York College of Pennsylvania, Mechatronics is a 4-credit, 6-contact hour course required of all second-year Mechanical Engineering majors. The overall objective of the course is for students to acquire technical competency in the fundamental analytic and experimental skills necessary to design and build basic electromechanical systems. This objective is met by achieving the following five learning outcomes, in which a student should be able to:

- analyze circuits using basic network theorems and constitutive laws
- analyze the steady-state response of various sensors
- apply knowledge of computer coding to write computer programs to perform simple tasks
- apply knowledge of microcontroller specifications and capabilities to design useful devices
- conduct experiments using basic electronic instrumentation and circuit elements such as resistors, capacitors, inductors, and op-amps

The most significant instructional challenge in Mechatronics is to generate interest and enthusiasm in the students, nearly all of whom are Mechanical Engineering majors. It is well known that students often lack motivation and interest when taking a course they consider outside their focus or major [13, 14, 15, 16]. Many non-ECE majors fail to see the value of Electrical Engineering concepts and skills to their future engineering career [13, 14, 15, 16]. The authors of [13] commented that they ”felt that the students came in with a pre-bias of not liking the content”. Over the past few decades, engineering educators have tried different strategies to improve the non-major student experience in Electrical Engineering courses. An effective teaching method is to use practical applications to demonstrate relevance to a wide range of engineering careers [14, 15, 16]. Hands-on laboratory experiments also help to reinforce lecture material and increase student interest [14, 15, 16]. Redesigning a course to be a blended learning experience can also appeal to different student learning styles [13].

The emphasis in ME270 is hands-on lab experiments and project work [17] with limited but sufficient lecture and analytic problem solving. Students usually work in pairs. Near the middle of the semester, each student is required to pass a basic analytic competency exam and a lab practicum, which entails one or more hands-on laboratory exercises designed to measure experimental competency and knowledge. In addition to these examinations, other assessment items include quizzes, short lab reports and attendance/participation.

A recent change to the course has been the use of ”Make: Electronics: Learning by Discovery” and ”Make: More Electronics”, both authored by Charles Platt [18]. These workbooks guide students through a series of experiments and short projects that introduce basic circuit concepts and gradually increase in complexity. Both texts are easy to read and comprehend, compared to a typical undergraduate-level circuit textbook. Each experiment has supporting technical information and images, including functional circuit diagrams and solderless breadboard layouts. The majority of the lab activities and projects for ME270 originate from these workbooks.

Hyflex Learning Format

To maintain social distancing in the physical classroom during the ongoing COVID-19 pandemic in Spring 2021, a synchronous Hyflex format was required of all courses at York College of Pennsylvania. This format presented challenges in addition to the previously mentioned challenge of motivating non-major students to learn circuit concepts. These new challenges centered around the need to provide an active and engaging learning environment with opportunities for project teamwork and hands-on lab experiments for students attending class in-person or remotely. The course instructors recognized that the Hyflex format required highly coordinated communication and carefully developed activities. Throughout the semester the instructors engaged in daily discussions to maintain a common understanding of the upcoming objectives, methods, content and activities. They also assessed what was working well and made appropriate modifications to improve learning in future class periods and semesters.

The students enrolled in each section of the course were divided into two classrooms to maintain social distancing. The instructor moved between the two classrooms and used a portable tablet and Zoom video conferencing software to maintain connection with both student groups at all times, to ensure that students were on task and to provide immediate responses to questions. Students were encouraged to attend class in person if possible.

To facilitate teaching in the Hyflex format, a freely available online tool (Nearpod [19]) was used to provide engaging and interactive learning exercises. Nearpod enabled the instructors to readily integrate active learning and formative assessment exercises within a slideshow of the technical content. For example, students used the ”Draw It” tool to circle the nodes in a circuit diagram. The quiz tool allowed multiple-choice questions to be embedded as needed. A competitive game format called ”Time to Climb” stimulated engagement and provided formative assessment data. As each class session progressed, students saw the same shared ”student screen” and interacted with various activities creating opportunities for active student participation. On a separate, private screen, instructors managed student interaction and gauged student comprehension from real-time data generated by the activities. A self-paced version of each complete Nearpod lesson was made available for review and for students who may have missed lessons due to illness.

Each student was given a lab kit at the start of the semester to allow for hands-on learning and completion of the lab experiments, regardless of where the student was located. The kit contained a breadboard, a pair of wire cutters, a multimeter, and various electronic components such as resistors, capacitors, switches, LEDs, alligator jumper wires, etc. and allowed students to complete lab assignments outside of the classroom. The parts kit was small enough to easily fit in a backpack and be transported easily to and from class.

Students also utilized another freely available online modeling software program (Tinkercad [20]) to model and simulate circuits. In Tinkercad, students were able to breadboard circuits virtually and simulate their behavior before constructing the same circuit on a physical breadboard, thus enabling students to experiment with a circuit and easily correct errors prior to the often tedious work of breadboarding. Instructors can create a ”Tinkercad classroom” for their course where students enroll so the instructor has access to all the designs a student creates. The Tinkercad circuit simulator does struggle with complicated circuit designs. In those cases, other dedicated circuit simulators can be used.

The “Make: Electronics: Learning by Discovery” book by Charles Platt [18] was first used in Spring 2020 to facilitate a rapid transition to emergency remote instruction. Since then the book has been fully integrated into the ongoing Hyflex course design.

Finally, all course materials were available through the Canvas learning management system [21]. Students used Canvas to complete short reading quizzes and submit documents and video reports. Announcements and modifications to the course schedule were posted on Canvas with an email announcement sent through the system. A course discussion board was also utilized for students to post questions and comments related to course material and assignments.

The first half of the semester was highly structured. Circuit theorems and concepts were introduced using Nearpod in the first half of the week. The second half of the week was reserved for related experiments and projects found in the Make: Electronics workbooks. The lab experiments were simulated using Tinkercad and then constructed on solderless breadboards. All experimental and project work was documented in hard-bound journals. The lab experiments initially were short ”discovery” activities focused on reinforcing foundational concepts such as voltage division, current division, equivalent resistance, and RC time constants. They also introduced students to using electronic measurement tools and components, such as multimeters, potentiometers, relays, transistors and 555 timers. Material from the Make: Electronics workbook was used along with supplemental instructions to detail the circuit to be built, data to be collected and analysis & calculations to be done.

In the second half of the semester, students worked on three projects with the first one being completed individually and the last two completed by teams of two students. For the two team projects, students were allowed to choose their own project partner. The project deliverables ranged from project planning, video summaries of the work completed for each class period, and brief written reports. The variety of project deliverables was intentional to allow students to get a feel of both engineering design and project management and also allow them to communicate what they learned in a variety of modes appealing to different learning styles.

At the start of the team projects, each team completed a project planning document that asked the students to either answer or think carefully about the following prompts:

- List three 1 hour time blocks each week (outside of ME270 class time) during which you will meet with your project partner to work on the project. Also, list the location where you will meet.
- What tasks need to be done?
- In what order do the tasks need to be done?
- What is your estimate of the minimum time needed to construct the breadboard associated with each task?
- How will each task be assessed/tested?
- What is your estimate of the minimum time needed to assess, inspect and correct the work associated with each task?
- Who is primarily responsible for each task?
- How often will you communicate, collaborate and support your project partner to reach a successful conclusion to the project?
- What is your estimate of the total time you will need to spend working with and supporting your project partner?
- Are there supplies and/or equipment beyond those provided to you that you will need to complete the project?

- What is a critical path in your project plan?
- What are the milestones and dates associated with your critical path?

It was the responsibility of the student to notify their lab partner if they expect to be absent from class. If one student was in-class and the partner was attending remotely the students would meet through Zoom during class and communicate on the progress of their project and what needed to be done. The project planning document at the start of the project helped to provide a detailed structure of small goals for each team to accomplish by the end of each class.

At the end of each project, students were asked to reflect on their experience and answer questions such as:

- Reflecting on the project, what challenges did you encounter?
- How did you overcome those challenges?
- Describe what you learned about successful project management from working on the project.
- Discuss what you learned during the project about troubleshooting breadboard circuits and describe at least five specific examples of problems you encountered while working on your breadboard circuit and how you solved them.

Results and Discussion

Twenty-six students participated in an anonymous survey of their opinions and attitudes towards the different Hyflex tools and resources used in the Mechatronics course. The survey consisted of twenty-five questions assessed using a five-point Likert scale, two multiple choice questions and one open-ended question. The key results of the survey are summarized here.

- Over 70% of students agreed or strongly agreed that the course increased their ability to:
    1. Understand basic circuit structures, such as branches and nodes.
    2. Solve circuit analysis problems.
    3. Interpret electronic circuit diagrams.
    4. Use Tinkercad to successfully simulate and observe the behavior of electronic circuits.
    5. Build a working electronic circuit on a solderless breadboard.
    6. Focus on important details in my work.
    7. Inspect my work for errors and successfully detect and correct them.
    8. Understand practical applications of electronic circuits.
- 60% of students agreed or strongly agreed that using Nearpod contributed to their learning and active engagement with the course. However, only 30% of students agreed or strongly agreed that Nearpod was enjoyable to use.

- At least 80% of the students self-reported that Tinkercad has contributed to their active engagement, learning and enjoyment.
- Over 85% of the students agreed or strongly agreed that the personal electronics kit contributed to their active engagement, learning and enjoyment.
- Approximately 50% of students agreed or strongly agreed that using the Make: Electronics textbooks contributed to their learning and active engagement. However, only 23% of the students agreed or strongly agreed that the book contributed to their enjoyment.

The student survey results were consistent with the observations of the instructors. The use of TinkerCAD and the personal electronics kits not only supported the learning of electronic circuits but facilitated active participation and ”learning by doing”. Although Nearpod can provide real-time assessment of student performance, it was mainly used to present technical material and thus was not viewed as appealing. Students were also indifferent to Canvas as it is more of a course management tool than a learning tool. The Make: Electronics book helped students understand the technical material but was not viewed as particularly appealing, which is consistent with the tendency of students to view books as reference materials rather than primary sources of learning.

Each course instructor wrote extensively on the perceived impact of the learning model on student learning and engagement and reflected upon the student feedback.

One author wrote:

> Moving to a Hyflex model was a huge undertaking as every aspect of the course had to be accounted for. A lot of additional planning and logistics had to be considered before the start of the semester such as which classrooms are available to use and ensuring the proper equipment was outfitted in the classrooms to allow for a Zoom connection. Although the course content was similar to previous years it took additional time and effort to upload slides to Nearpod and add engaging activities. Classroom management was challenging at times in ensuring students who attended remotely were engaged throughout the class period. Some remote students had their cameras off the entire class and would not respond when a question was posed to them. A few students could be seen talking to others while class was ongoing and not engaging with the material being taught.

Also:

> Through this experience, I learned to use new tools, such as Nearpod and Tinkercad, which I will continue to use in future courses as we move back to a fully in-person classroom. Also allowing each student to have their own electronics kit to use throughout the semester made learning more accessible to all and disproved the notion that hands-on learning can only occur in the engineering classroom on campus. Students were no longer restricted to campus to use the equipment as now the hands-on learning could take place wherever the student was.

Feedback was collected on the student experience during the end of semester student observation surveys. Student feedback was positive about the hands-on aspects of the course. When asked which aspects of the course were most valuable, typical comments included:

- *Using electrical circuits in a practical way to give an idea of what I may potentially be doing in the future.*
- *Building the circuits from the schematic to understand how all the components interact. Team work and the engineering process.*
- *I really enjoyed getting to build the experiments described in the course textbook. I think that those hands-on learning experiences, especially the few long-term projects, were the most beneficial to my learning.*
- *Learning how to construct circuits out of diagrams.*

Students also offered positive comments on the online tools, such as:

- *I liked the use of Nearpod during the lectures, as it helped us stay involved and we were able to receive prompt feedback. I also liked the use of TinkerCAD in general.*
- *The Nearpods in class were nice.*

When asked which aspects of the course were least valuable, typical comments included:

- *Theoretical calculations from the beginning of the semester'*
- *The journal was not as useful as I thought it would be.*
- *Some projects felt tedious and almost like a Lego set.*

Overall, student feedback indicated difficulty in finding useful applications of the basic circuit analysis taught in the first half of the semester. Students also found it difficult to understand the relevance of the skills learned to their mechanical engineering education and career goals. Despite encouragement from the instructors to avoid simply copying the excellent breadboard layouts provided by the "Make: Electronics" book without reflecting upon the details of the breadboard construction and without exploring the roles of various components and sub-circuits, students too often did just that. In future implementations of this particular Hyflex course model it will be important to include significant incentives and rewards for comprehension in addition to those for successful breadboard construction.

Conclusion and Future Work

The instructors of ME270 plan to continue to use many of the Hyflex teaching strategies and tools, mentioned in this paper, in future offerings of the course and in other courses they also teach. Future work will be focused on a deeper quantitative approach on how effective these strategies and tools are in a fully in-person classroom.

References

[1] E. Maloney and J. Kim, ”15 Fall Scenarios”, Inside Higher Ed, 2020. [Online]. Available: https://www.insidehighered.com/digital-learning/blogs/learning-innovation/15-fall-scenarios. [Accessed: Jan. 30, 2022].

[2] B. J. Beatty, ”Hybrid-Flexible Course Design”, 1st ed. EdTech Books, 2019. [Online]. Available: https://edtechbooks.org/hyflex. [Accessed: Jan. 30, 2022].

[3] N. Milman, V. Irvine, K. Kelly, J. Miller and K. Saichaie, ”7 Things You Should Know About the HyFlex Course Model”, EDUCAUSE Learning Initiative, 2020. [Online]. Available: https://library.educause.edu/resources/2020/7/7-things-you-should-know-about-the-hyflex-course-model. [Accessed: Jan. 30, 2022].

[4] Zoom Meetings, [Online]. Available: https://zoom.us [Accessed: Mar. 25, 2022].

[5] Mechanical and Mechatronics Engineering: Future undergraduate students, ”What is Mechatronics Engineering?”, University of Waterloo. [Online]. Available: https://uwaterloo.ca/mechanical-mechatronics-engineering/undergraduate-students/future-students/what-is-mechatronics-engineering. [Accessed: Jan. 30, 2022].

[6] J. G. Cherng, B. Q. Li and N. Natarajan, ”Development of a Senior Mechatronics Course for Mechanical Engineering Student”, Proceedings of ASEE Annual Conference and Exposition, 2013.

[7] M. Tomovic, C. Tomovic, V. M. Jovanovic, C. Y. Lin, N. Yao and P. J. Katsioloudis, ”Integrative Experiences through Modeling and Simulation of Mechatronic Systems”, Proceedings of ASEE Annual Conference and Exposition, 2017.

[8] M. Lobaugh and R. Edwards, ”Mechatronics for Non-Engineers”, Proceedings of ASEE Annual Conference and Exposition, 2011.

[9] J. A. Riofrio and S. G. Northrup, ”Teaching Undergraduate Introductory Course to Mechatronics in the Mechanical Engineering Curriculum Using Arduino”, Proceedings of ASEE Annual Conference and Exposition, 2013.

[10] A. L. Sala, ”Infusing Mechatronics and Robotics Concepts in Engineering Curriculum”, Proceedings of ASEE Annual Conference and Exposition, 2013.

[11] V. Giurgiutiu and B. Mouzon, ”Functional Modules for Teaching Mechatronics to non-EE Engineering Students”, Proceedings of ASEE Annual Conference and Exposition, 2003.

[12] S. Kiefer, ”Project Oriented Course in Mechatronics”, Proceedings of ASEE Annual Conference and Exposition, 2004.

[13] A. Kaur and T. M. Swift, ”Blended Learning: Electrical Circuits for non-EE students”, Proceedings of ASEE Annual Conference and Exposition, 2020.

[14] A. Oliveira, ”Challenges of Teaching Electrical Engineering Classes to Non-majors”, Proceedings of ASEE Annual Conference and Exposition, 2009.

[15] A. Ganago, S. Sivaramakrishnan and R. M. DeMonbrun, ”Development of student motivation in a required Electrical Engineering (EE) course for non-EE majors”, Proceedings of ASEE Annual Conference and Exposition, 2014.

[16] Q. Du and J. Schneider, ”Improvement of an Electrical Engineering Course Offered to Non-Electrical Engineering Majors”, Proceedings of ASEE Annual Conference and Exposition, 2006.

[17] K. Meah, ”First-Time Experience of Teaching a Project-Based Mechatronics Course”, Proceedings of ASEE Annual Conference and Exposition, 2016.

[18] C. Platt, ”Make: Electronics: Learning though Discovery”, 2nd ed. Santa Rosa, CA: Maker Community, 2015.

[19] Nearpod, [Online]. Available: https://nearpod.com. [Accessed: Jan. 30, 2022].

[20] Tinkercad, [Online]. Available: https://www.tinkercad.com. [Accessed: Jan. 30, 2022].

[21] Canvas LMS, [Online]. Available: https://www.instructure.com/product/higher-education/canvas-lms. [Accessed: Jan. 30, 2022].