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University of Utah Hybrid-Flexible Education

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***Abstract*— This paper describes methods we are using in ECE at the University of Utah to support a Hybrid Flexible (HyFlex) classes. Classes are offered both in person and online. We describe the teaching approach for two asynchronous online courses – Intro. to EM and Numerical EM and a synchronous freshman circuits course. We will also describe three hands-on take-home labs – Intro. to EM. Microwave Eng I, and Intro. to ECE (freshman circuits). Finally, we will report on an undergraduate research project on what students want in post-Covid education.**

Keywords—engineering education; hybrid classroom

I. Introduction

Education in the post-Covid era will take advantage of flexibility and active problem solving. This paper describes methods we are using in ECE at the University of Utah to support a Hybrid Flexible (HyFlex) environment for our students. Classes are offered in person, and most provide an online (synchronous or asynchronous) version the students can use either for the full semester or briefly as needed (such as due to a health or family issue). We will describe the teaching approach for two asynchronous online courses – Intro. to EM and Numerical EM (both taught by Dr. Simpson) and a synchronous freshman circuits course (taught by Dr. Furse). We will also describe three hands-on take-home labs – Intro. to EM (taught by Dr. Sensale-Rodriguez). Microwave Eng I (taught by Dr. Nagel), and Intro. to ECE (freshman circuits) (taught by Drs. Furse, et al.). Finally, we will report on an undergraduate research project on what students want in post-Covid education.

II. Introduction to Electromagnetics

A. Asynchronous Online Course

This online course is taught with a project-based active learning approach. Video lectures are 1-7 min each, with questions or problems throughout. Lecture notes and example practice problems with solutions accompanied each video lecture. This course is available at [1]. The semester is divided into six "design challenge" segments, where the basic theory is introduced, and we solve the challenge together as a class:

- Design a test to find faulty wiring in a commercial aircraft (Explosion of TWA 800).
- Replace an antenna on the Millennium Falcon.
- Test the impact of an electromagnetic pulse on a commercial aircraft.
- Design a new spy satellite that can protect itself from other satellites and keep cameras on board hidden.
- Design a noninvasive tool for removing colon cancer.
- Design a telecommunications system to bring internet to two remote elementary schools.

B. Take-Home Lab

The traditional in person lab [2] was converted to at-home lab kits using the NanoVNA [3]. Simple, 433 MHz microwave circuits were designed and fabricated by the students at home using RF substrates and copper tape. Labs included:

- Microstrip dielectric materials, attenuation, use of VNA.
- Monopole Antenna and Single Stub Matching Network
- Antenna radiation pattern, effect of dielectric environment, and simplex (one-way) communication link budget.

III. Microwave Engineering I

A. Synchronous Online (Zoom) Course

Before class, students would watch a series of 2-3 recorded video lectures where each video was typically 5-10 min. long. Class met remotely via Zoom. This time was devoted to answering questions and working through example problems. Screen-sharing MATLAB code allowed students to experience the problem-solving process and observe theoretical results in real time. An overhead desktop camera was used for hands-on demonstrations, such as handwritten derivations, Smith Chart walkthroughs, and lab demos with various microwave tools.

To encourage student attendance to the Zoom sessions, each lecture was devoted to solving a handful of relevant problems that would feature on both homework and exams. The question was also framed as an in-class quiz. Zoom sessions were recorded and posted.

B. Take-Home Lab

The NanoVNA was also used to create take-home kits for this lab, and numerical simulation using MATLAB was used throughout the labs. Though the capabilities are somewhat limited (1.5 GHz bandwidth), there are still many interesting projects that can be performed with relatively low cost. Take-home kits were assembled at the beginning of the semester to contain all parts required. For a fee, students would check out the kit (or have it mailed directly to their homes), and then return the kits at the end of the semester for a partial refund.

In total, the course required five laboratory projects, each designed to provide a learning experience with some foundational skillset in microwave engineering. The projects were built around the expectation of 3 hours to work through material and gather useful data, plus another 3 hours to write up a formal report. A special lab TA would then hold a remote session via Zoom to walk students through the projects and grade their reports after submission. These projects were:

- Numerical simulation of the Telegrapher's equations using the finite-difference time-domain method (FDTD) in MATLAB. Students are given a code template and asked to write their own working FDTD code for transmission lines.
- VNA error correction. Using the NanoVNA, students measure an open, short, and matched load, then write a function in MATLAB that automatically performs the calibration for further measurements.
- Time-domain reflectometry (TDR). Frequency- to time-domain conversion from the NanoVNA to generate a time-domain impulse response. Data is validated by measuring the phase velocity of their coaxial cables.
- Microstrip characterization. Students calculate and measure (using TDR) the characteristic impedance of a microstrip line as a function of strip width. Students construct microstrip lines using copper tape and a copper-clad board.
- Single-stub matching networks. Using the copper tape and boards, construct a circuit and its single stub match.

IV. Numerical Electromagnetics

A. Asynchronous Online Course

This senior/graduate course is designed as in Section II(A), using a project-based, active learning approach. Students program their own FDTD and finite element codes.This course is available at [4]. The semester was divided into five "design challenge" segments, which were solved together as a class:

- Design a radar system for locating people buried in an avalanche.
- Since satellite-based GPS may be easily spoofed, design a back-up geolocation system.
- Solve an electromagnetic interference problem at a construction site.
- Investigate whether cancer may be detected at an ultra-early stage and non-invasively.
- Develop prosthetic limbs that respond to signals from the brain.

V. Freshman Circuits

A. HyFlex Course

Intro to ECE has been taught as a flipped class prior to Covid, using video lectures and in person problem-solving. It covers Ohm's law, voltage and current through resistive networks, analysis methods (Kirchhoff's laws, node voltage method, Thévenin/Norton equivalents, etc.), op amp circuits, RLC circuits and a brief intro to digital circuits. The course uses a free online textbook [4]. Content from the course, including videos, lecture notes, old exams with solutions, labs, etc. is available open source at [5]. A companion course covers Matlab basics [6].

In 2020, the course was taught via Zoom, and in 2021 it was converted to a HyFlex model by Prof. Rasmussen, who explains how she teaches in person and remote students (using Zoom) simultaneously here [7]. The in-person classroom has a video camera and microphone, which projects the professor into the Zoom lecture. Using screen cast tools, slides / tablet-based white board are combined with the image of the lecture to produce an engaging lecture environment for both in person and Zoom-based students. More details can be found at [8] (parts 1-6). As with the flipped class, students watch video lectures before class, and class time is used for active problem solving.

B. Take-Home Lab

The hands-on lab for ECE1240 used the Analog Discovery 2 take-home equipment prior to Covid. During Covid shut-downs, additional video support was added to supplement Zoom-based TA support. This lab is now offered both in person and via Zoom. It is available here [9]. Content includes:

- Series and parallel resistance
- LEDS and voltage divider
- Node voltage and D-to-A conversion
- Thevenin equivalents
- Sensors and Comparator Op-Amp
- Non-inverting Op-amp
- Logic Gates
- Capacitors
- Final Project: Design Your Own Invention

VI. What Students Want

Students want (1) Clear Communication (about expectations, assignments, learning objectives), (2) Coordination between course elements (homework, labs, exams), (3) Caring (recognizing the learning and life challenges, and helping them work through them). [10]

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