

## **Transition back to in-person class for an embedded system course in Engineering Technology during the COVID-19 pandemic**

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### **Abstract**

A larger number of higher education institutions in the U.S. have experienced the shift to a virtual format of course delivery in Spring 2020. During this shift of course delivery, software related courses may have less trouble in transitioning to a virtual format compared to hardware related courses. An embedded system course has both components of hardware and software. Students may need to learn about specialized hardware devices, as well as learning to program and operate the devices. For an embedded system course in the Electronics Systems Engineering Technology (ESET) program at Texas A&M University, there have been various efforts for effective teaching and learning in this virtual format. One of the key efforts is to deliver an individual essential version of an embedded systems laboratory kit to each student so that the student can use it and study it at their favorite location, such as their home. Students can obtain their own embedded system board and use it with this essential laboratory kit. In the Fall semester of 2021, some of the higher education institutions returned to the in-person format of the course delivery for most of the classes. Texas A&M University at College Station has offered in-person classes in the Fall semester of 2021. There have been several efforts in readjusting to in-person learning due to the several changes. The transition was carried out successfully. In this paper, various transition efforts and the changes that were carried out will be presented.

### **Introduction**

In the Spring semester of 2020, there was a shift to a virtual format of course delivery for a large number of higher education institutions in the U.S [1][2]. During this shift of the course delivery, hardware related courses seemed to have been impacted more heavily than software related courses.

For a microcontroller/microprocessor application course such as an embedded system course, both hardware and software components are important. In this course, students study and learn about specialized hardware devices as well as how to program and operate the devices. Although an embedded system course tends to gear toward more on software, an embedded system course has been affected by the transitions of course delivery.

The Electronics Systems Engineering Technology (ESET) program at Texas A&M University offers embedded systems related courses. Specifically, in the embedded systems software course (ESET 369), there have been various efforts to promote effective teaching and learning even in this virtual format of course delivery. During Fall 2021 and Spring 2022, one of the key efforts in this

ESET 369 embedded systems software course was to deliver an individual essential version of a laboratory kit to each student. In this way, students can use the kits and study the course topics at a location of their choice. Students can borrow laboratory kits without charge. Students obtain and bring their own Launchpad board and mount it on the custom laboratory board.

In the Fall semester of 2021, some of the higher education institutions returned to the in-person format of the course delivery for most of the classes. Texas A&M University at College Station has offered in-person classes since the Fall semester of 2021. There have been several efforts in readjusting to in-person learning due to the several changes in mode of operation. Moreover, in 2021, due to the global chip shortage and other issues such labor and supply chain issues, some electronics products were difficult to obtain.

For this embedded system course, MSP432 Launchpad boards have been used. Specifically, the board name is an MSP432P401R Launchpad [3]. Although there were enough boards to carry out classes and laboratories, students have experienced difficulties in getting their own MSP432P401R Launchpad for their learning in Fall 2021. As a proactive step for the upcoming semester, an alternative Launchpad board model such as an MSP430FR5994 Launchpad [4] can be used instead. In this paper, the transition efforts and observations will be presented.

### Embedded system course organization during COVID-19

The Engineering Technology and Industrial Distribution (ETID) Department at Texas A&M University in College Station offers an Electronics Systems Engineering Technology (ESET) program and a Multidisciplinary Engineering Technology (MXET) program. The MXET program offers students a Mechatronics focus. Moreover, ETID Department offers an Embedded System Integration minor. This is also available to students who are outside the ETID Department. For the ESET program, Mechatronic focus of MXET program, and Embedded System Integration minor, one of the core courses is ESET 369 Embedded System Software course. Table 1 shows the number of students enrolled in ESET 369 for the semesters that were impacted by COVID-19 [5].

Year	Semester	Number of students	Number of Lab sections	Course delivery
2022	Spring	118	8	Lecture: Face-to-face Lab: Face-to-face
2021	Fall	110	8	Lecture: Face-to-face Lab: Face-to-face
	Spring	124	8	Lecture: Remote Lab: Face-to-face (*Remote)
2020	Fall	139	8	Lecture: Remote Lab: Face-to-face (*Remote)
	Spring	100	7	Lecture: Remote (Partial) Lab: Remote (Partial)

(\*Remote: Remote option available)

Table 1. Numbers of students and laboratory sections for the ESET 369 course.

The data show that the enrollment remained strong. This is partially because ESET 369 is a core course as it was explained. The enrollment may vary by semester; but the data show a high student enrollment exceeding 100 with a maximum of 139. For laboratory (Lab) sessions, each Lab section allows 14 to 16 students. This number is based on the available instrumentation sets as well as the determined number of students for effective learning. This ESET 369 course was divided by 7 or 8 laboratory sections during the given semesters. For the lecture session, two lecture sections were made available.

In the middle of the Spring 2020 semester, the school switched to remote learning due to the health and safety related to COVID-19. For an embedded system course such as ESET 369, the laboratory kits are important tools for education and for students' learning [6]. Students were not able to access some electronics parts physically. Fortunately, they have their own MSP432 Launchpad boards. Using LabVIEW™, the author provided virtual laboratories and term projects. Students were asked to program and debug their physical Launchpad boards to make their individual boards to communicate with the various software portions of the virtual parts and instrumentations given and created by the instructor [6]. Moreover, two split volumes of the first edition of the author's embedded systems book were published this semester, which may help students understand the course material [7]. After this spring semester concluded, efforts were made to prepare for the following Fall 2020 semester as the course transitioned to a face-to-face format.

### **Mixed-mode course delivery for Fall 2020 and Spring 2021**

The author's institution offered the choice of course delivery including face-to-face, remote, or mixed-mode course delivery. For the ESET 369 course, the mode of the course delivery for the lecture portion was chosen as remote, while the mode of delivery for the laboratory portion was chosen as face-to-face. This is referring to as mixed-mode course delivery. Therefore, the lecture portion was delivered remotely using Zoom meetings. For the laboratory portion, face-to-face laboratory delivery was offered, but students could choose to stay remote for the laboratory portion as well. For this reason, the laboratory management was challenging. For instance, during the assigned laboratory hours, laboratory instructors had to teach students in the laboratory room as well as the students who joined the laboratory remotely via a Zoom meeting.

During pre-COVID-19 semesters, the available number of kits was close to the maximum enrolled students in one lab section. For example, 18 lab kits can cover one lab section and can be shared throughout the rest of the 8 sections. Therefore, 18 lab kits used to be the number of kits needed for the semester. However, to serve a COVID-19 laboratory setting with the students both in the laboratory room and those connected remotely, it was essential to increase the number of available lab kits.

Ideally, it would be best if one lab kit could be provided per student. For this reason, it was attempted to build a large number of ESET 369 laboratory kits from the summer 2020. As shown in Figure 2, approximately 137 kits were assembled in house. All of these kits were tested and packaged to be ready for distribution. Students could check out this kit and use it for the semester and return it after their term project.



Figure 2. The initial batch of the individual lab kits that are tested and packaged.

Students who came to the laboratory room were able to check out lab kits. For those students who were not in town, the lab kits were mailed to them. Due to health concerns, it was understandable that there could be some students who were in town but did not want to come to the laboratory room to check out their lab kits. For these students, a drive-through lab kit distribution was offered. Figure 3 shows the drive-through laboratory kit distribution. This drive-through laboratory kit distribution was available to all the students in class. For those who wanted to receive their kits using this drive-through laboratory distribution option, they needed to submit an online request form and come to the designated location as shown on the right side of the figure, during a specified date and time on the weekend.



Figure 3. Drive-through Laboratory kit distribution.

The stacked lab kits shown on the left side of Figure 3 were the kits to be distributed during the drive-through pick-up session. When students arrived at the location and their IDs were checked,

their serial numbers were retrieved. Their kits were then handed to them once the information was verified. All laboratory kits have serial numbers, and they were pre-assigned to each student in class. Students needed to return their kits after the completion of their term project. Those students who were in the laboratory could return their kits on location, or mail them back. There was also a drive through drop-off session that was carried out similar to the drive-through pick-up session.



Figure 4. BH EDU kit for ESET 369

The content of the laboratory kit is shown in Figure 4. It includes a BH EDU board [8]. This BH EDU board has a custom designed board with 40-pin booster headers. An MSP432P401R Launchpad can be mounted on this expansion board. This BH EDU board has several components that are useful in learning embedded systems. These specific models of approximately 137 BH boards were soldered and assembled on campus by the author, observing COVID-19 restrictions. It is worth mentioning that assembling and testing these boards on campus during the COVID-19 pandemic was a challenging task due to the restrictions. The BH EDU kit also included components such as a battery holder, geared motor, ultrasonic sensor, and servo motor.



Figure 5. Reconditioned, cleaned, and re-packaged batch of the lab kits.

At the conclusion of the Fall 2020 semester, all laboratory kits were reconditioned to prepare for the following Spring 2021 semester. All electronics parts were cleaned with isopropyl alcohol and tested. Testing electronics parts was an important process because there were some damaged parts in the kits upon return. These components needed to be replaced or repaired. Moreover, due to health

concerns, all boxes for the Spring 2021 were replaced and re-packaged as shown in Figure 5. Overall, the course organization for Spring 2021 was similar to the one for Fall 2020.

In February 2021, there was a severe weather event in Texas causing power grid failure in some areas. The city where this institution is located, College Station, also experienced power grid failure during this severe weather event. This interrupted the semester school-wide, which significantly had impacted this course in Spring 2021.

### **Return to face-to-face course delivery for Fall 2021 and Spring 2022**

Texas A&M University decided to operate in-person classes at full capacity for the Fall semester of 2021 [9]. Therefore, the mode of operation for ESET 369 changed back to the traditional face-to-face model of in-person learning. There have been some efforts in adjusting back to the traditional model in the early portion of the class.

Several important observations were made at the conclusion of the Fall 2021 semester. Overall, this in-person class management turned out surprisingly smoother than the author was predicted. For this semester, it was recognized that students could perform well for the given laboratory assignments. As an instructor, it was observed that the students engaged with each other actively during the laboratory session to solve the given problems or objectives, rather than heavily depending on the lab instructor's help. Student's interactions seem to have improved students' laboratory learning experience.

For the laboratory kit management, students could access the laboratory kits upon arrival to their laboratory session. All the kits were not distributed to the students. Students could request to borrow a kit, if needed. If so, the students could check out the kit and use it for the remainder of the semester. There were 71 students who checked out their kits, which was approximately 60% of the enrolled students.

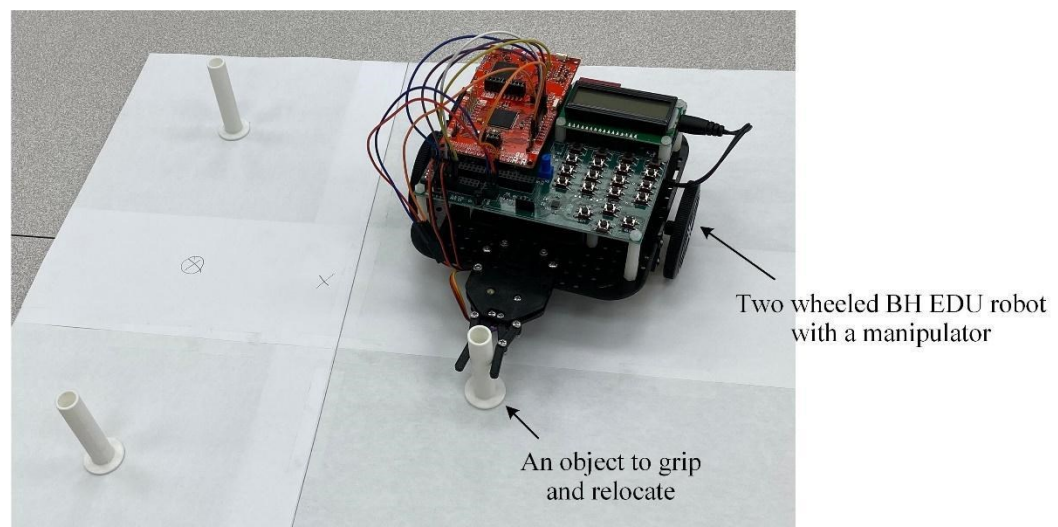


Figure 6. Term Project using BH EDU robot kits

For an ESET 369 term project in pre-COVID19 semesters, students used to build two-wheeled robots. In Fall 2021, the two-wheeled MSP432 BH EDU robots were back, and they were used as a part of their term project as shown in Figure 6. A BH EDU robot frame is a custom designed 3D printed robot platform that works with a BH EDU board. One of the accessories is a manipulator. It can grip and release an object. Students were given a manual mission consisting of controlling the robot manually over a serial terminal, to grip the objects and relocate them to a designated area. Additionally, students were given an automatic mission to perform a pre-programmed sequence to move the robot and to attempt to retrieve an object. This term project is an educational, intriguing, and engaging experience. This MSP432 robot term project was brought back, and students can program the microcontroller to move a physical robot rather than a virtual robot or virtual experimentation. Moreover, for the same the author's embedded system book was extended, and the third edition was published to assist the students' learning. Recently, in order to include important and up-to-date information for readers, this book was further expanded, and the fourth edition was published [10]. Students received structured lessons using the customized course materials.

However, one of challenges in Fall 2021 is related to the global chip and electronics shortage [11][12]. Some of the electronics, ICs, and parts became difficult to obtain. During Fall 2021, the specific MSP432P401R Launchpad board model that was used in this course was not easy to obtain from suppliers in the U.S. There were students who wanted to purchase one, but were unable to find one for themselves. For this reason, it was not assumed that all students had their own Launchpad boards in this course and the class was managed accordingly. For the laboratory management, there were already enough MSP432 Launchpad boards for students to use during their laboratory period.

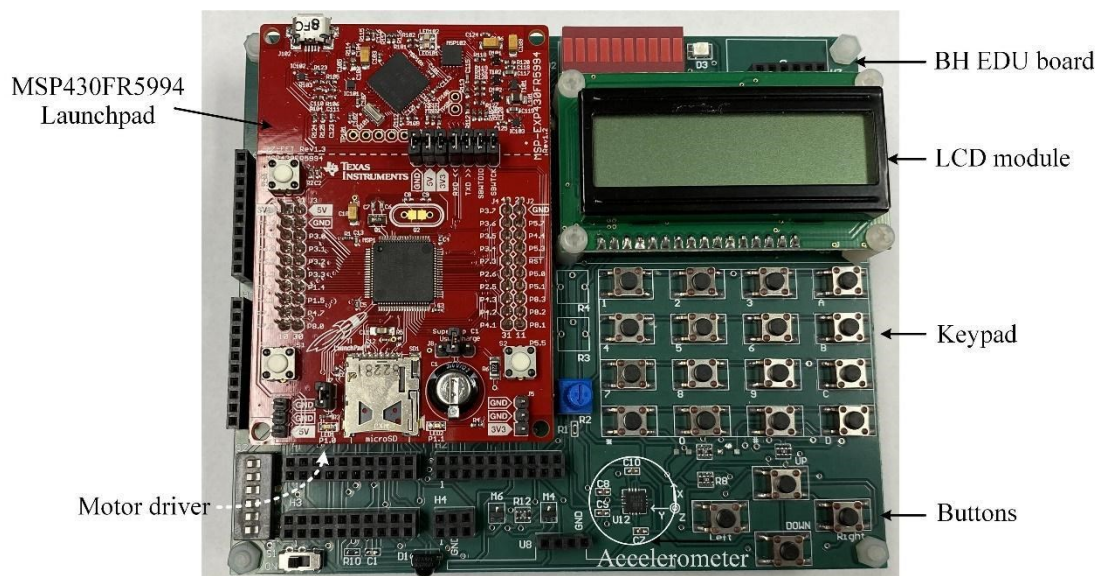


Figure 6. MSP430FR5994 based BH EDU board in testing

Similar to the MSP432 Launchpad board, this MSP430FR5994 Launchpad board has 40-pin booster pack headers. Therefore, this MSP430FR5994 Launchpad board can be mounted on the BH EDU board. The author has been preparing materials for a new embedded systems book using this Launchpad model. For the coming Fall 2022, the course management has not been determined yet.



One of the possibilities is to use a new microcontroller model such as this MSP430FR5994 Launchpad.

## Summary and Conclusions

There were several transitions and changes in the course delivery method in an embedded systems course from Spring 2020. For an embedded system course, students need to understand both hardware and software components. Students need physical development board and hardware components to carry out laboratories for an embedded system course. Therefore, this course can be dependent on the availability and the status of the laboratory kit and the microcontroller. For the Electronics Systems Engineering Technology (ESET) program at Texas A&M University, students learn about a microcontroller and its applications using a development board and extra parts such as motors and sensors. This course has been affected by the COVID -19. The impact and changes to this course during the COVID-19 pandemic have been reviewed, and the observations were shared. One of the key efforts was to deliver an individual essential version of an embedded systems laboratory kit to each student. In the Fall semester of 2021, Texas A&M University at College Station offered in-person classes in the Fall semester of 2021. The ESET 369 course also returned to the face-to-face mode of course delivery. There have been several efforts in readjusting to in-person learning. The transition was carried out successfully. However, there have been several ongoing challenges related to the chip and electronics shortage. A potential solution of using an alternative microcontroller model was introduced. As of today, COVID-19 still has impacted us due to the variants. We cannot predict the future; however, we can see that the engineering educators in the U.S. will continue striving to provide good education to the engineering students.

## Acknowledgments

The electronics parts for about 137 ESET 369 lab kits were supported by the Engineering Technology and Industrial Distribution (ETID) Department in College Station, Texas. I would like to recognize Xuan Dang, Mariam Nida Usmani, and Carter Wheat for their extra time and effort in managing and teaching their laboratory sessions during the challenging transition period.

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