Improving Undergraduate STEM Education (IUSE) By Using Active Learning – IoT Fundamentals to AI Enhanced Edge Devices

Dr. Lifford McLauchlan, Texas A&M University - Kingsville

Dr. Lifford McLauchlan is an Associate Professor in the Electrical Engineering and Computer Science Department at Texas A&M University - Kingsville, and has also worked for Raytheon, Microvision, AT&T Bell Labs, and as an ONR Distinguished Summer Faculty at SPAWAR San Diego, CA. He has over 85 publications covering areas such as IoT, adaptive and intelligent controls, robotics, an ocean wave energy converter, green technology, education, wireless sensor networks and image processing. He is a co-inventor on 3 US patents related to control systems. Dr. McLauchlan is a senior member of ASEE and is the current Program Chair for the Ocean and Marine Engineering Division (OMED); in prior years, he was an officer for the OMED as well, including 2012-2014 Chair, 2014-2016 Past Chair and 2023-2025 Secretary/Treasurer. He is also a senior member of IEEE, and a member of SPIE, Eta Kappa Nu, ACES and Tau Beta Pi, and has served on the IEEE Corpus Christi Section Board in various capacities such as Chair, Vice Chair, Secretary, Treasurer and Membership Development Officer. Dr. McLauchlan has received the Dean's Distinguished Service Award twice and the Dean's Outstanding Teaching Award once for the College of Engineering at Texas A&M University-Kingsville.

Dr. David Hicks

David Hicks is an Associate Professor in the Electrical Engineering and Computer Science Department at Texas A&M University-Kingsville. Before joining TAMUK he served as Associate Professor and Department Head at Aalborg University in Esbjerg, Denmark. He has also held positions in research labs in the U.S. as well as Europe, and spent time as a research scientist in the software industry.

Dr. Mehrube Mehrubeoglu, Texas A&M University - Corpus Christi

Dr. Mehrubeoglu received her B.S. degree in Electrical Engineering from The University of Texas at Austin. She earned an M.S. degree in Bioengineering and Ph.D. degree in Electrical Engineering from Texas A&M University. She is a professor of Electrical Engineering at Texas A&M University-Corpus Christi currently serving as the Program Coordinator for BS in Electrical Engineering, and MS in Engineering programs. Her research interests are multidisciplinary in nature and entail applications of imaging modalities (hyperspectral, thermal, color) for image segmentation and object classification using classical image processing and machine learning/deep learning models. She is also interested in engaged student learning using engineering pedagogies, advanced technologies such as IoT and the cloud, with consideration of sustainable design and professional skills.

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Abstract

The concept and implementation of Internet of Things (IoT) continues to make inroads into applications and products. During the last few years at Texas A&M University-Kingsville and Texas A&M University-Corpus Christi, both Minority Serving Institutions, a team developed exercises and materials related to IoT for use on two platforms: a Raspberry Pi IoT kit as well as a commercial IoT kit built around a BeagleBone Green microcontroller. The initial exercises introduced students to each of the platforms, various sensors, motors, cloud-based platforms such as Thingspeak and Xbee communications. Next student materials introduced using cloud-based AI processing for object detection in images using an application programming interface (API) to implement the cloud -based artificial intelligence (AI) functionality. Finally, the team has built upon the prior IoT and AI related materials to include using a YOLO machine learning algorithm for object detection running on an edge device, in this case a Raspberry Pi 5.

Over the course of the grant, the developed student materials progress from introductory materials and implementations, and continue to more advanced applications and functionality, such as including machine learning and other AI algorithms for processing or object recognition. Through these developed exercises, students will gain experience with IoT that they can then utilize in their senior design projects. As AI and IoT continue to become more ubiquitous in commercial products, it becomes more imperative to introduce students to these concepts before graduation.

Introduction

Artificial intelligence (AI) tools continue to make inroads into different applications and fields. Companies continue to expand its use in products and everyday work activities. Many of these products also include an Internet of Things (IoT) aspect as well. For these reasons, it has become imperative that students gain experience related to ethical use of AI, IoT and their applications to engineering, programming and communication.

During this project, conducted at two HSIs, Texas A&M University-Kingsville and Texas A&M University-Corpus Christi, various lab exercise materials utilizing either a Raspberry Pi [1] based IoT system or a BeagleBone Green [2] based IoT system were created for students. Thingspeak [3] was utilized for incorporating internet-based aspects into the exercises in the student materials. National Science Foundation IUSE grant, grant no. 2044255 supported this work on introductory assignments and exercises as well as on the more advanced applications; these were developed to facilitate student understanding of IoT and AI in order for students to better utilize the technology in their course, senior capstone or individualized study student projects. Recent work on these student materials is described and discussed in [4]-[9]. Since the start of the project, the total number of students impacted by this work at Texas A&M University-Corpus Christi is 127 and at Texas A&M University-Kingsville is 70.

Background

Students maintain more interest on topics in which they are actively participating in an activity related to the topic. “Experiential Learning Theory (ELT) … is an educational framework that emphasizes learning as a process through which knowledge is created through hands-on experience.” [10] In [11] Burcin and Sedas-Gursey explore the use of communities built upon concepts such as ELT. Another example is problem-based learning (PBL); this has been shown to help maintain student involvement and interest on engineering-related topics by engaging the students thereby facilitating the students’ learning [12]-[13]; common examples of PBL include robotics or practical real-world applications.

With ELT and PBL, students learn by applying the concepts being learned to hands-on applications. In this project the initial hands-on exercises introduced students to each of the platforms, a Raspberry Pi [1] based IoT system or a BeagleBone Green [2] based IoT system. In addition, students used various sensors, motors, and cloud-based platforms such as Thingspeak [3]. In this work, students learn the material through hands-on applications or projects.

Artificial Intelligence and Cybersecurity

First the basic IoT materials were introduced. To add more capability, AI student materials were introduced using cloud-based AI processing for object detection in images using an application programming interface (API) to implement the cloud-based artificial intelligence (AI) functionality. The team has built upon the prior IoT and AI related materials to include using a YOLO [14] machine learning algorithm for object detection running on an edge device, in this case a Raspberry Pi 5. For more details please see [4]

Capstone Design Projects

Recent senior capstone design projects have included an IoT-based parking system [15] as seen in Figure 1 and a digital pressure recorder [16] as seen in Figure 2. Student capstone senior design project groups are encouraged to utilize IoT and AI into their projects.

Figure 1 - IoT-based Parking System [15]

Figure 2 - Digital Pressure Recorder [16]

Some capstone design project members at Texas A&M University-Kingsville performed a whole system mapping for their senior design project as an extra credit assignment in Fall 2024 and in Fall 2025; as part of this assignment students were required to address cybersecurity issues that might affect their capstone senior design projects.

Assessment

For the grant there were six research questions (RQs) that were assessed. At TAMUK, capstone senior design students (n=7) responded to an extensive survey that included over 50 questions [17]. The results for the last two research questions (RQ5 and RQ6) are shown below.

> RQ5 - Can transfer of learning be successfully achieved in remote hands-on engaged student learning scenarios? – 8 survey questions related to RQ5
>
> RQ6 - How well do online tutorials contribute to hands-on ESL, when coupled with physical hardware accessible at home? – 13 survey questions related to RQ6

The student responses for the survey questions for the research questions RQ5 and RQ6 are graphed below in Figures 3 and 4. As can be seen, students generally answered Very True or True to the questions related to RQ5 and RQ6. Based on the survey data, the students who responded have gained experience and skills with utilizing IoT.

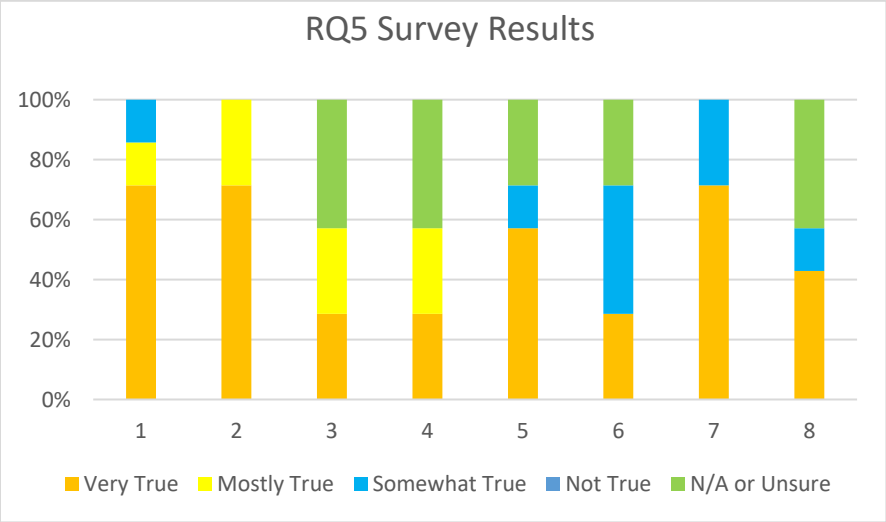

Figure 3 - RQ5 - Survey Results (students responding to the survey, n=7)

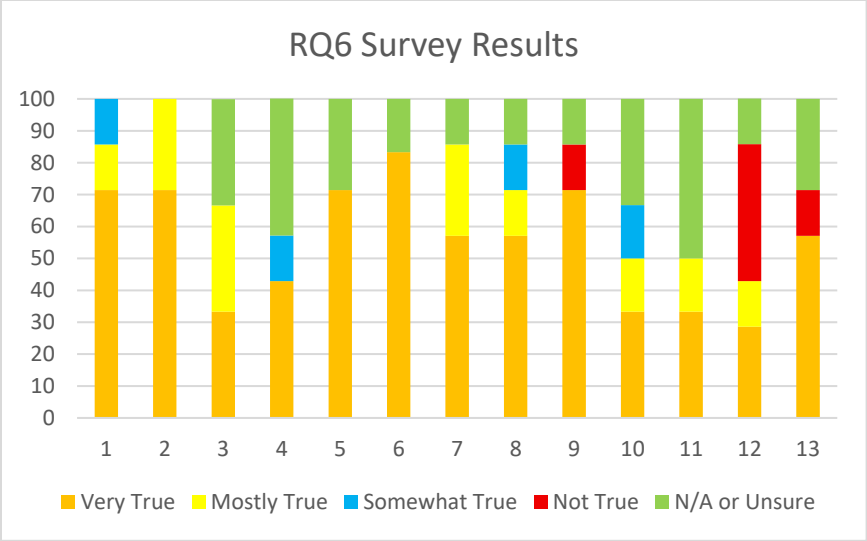

Figure 4 – RQ6 - Survey Results (students responding to the survey, n=7)

Conclusions

Through these developed exercises, students gained experience and skills utilizing IoT and AI that they can then utilize in their senior design projects or after they enter the workforce. Cybersecurity. IoT and AI continue to be important topics for students to learn since they have become commonplace in commercial applications. Introducing students to these concepts before graduation benefits students in their careers.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Award No. 2044255.

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