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# WHO TURNED THE LIGHTS OUT? USING HOME AUTOMATION TO TEACH IOT

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**Abstract**

With a plethora of interconnected devices, Internet of things (IoT) technologies offer an exciting area for information systems researchers; however, with these opportunities comes the need to effectively educate information systems professionals in this area. Research suggests that enactive mastery provides the greatest educational improvement to individual self-efficacy, yet not all enactive experiences are the same. Given the hardware-based tie of many IoT devices, the question becomes how these hands-on experiences can be replicated given the increasing nature of online education. This research provides a first step towards this understanding. Through the use of home automation IoT technology, we experimentally evaluate hands-on instruction in IoT in online versus traditional face-to-face environments. Our goal is to provide educators better understanding of the types of experiences that facilitate the most optimal IoT educational environment for learners.

**Keywords:** Internet of Things, IoT, self-efficacy, virtual labs

## I. INTRODUCTION

Internet of things (IoT) technologies are becoming more and more ubiquitous in today's society. From Amazon Alexa to smart watches to your refrigerator alerting you to a low supply of milk, consumers demand more and more devices to help easily complete tasks. Within the past decade, research has begun to look at various areas related to IoT and information systems (Baiyere, Topi, Venkatesh, Wyatt, & Donnellan, 2020; Li, Da Xu, & Zhao, 2015; Whitmore, Agarwal, & Da Xu, 2015). These articles provide an overarching view of research as it relates to IoT, including future directions as we move forward in this yet nascent area. One common theme is that IoT is a burgeoning area on the rise, and we as academic researchers need to more fully engage in various research paths related to IoT.

With the rise of IoT, more organizations require the necessary knowledge from employees for working with these technologies; however, little research within information systems has explored educational delivery regarding IoT technologies (for examples, see de Haan, 2016; Lichtenecker, Marchesan, dos Santos Sachete, & Rossi, 2020; Olagunju & Khan, 2016). One challenge regarding IoT technologies is the inherent tie to hardware devices of these technologies. Social Cognitive Theory (Bandura, 1986) suggests that self-efficacy sees the biggest effect when individuals learn through hands-on experience, or enactive mastery (Luse, Townsend, & Mennecke, 2018); however, research has neglected the *level* of this hands-on experience and how this enactive mastery can differ across mediums (Luse, Brown, & Rursch, 2020). Given the increasing prevalence of online instruction (Dykman & Davis, 2008), can hands-on instruction in IoT be as effective in a virtual environment as compared to a traditional physical environment?

This research answers the question regarding IoT education asking "…how should we educate the future workforce of tomorrow for these new jobs of the future?", given IS has a pivotal role in education where IoT is pervasive (Baiyere et al., 2020). To aid in this endeavor, we build on research in self-efficacy (Bandura, 1986) by examining this instruction in both a traditional versus an online course environment. Using an experimental design, the goal of this research is to assess IoT instruction using the example area of home automation to evaluate the impact on self-efficacy between two mediums of instruction. Our hope is to provide prescriptive evidence for others wishing to utilize these mediums for IoT instruction.

# II. BACKGROUND

## IoT Education

Past studies have looked into the implementation of IoT curricula and how the current IoT curriculum can be improved. The motive for most of these works was the need for students going into industry to have sufficient experience with IoT technology (de Haan, 2016; Lichtenecker et al., 2020; Olagunju & Khan, 2016). Each of these studies focused on methods to implement IoT curricula. Some of these studies used traditional IoT technology like Arduino boards as a base introduction to IoT (de Haan, 2016), then progressively increasing the difficulty of the lessons throughout the semester, (de Haan, 2016; Lichtenecker et al., 2020). Other studies used a variety of methods such as restructuring the progression of courses (Burd, Barker, Divitini, Guerra, et al., 2018; Burd, Barker, Divitini, Perez, et al., 2018; Guerra Guerra & Fermin Perez, 2017; Lichtenecker et al., 2020), integrating in more interdisciplinary courses (Olagunju & Khan, 2016), or providing a more hands-on approach (Ban, Okamura, & Kaneko, 2017; de Haan, 2016). These studies each found several unique outcomes, whether that be industry companies being pleased with new hire understanding of IoT technology (de Haan, 2016) or students having an increased interest/motivation to learn more about IoT (de Haan, 2016). Even though these articles approach IoT implementation differently, all these studies found some improvement that can be made to the pedagogical methods and implementation of IoT given flaws in current IoT curricula or improvements that can be made in regard to the current curricula at various institutions.

## Self-efficacy

Social Cognitive Theory (Bandura, 1986) provides a widely accepted model to explain individual behavior (Davazdahemami, Luse, Scheibe, & Townsend, 2018). Bandura identifies two cognitive components influencing behavior: outcome expectations and self-efficacy (Compeau & Higgins, 1995). Self-efficacy measures the confidence of an individual that they can successfully complete a task in the future, which has been shown to lead to success with the task. Four sources of self-efficacy have been identified – emotional states, social persuasion, vicarious experience, enactive mastery – with enactive mastery providing the greatest influence on individual self-efficacy (Bandura, Freeman, & Lightsey, 1999). Enactive mastery achieves this by allowing an individual to participate through hands-on interaction with a task, allowing the individual to succeed performing the task and provide affirmation they can perform the task successfully in the future (Scheibe, Mennecke, & Luse, 2007).

While enactive mastery provides the most potential benefit to self-efficacy through direct, hands-on experience, the type of hands-on experience can differ across contexts. Given the increase in online education, how does "hands-on" differ in this virtual context? Research has begun to explore these differences in an attempt to compare traditional versus online hands-on experiences (Luse et al., 2020). What becomes apparent is a lack of differentiation, not just between the four sources of self-efficacy, but between the varying levels within each of these sources. This research attempts to investigate this differentiation in one of the four sources, namely, the difference in enactive mastery experiences for online versus physical environments. Figure 1 shows the theoretical model with our focus being on the two differing levels of enactive mastery. While research shows virtual lab experiences to not differ significantly from that of physical lab experiences (Luse et al., 2020; Luse & Rursch, 2021), the hardware instantiation of many IoT devices provides a different expected experience from users. Given this, we hypothesize:

> H1: Students who learn IoT by means of physical enactive mastery will have a greater level of task-based self-efficacy as compared to students who learn IoT by means of virtual enactive mastery.

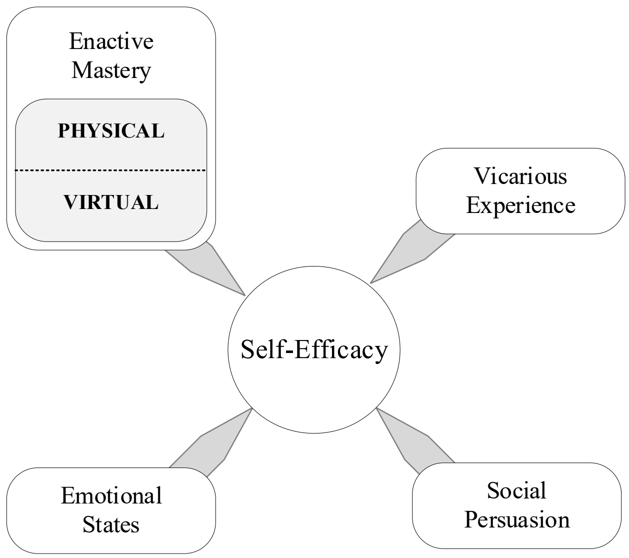


Figure 1. Theoretical Model

## III. VIRTUAL LAB FOR IOT

The virtual lab implementing IoT utilized for this article consisted of a server consisting of four 8-core processors, 512-GB RAM, and for 2-TB solid-state hard drives. VMware ESXi with vCenter was the installed operating system used to provide the virtual machine infrastructure. Students were able to access the system using a web interface, with all students provided external access to the environment from both on and off campus. The sever used for the exercise is used for other courses and course content, so the overall size is significantly larger than what would be needed if only performing the IoT exercise alone.

Each student was provided with three VMs for the exercise: 1) Windows 10, 2) Android, and 3) Home Assistant (HA).[1] The Android device utilized LineageOS, an open-source operating system based on the Android platform.[2] The device was configured to resemble a mobile phone. HA is an opensource home automation system that provides the ability to control a number of IoT devices inside the home. HA provides a prebuilt virtual machine for VMware that can be ported to ESXi. The virtual lab environment allowed the students to display the console for each of the VMs, thereby enabling the students to interact with each of the systems as if they were physical devices. Furthermore, the three systems were each connected to an individual virtual switch for each student and configured with IP settings to allow the systems to communicate with each other on the same virtual network.

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[1] https://www.home-assistant.io/
[2] https://lineageos.org/

## IV. DATA COLLECTION

The IoT module for this study provided an introduction to IoT utilizing home automation technology. Home automation was chosen given the familiarity of most subjects with home environments (lights, fans, wireless access points, etc.). The scenario included each student being given their own instance of HA inside a virtual machine. Each of these virtual machines was connected to a separate virtual switch to prevent students from interfering with each other during the activity. While each student was provided with an instance of HA, they did not interact with the HA virtual machine directly, but instead used their Windows 10 machine to remotely configure HA using a web connection. The students were given the password to their individual instance of HA so that they could log on to its configuration page.

After using their Windows 10 client to connect to their HA configuration page, students configured two separate modules. These configuration changes were made utilizing YAML (YAML Ain't Markup Language) to program HA. The first exercise was intended as a simple setup of a device by adding the ability to turn on and off a light. Students added this device, including a visual toggle to turn on and off the light. Next, students implemented a more complex task by employing presence detection. Students were instructed to utilize the Android VM as if it were a phone and implement code in HA to detect their "presence" once they had connected the phone to their network, to simulate arriving in their residence and their phone connecting to their local wireless access point. The students then programmed an automation within HA to automatically turn on the light once their Android device connected to the network.

An experiment was used to test the module using several measures that were utilized from previous studies. The primary variable of interest – self-efficacy – was developed using previous research that argues task-specific self-efficacy is needed to understand individual self-efficacy with regard to a particular task (Marakas, Johnson, & Clay, 2007; Marakas, Yi, & Johnson, 1998). Measures for this study were formulated using previously validated measures by modifying the context to IoT (Luse, Rursch, & Jacobson, 2014; Rursch, Luse, & Jacobson, 2009).

To evaluate the differing hands-on nature of the module, two separate sections of the same course taught by the same instructor in the same semester were utilized. Both sections were taught the same content, with the only difference being that one section was taught online while the other in a traditional face-to-face environment. The course offered an introduction to networking infrastructure, thereby providing a sample whereby the subjects were familiar with communication technology and could more easily grasp IoT communication technology. The course was a required course for all MIS majors. The online section utilized the virtual lab environment described previously, while the other section completed the module using physical technology including a Windows 10 client computer, their own personal phone, and HA running on a Raspberry Pi.[3] Both the Windows 10 client machine and HA running on the Raspberry Pi were both configured using the same configurational settings as those in the virtual environment.

The same script was followed for both sections. First, students were given a pre-survey with self-efficacy measures asking about their feelings towards IoT technology. Next, the student completed the same exercise using either the physical devices or the virtual environment. To provide a better picture of the experience, the student first performed the light setup task and then completed a second survey with the same pre-survey measures as well as assessing their levels of usefulness, ease-of-use, and satisfaction with the module. Next, the student performed the presence detection task before completing the same survey a third time. This provided a method to subjectively measure their feelings of self-efficacy, usefulness, ease-of-use, and satisfaction with the system as well as a more objective measure of whether they were able to complete none, one, or both tasks.

[3] https://www.raspberrypi.org/

## V. RUSULTS

Analysis of covariance and longitudinal residualized change scores will be used to analyze the data.

## VI. DISCUSSION

This study provides an introductory module for education in IoT technologies. As a relatively novel technology, IoT technology is still in its infancy with regard to establishing methods for instruction in the topic. While several studies have begun to look at education and IoT including improvements found for varying pedagogical approaches (de Haan, 2016; Lichtenecker et al., 2020; Olagunju & Khan, 2016). One area lacking is the ability to educate IoT concepts within an online setting. IoT technologies are inherently physical in nature, yet given the increasing prevalence of online education, greater understanding is needed on how to effectively instruct on IoT concepts in this non face-to-face setting.

This research builds on self-efficacy theory (Bandura, 1986) to better understand the educational needs for non co-located students and IoT curriculum. While enactive mastery has been shown to have the greatest positive impact on self-efficacy (Bandura et al., 1999; Scheibe et al., 2007), this research postulates that not all enactive mastery experiences are the same. Specifically in the online environment, students can have “hands-on” training but this training may not be equivalent to hands-on training with actual physical devices (Luse et al., 2020). This research provides one step forward by comparing these two types of enactive mastery experiences. Through the use of an experimental design, we are able to effectively evaluate the differences in self-efficacy with regard to IoT between an online and physical setting. Our hope is that this provides an initial step towards better understanding how to effectively educate those individuals in an online setting in IoT technology.

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