

## Cover page for Otilie Schillig Special Teaching Projects

Title of Proposed Project:  <h3 style="margin: 0;">An Individual Hands-on Approach to Teaching &amp; Learning PLCs by Addition of a Virtual Laboratory</h3>		
Project Director (PD) Name: Emily Spayde	PD Phone Number: (662)-325-8231	PD Email: espayde@me.msstate.edu
PD Department: Mechanical Engineering	PD College: Engineering, College of	Estimated # of Students Impacted each Semester:  120
Requested Amount from Schillig Funds (\$ 3,000.00 maximum):  \$3,000.00	Cost Share Amount (optional):  \$14,000.00	Total Amount for Project:  \$17,000.00
PD Signature: <b>Emily Spayde</b> <small>Digitally signed by Emily Spayde Date: 2019.03.18 10:25:16 -05'00'</small>		Date: 3/18/2019
Department Head Signature (if cost share included): <b>Pedro Mago</b> <small>Digitally signed by Pedro Mago DN: cn=Pedro Mago, o=Mississippi State University, ou=Mechanical Engineering, email=mago@me.msstate.edu, c=US Date: 2019.03.18 09:05:39 -05'00'</small>		Date: 3/18/2019
Co-PD Name: Dustin Spayde	Department: Mechanical Engineering	Email Address: dspayde@me.msstate.edu
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# AN INDIVIDUAL HANDS-ON APPROACH TO TEACHING & LEARNING PROGRAMMABLE LOGIC CONTROLLERS (PLCs) BY ADDITION OF A VIRTUAL LABORATORY

## Objective and Overview

The objective of this project is to improve the teaching quality and student learning experience in a mechanical engineering junior class, *Experimental Methods and Techniques* (ME 3103), through the addition of a cost-effective virtual laboratory dedicated to giving each individual student a hands-on experience while being introduced to the topic of programmable logic controllers (PLCs). This virtual laboratory will allow students to individually experiment with programming and executing customizable PLC driven automation systems at their own pace inside and outside the classroom. The software itself is a permeant license purchase, meaning there are no recurring or renewing software license costs. The software will support mechanical engineering students in both the Starkville main campus as well as the Engineering on the Coast campus with one purchase. Finally, while this software will be introduced into ME 3103, the mechanical engineering department is also exploring the possibility of implementing this virtual laboratory into other courses such as *Introduction to Vibrations and Controls* (ME 4643) and *Solid Mechanics Laboratory* (ME 4401). The implementation of this project will benefit over 250 mechanical engineering juniors per year by proving access to more “hands on” activities that will enhance the active learning process. Details of the motivation, activities, and budget are provided below.

## Motivation

*Experimental Methods and Techniques* is a junior level mechanical engineering curriculum lecture and lab course required to be taken by all mechanical engineering students. The main goal of the course is to introduce students to measurement concepts and sensor systems as well as methods used to control and automate these systems. Currently the course lacks any hands-on experience for these control systems. PLCs represent one of the most common automation and control systems widely used in industry today. **Experience with automation and control systems is a critical skill for our mechanical engineering graduates to be competitive in the job market.** Last academic year the mechanical engineering department received feedback from **regional industry, alumni, and interviewing seniors all asking to have the instruction and experience with PLCs expanded** within the mechanical engineering curriculum. With this feedback, the mechanical engineering department began to search for a solution that would allow for a substantial hands-on PLC experience.

## Rationale for Requesting Funds

Unfortunately, the laboratories within the Department of Mechanical Engineering do not have a suitable solution to allow a hands-on approach in the instruction of PLCs. The mechanical engineering department began by looking at PLC laboratory hardware to solve this issue. When purchasing equipment for a PLC lab it became apparent that at least two purchases were required to allow a hands-on experience. The first is the PLC itself and the second is the system the PLC will automate and control. The automated system is typically a small-scale version of something found in a manufacturing facility, such as a collection of tiny conveyor belts, simple actuators, and a handful of sensors. An example of a complete setup from a major engineering education lab manufacturer can be seen in Figure 1. This setup with both pieces of equipment would allow a very limited number of students a narrow hands-on experience. Unfortunately, considering the number of students in the course each semester it would require purchasing multiple units in order to facilitate a meaningful hands-on experience. The mechanical engineering department was quoted from the manufacturer **totaling to \$28,120.00 per complete set**. To service both the Starkville main campus and the Engineering on the Coast campus the ME department would **require a bare minimum of 8 of these complete sets**. At that number, students would still need to work in groups due to time constraints and would only have access to the equipment during scheduled lab hours. Also, the automated system consists of a limited number of scenarios for the students to control with the PLC.



Figure 1: PLC Trainer (left) & Automation System (right)[1]

[1] <https://www.gunt.de/en>

[2] <https://bin95.com/siemens-plc-simulator.htm>

It is at this point the ME department discovered the option of the virtual PLC laboratory called Factory I/O by Real Games. Factory I/O is a three dimensional, virtual, factory simulation created for the purpose of training students in automation technologies. Images of the Factory I/O user interface are shown in Figure 2. This software allows the instructor or student to build custom full-scale factory automation scenarios called scenes. These scenes can then be programmed using a software PLC, eliminating the need for physical PLC hardware. In addition, the software PLC allows students to program in ladder logic, function block diagram (FBD), or statement logic (STL), all common PLC programming languages used in industry. Finally, the student's PLC program can be executed while interfacing with the Factory I/O virtual factory scenario to test the program in a simulated real-world environment. This simulation includes many physical properties such as gravity, force, mass, and friction between surfaces all rendered simultaneously while the simulation is running. This feature also allows students to interact with their simulation in real-time, enabling them to explore how their programs will react to unexpected situations or inputs. The mechanical engineering department was quoted for 150 permanent seats of Factory I/O **totaling to approx. \$17,000.00. This one-time purchase is enough to support both campuses and give every individual student each semester (96 at Starkville & approx. 25 at the coast per term) a hands-on experience with PLCs** that they can explore inside and outside of lab hours. These 150 seats are permanent floating licenses meaning students will be able to install the software on their own computers and the department will **never have recurring costs associated with this software**. Each semester the licenses will roll over to new students. The virtual environment alleviates many of the restrictions and costs of PLC training with physical equipment.

### Implementation and Student Response

A pilot implementation of this software was recently performed using a trial version of Factory I/O. Students were introduced to PLCs and guided through programming custom-made Factory I/O scenarios. Students were also tasked with developing their own PLC solutions to other scenarios. **Student feedback was collected from this trial and presented at American Society for Engineering Education (ASEE) Southeastern Section Conference on March 11, 2019. The student feedback was overwhelmingly positive to the Factory I/O software.** Permanent implementation will begin immediately upon funding. The first major task is to complete the purchasing process. This is expected to take up to 1.5 months after funding is secured. Once purchased the software will need to be setup on a university-controlled license server. This process involves multiple departments, and largely out of the mechanical engineering department's control. Setup is expected to take up to 4 months. Simultaneously, after funding is secured work will begin on creating new teaching exercises, scenarios, and lectures to support the laboratory software. While a full implementation in late fall 2019 is possible if purchasing and server setup go smoothly, a conservative estimate for full implementation is spring 2020 with the possibility of integration into another ME course following soon after.

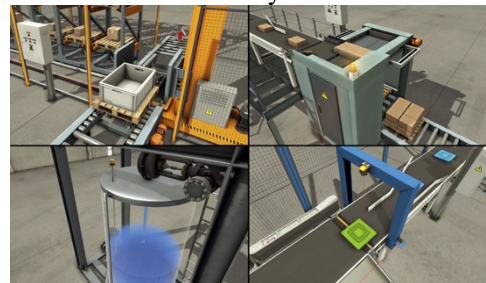


Figure 2: Factory I/O User Interface [2]

### Budget

Funds in the amount of \$3,000 are requested for this project. The Mechanical Engineering Department will provide cost share in the amount of \$14,000, for a total project cost of \$17,000. A letter of support from Dr. Pedro Mago, Mechanical Engineering Department Head is included in this proposal.

### About the Proposers

Dr. Emily Spayde is an Assistant Clinical Professor in the Department of Mechanical Engineering. She has been teaching courses in engineering laboratories and thermal systems. Dr. Spayde has also been active in ASEE by publishing papers and holding positions in multiple ASEE Southeast Section divisions.

Dustin Spayde is an Instructor in Mechanical Engineering. He has been coordinating all the undergraduate laboratories in the department. Dustin has also been involved with ASEE for several years and has published several papers and served in multiple positions within ASEE Southeastern Section.

[1] <https://www.gunt.de/en>

[2] <https://bin95.com/siemens-plc-simulator.htm>



March 18, 2019

Center for Teaching and Learning  
Mississippi State University  
Ottillie Schillig Special Teaching Projects

Dear Member of the Selection Committee,

This letter is to serve as a commitment of financial support from the Department of Mechanical Engineering for the Schillig Special Teaching Project "*An Individual Hands-on Approach to Teaching & Learning Programmable Logic Controllers (PLCs) by Addition of a Virtual Laboratory*," by Dr. Emily Spayde and Dustin Spayde. The Mechanical Engineering Department is willing to provide a cost share amount of \$14,000 to fulfill the financial requirements to complete this project.

This virtual laboratory software has already been shown to be a cost-effective and student-friendly solution during the trial implementation in our *ME 3013 Experimental Methods & Techniques*. The flexibility of this solution to simultaneously support our mechanical engineering students in the main campus as well as the Gulf Coast campus is a major advantage of selecting this system. Implementing a hands-on approach to PLCs will have a substantial impact on more than 240 of our students per academic year and will help to ensure they remain competitive graduates to industry. Also, due to the permanent license of this software, this will be a solution that will last for many years for the department and our students.

We hope that with the support of the Ottillie Schillig Special Teaching Projects Grant Dr. Emily Spayde and the Mechanical Engineering Department will be able to fill this educational need for our mechanical engineering students in an effective and engaging manner. Please, feel free to contact me with any questions regarding the proposal or the financial support of the mechanical engineering department.

Sincerely yours,

Pedro J. Mago  
Department Head and PACCAR Chair  
Mechanical Engineering Department