Exploitation plan for problem-based learning laboratory National University of Future and Emerging Sciences

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1. Name of the lab

The name of the lab is Problem-Based Learning Lab.

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2. Faculty in which the lab belongs

The Problem-Based Learning Lab belongs to the School of Computing, Department of Software Engineering. The following organogram demonstrates how the lab fits into the organizational structure.

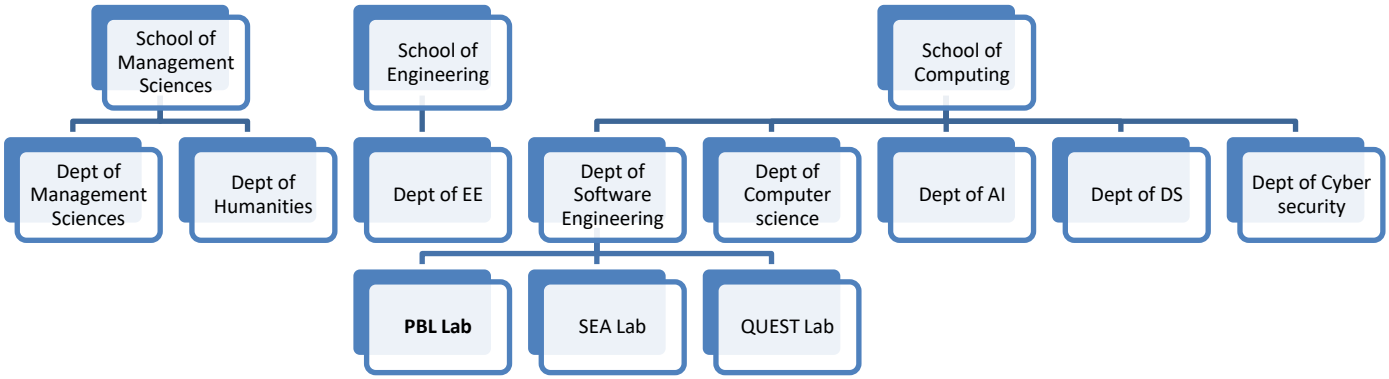

Figure 1. The organogram of the School of Computing, Department of Software Engineering.

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3. Purpose of the lab

The Problem-Based Learning Lab is being used for different courses and for conducting teacher trainings. The lab is used in multiple courses that deploy active learning methods for effectively engaging students. The lab allows students to work hands-on with technology towards building their understanding of the course content. The lab allows the replacement of the conventional method of teaching that is based on lectures and promotes the broad deployment of active learning among colleagues and students.

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4. Guidelines for the use of the lab

The lab can be used for conducting group work in courses and lab assignments. Along with that, it can be used for conducting teacher trainings.

Two pilot courses that have already been conducted using the lab, as well as the ALIEN digital learning platform, are:

Subject	**Number of students**	**Number of teachers**	**Equipment**	**Semester**
Software Engineering for Industrial Automation Systems	22	1 teacher	Virtual reality	August 2019
Software Engineering	250	3 teachers and 2 lab instructors	Augmented reality	March 2020

Table 1. Examples of courses in which the Problem-Based Learning Lab was used.

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5. Activities and courses that take place in the lab

5.1 Example of a course taking place in the lab

5.1.1 Course description

The course Software Engineering in Industrial Automation (SE593), which is part of the School of Computing, Master's in Software Engineering, Master's in Computer Science, and Master's in Cyber Security, was delivered in the Problem-Based Learning Lab.

The main objectives of the course are:

- To develop understanding on the concepts of industrial automation and control systems.
- To be able to use software engineering lifecycle steps for industrial automation and control systems.
- To build knowledge on risk assessment techniques for Industrial automation systems.
- To build knowledge on cyber security of SCADA systems.
- To build knowledge on the standards of cyber security and functional safety in industrial automation.

The course contents are:

- Introduction to Software Engineering principles.
- Industrial Automation Systems: Programmable Logic Controllers (PLC), Motion Control Systems, Computer Numerical Controls (CNC), AC Drives, Human Machine Interface (HMI) Software, Supervisory Control and Data Acquisition (SCADA), PXI, and PC based Systems Automation Software. Categories: Software tools, Manufacturing Systems, Resource, Planning, and Real-time systems.

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- Industrial Software Standards: IEC 61131-3, ISA 88/95, IEC 61499, IEC 61804, IEC 61850.
- Requirements Engineering for industrial automation systems, and specifically:
    - Quality requirements industrial automation systems.
    - Requirements patterns for industrial automation systems.
- Risk management in industrial automation systems analysis, security failure analysis, safely failure analysis, STPA, FMEA, HAZOP, and FTA.
- Industrial Software Design Practices: Model-Driven Engineering (MDE), Component-based software engineering (CBSE), Design Based on Formal Model, Multi-Agent Architecture, Service-Oriented Architecture (SOA), and OO Approach for Industrial Automation Software Development.
- Industrial Software Testing, Management, and Validation: Software Testing, Software Maintenance and Evolution, Software Configuration and Engineering Management, Software Process and Tools, and Software Quality.
- SCADA systems, DCS, and Cyber Security in SCADA Systems Cyber security, SCADA systems, attack models, mitigation techniques, and Security constraints.

The number of students that was engaged in the 2020 academic year was 57.

5.1.2 Problem-based learning activities that are part of the course

The course was delivered through the flipped classroom learning model. Course work includes a student project. The goal of the project is to build student skills that lower the barrier of malicious entry into industrials control systems. The course deploys active learning principles. During the course, students are asked to practice common attacks like including command injection, man-in-the-middle, and buffer overflows on the PCs and visually see the impact of their attacks in 3D visualization through the VR headsets as shown in the following figure. Users can also practice their defensive skills by properly segmenting the network with strong firewall

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rules or intrusion detection rules. Upon completion of the projects students are familiar with concepts related to ICS simulation, attach simulation, and attach results.

Figure 2. Simulation of ICS.

5.1.3 Equipment, software, and educational material deployed

Hardware

The following hardware was used in the course:

Equipment	**Features**	**Purpose**
PCs for Development	Ci7 8700, ASUS ROG Motherboard B360, 32 GB DDR4 RAM, 2 TB SATA HDD, 500	Application / Game Development and Usage

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	GB SSD, GeFORCE GTX1080 8GB, DVD RW, Corsair Casing, Corsair 750W Supply, HP27F 27'' LED Display	
PCs for Gaming	Ci7 8700, ASUS ROG Motherboard B360, 16 GB DDR4 RAM, 1 TB SATA HDD, 128 GB SSD, NVIDIA GTX1050Ti 4GB, DVD RW, HP27F 27'' LED Display	Application/ Game Usage
Projectors	Acer Projector Model: X118H	To present lecture slides, play videos, show examples etc.
VR Headsets	Oculus Rift + Touch VR System with Leap Motion	

Table 2. Equipment used in the Software Engineering in 'industrial Automation course.

Software

- OpenPLC.
- AdvancedHMI.
- JSON API for plant automation.
- SteamVR.

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- OpenVR.

Educational content

- Industrial Cloud-Based Cyber-Physical Systems, Editors Armando W. Colombo, Springer, Cham
- Title of Book Advanced Industrial Control Technology, By Peng Zhang

5.1.4 How ALIEN equipment is used in the course

The lab will be used as a general purpose classroom for multiple problem-based learning courses. The lab is designed in such a way that it has all 8 PCs settled in a big room with moveable semi-circular tables and chairs as shown in the following figure. The tables and chairs can be adjusted into any design required by the instructor for the purposes of a particular course. There are no fixed LEDs so the computers can be kept in any required fashion. There is a projector installed to disseminate instruction and share material with the students.

The lab can also be used for teacher training in problem-based learning.

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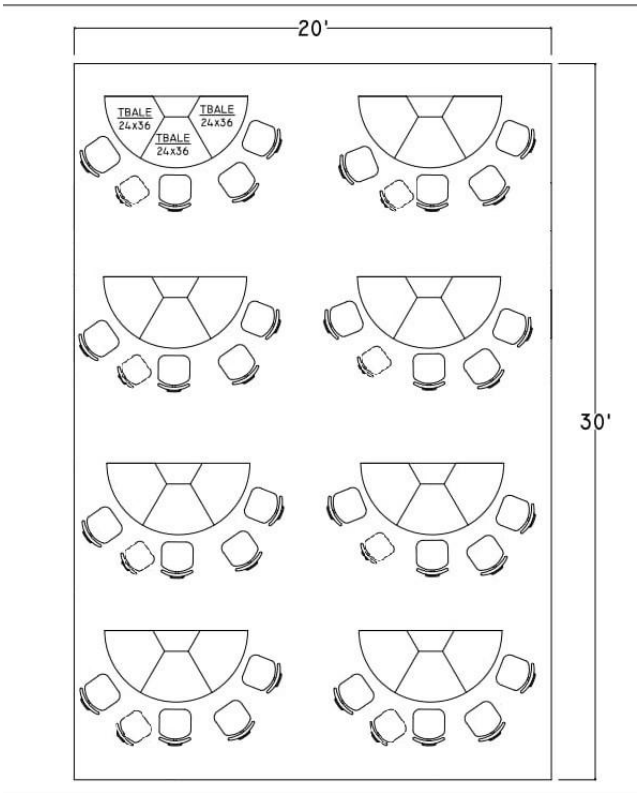

Figure 3. Floor plan of the Problem-Based Learning Lab.

5.2 Courses in which the lab will be used in the future

The lab can be used for multiple courses such as:

- User experience engineering.
- Design thinking.
- IOT security.
- And more.

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6. Resources

The Problem-Based Learning Lab offers the following equipment:

Item	Qty.	Supplier
Oculus Rift + Touch Virtual Reality System Oculus	2	Superior Elec.
LEAP Motion VR DEV Bundle	2	Superior Elec.
Windows 10 Professional	11	Superior Elec.
PC for Development Ci7 8700, ASUS ROG Motherboard 8360, 1 32GB DDR4 RAM, 2 TB SATA HDD, 500GB SSD, GeFORCE GTX1080 8GB, DVD RW, Corsair Casing, Corsair 750W Supply, HP27F 27" LED Display, 2.5" Passport Drive 4TB, Keyboard and Mouse	3	Asktech
PC for Gaming Ci7 8700, ASUS ROG Motherboard 8360, 16GB DDR4 RAM, 1 TB SATA HDD, 128GB SSD, NVIDIA GTX1050Ti 4GB, DVD RW, HP27F 27" LED Display, Keyboard and Mouse	5	Asktech
Acer Projector Model: X118H	2	Asktech

Table 3. The equipment in the Problem-Based Learning Lab.

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7. Staffing

The Problem-Based Learning Lab will be supported by the following personnel:

- Teachers and lecturers who will
  - Use the lab for conducting their courses and labs.
  - Conduct trainings and workshops
- Technicians who will
  - Assist students with equipment use in final year projects and Master's projects
  - Maintain the software and ensure that it is up to the date

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8. Financial support

The lab staff comprises of university staff including lecturers and technicians who are already employed by the university. The staff is already employed by the organization, is part of the organizational organogram and is included in the organizational payroll. For this reason, not additional funding is required for supporting the Problem-Based Learning Lab team.

However, a very important part of the lab is students (BS, Master's, and PhD students). Student stipends and salaries will be supported through the pursuit of additional research projects.

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