Iyer, S. et al. (Eds.) (2022). Proceedings of the 30th International Conference on Computers in Education.
Asia-Pacific Society for Computers in Education

Learning Factory: A Proposed Framework for Engineering Learning Ecology by Automated Manufacturing System Kits

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Abstract: In the engineering education program, how to help engineering students fully understand the concept and practical procedure in industry, especially, mechatronic engineering students are encouraged to learn many concepts related to industrial, especially the challenges of Industry 4.0 technology. However, the industrial process is complex and lacks learning material covering the industrial manufacturing context, causing engineering students with no experience and knowledge of automated manufacturing technology. It is necessary to educate the next generation of student engineering, but the learning tools needed for education are often expensive, and lack of funding to buy learning material. Most importantly, technology changes and evolves rapidly. This study offers the development of an automated manufacturing system learning kit that can be used to teach engineering education. It consists of three stations: loading, assembly, and warehouse packing. In addition, the learning factory ecosystem presented in this study aims at a much broader use of novel learning methods to introduce mechatronics engineering students to understand the new digital manufacturing process. The study results inspire instructors and educational institutions to prepare engineering students with the knowledge and practical skills based on the learning factory ecosystem.

Keywords: Learning outcome, engineering education, learning kit

1. Background and Motivation

Nowadays, many countries demand multidisciplinary engineering and flexible workers capable of using new technology and solving relevant problems in the industry. Thus, mechatronics engineering is popular because it integrates mechanical, electronic, and electrical engineering systems and combines robotics, computer science, control systems, and product engineering.

In the development of the engineering education program, how to help engineering students fully understand the concept and practical procedure in the industry, especially mechatronic engineering students are encouraged to learn many concepts related to industrial, especially the challenges of Industry 4.0 technology. Therefore, they should receive methods to apply experiential learning concepts, which encourage creativity to provide solutions to real-world focus on competency-based education with learning experiences (Félix-Herrán, 2019)

Learning factories have become interested and expanded worldwide, especially in Thailand; it is popular to integrate teaching and to learn for engineering education. A learning factory is a learning environment that matches an industrial production setting to simulate production processes realistically while enabling practical training in many topics and professional levels through technologies and functions inside the learning factory based on current industry standards (Scheid, 2018). Learning factories appear as complex learning environments that allow the development of high-quality and autonomous competencies connected to training, education, and research (Baena et al., 2017). It includes implementing several technologies in the industry 4.0 environment driven by existing technological developments and the ability to process large amounts of data (Centea, Singh, & Elbestawi, 2019).

Many studies propose the learning material for utilization in the learning process. For example, Mourtzis et al. (2020) offered a highly automated and flexible manufacturing cell to enhance skills, competencies, and hands-on experience for a new generation of engineers. Berman et al. (2021) offered low-cost, portable air conditioning teaching and learning kits to improve students' understanding of vocational education. Mohammad et al. (2021) proposed a smart factory reference model as a guide to upgrading an existing production system towards the vision of Industry 4.0 using readily available components. It is a modular production system connected to a server accessible locally or through the internet with the application software to create the user interface.

The scope of this study effort is descriptive how to design and develop the low-cost learning material for mechatronics engineering students. An automated manufacturing system learning kit consists of three stations: loading, assembly, and warehouse packing.

2. Conceptual Framework

Learning outcome

The context of an educational institution of higher education focuses on developing student learning outcomes throughout the curriculum. The learning outcome is the goal of students learning and helps direct the instructional structure and determine how students will be after the teaching and learning process (Wongwatkit et al., 2018). This study proposed the automated manufacturing system learning kits to promote mechatronics engineering students based on the learning factory ecosystem. The automated manufacturing system concepts for mechatronics engineering students should be learned based on learning outcomes as follow the table below:

Table 1. *Program Learning Outcome*

Course concepts	Leaning outcomes
1. Manufacturing process component	Understand the manufacturing process.
2. Programmable logic controller (PLC)	Use PLC to control hardware.
3. Ladder programming	Write Ladder logic programming with PLC.
4. Pneumatic cylinders	Write programming to control pneumatic cylinders.
5. Photoelectric sensor	Apply a photoelectric sensor to detect an object.
6. Vision inspection systems	Apply a vision inspection system to track an object.
7. Robot control	Write programming to control Robot
8. Vacuum grippers control	Use Vacuum grippers to pick and plate the workpiece.
9. Dashboard	Display information on the dashboard.

3. Development of an Automated Manufacturing System Kit

In general, using the existing commercial products available in the market is expensive in a teaching and learning factory for engineering education. This study is based on a low-cost concept using a simple design and affordable materials and components to simulate the industry situation, allowing the students to apply their theoretical knowledge in practice. This learning kit's development consists of three aluminum profile stations. Each station includes sensors (machine vision), conveyors, a SCARA robot, Articulated robot. Overall stations were controlled with a programmable logic controller (PLC) to connect hardware devices and online services through Sysmac Studio Software to support ladder, structured text, and function block programming. Furthermore, Node-RED was used to show the dashboard performed data monitoring graphically. The design basis of the automated manufacturing kit consists of three stations, as seen in Figure. 1 and Figure. 2.

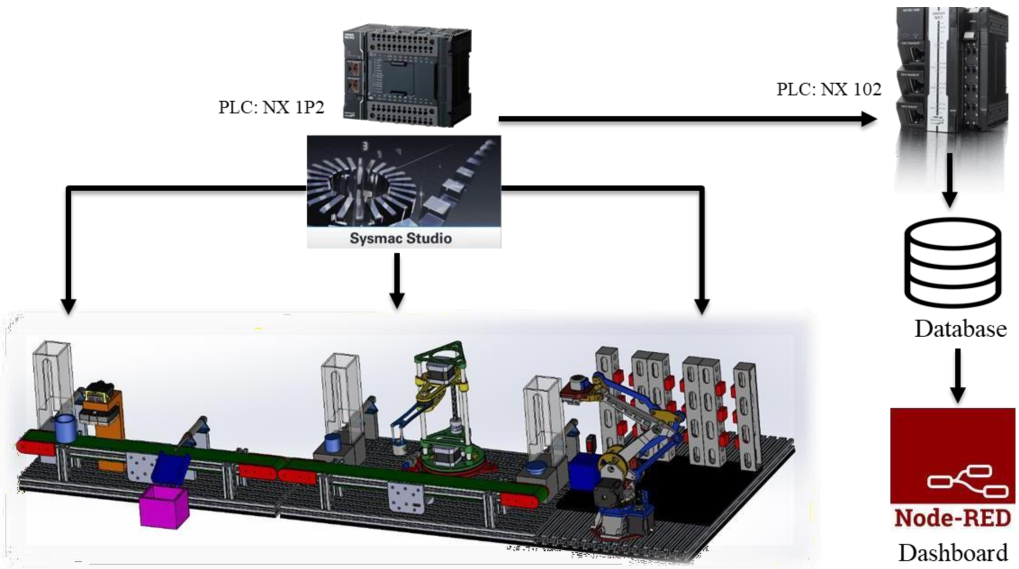

Figure 1. Design of an automated Manufacturing system kit.

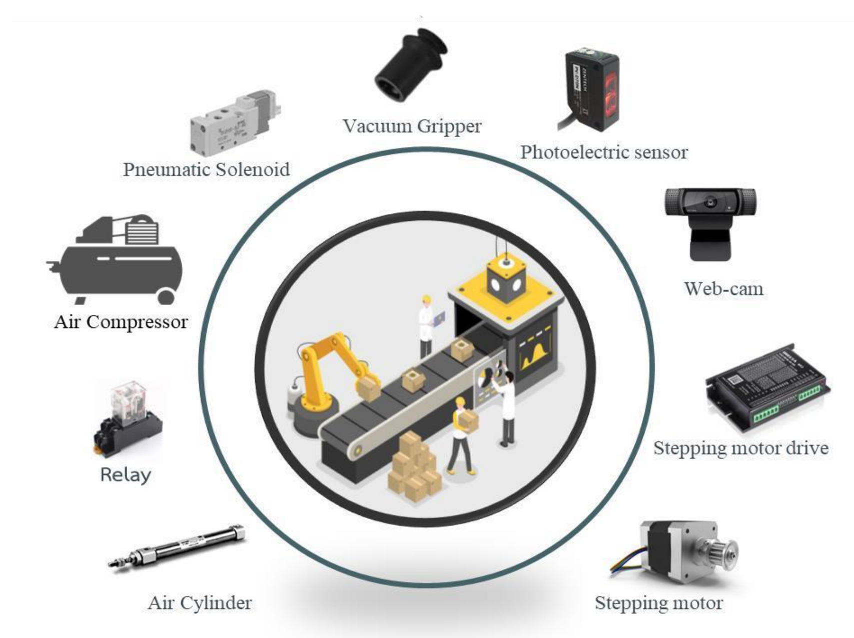

Figure 2. Basic material to developing learning kit.

3.1 Loading Stations

The loading station is a prototype for controlling the loading station of a factory automation system. It serves to load workpieces into the conveyors run and transport workpiece carriers with machine vision technology. It offers reliability and fasts detected based on machine vision that can help achieve real-time data analysis in a manufacturing environment. It can be implemented in any industry to perform real-time monitoring of workpieces. A conveyor for the workpiece carrier fed to the next station with programmable logic controller (PLC) order and notifying defects, sorting workpieces based on their physical parameters, and analyzing process abnormalities can be achieved using real-time color detection using webcam, as shown in Figure 3 and Figure 4.

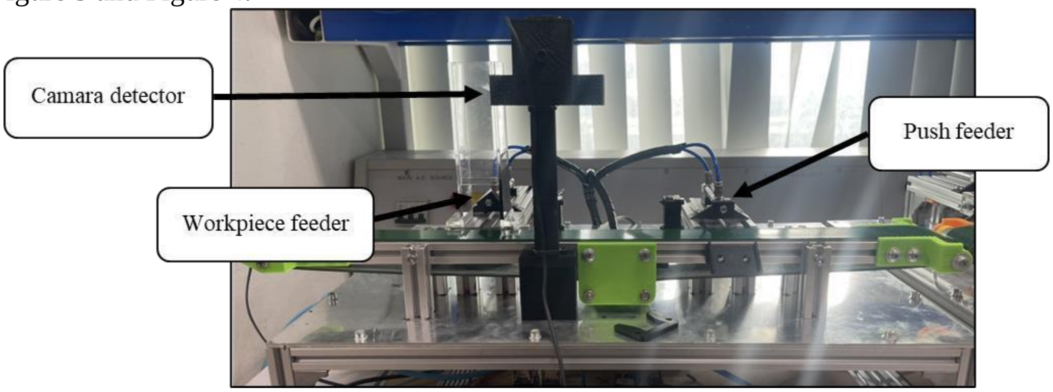

Figure 3. The structure of loading station.

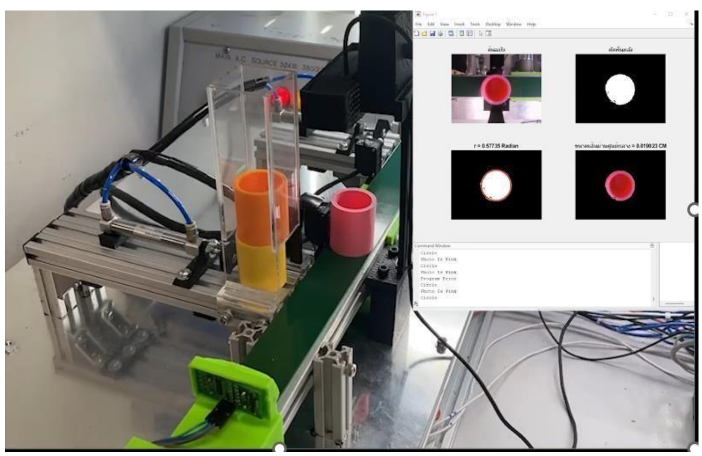

Figure 4. Real-time color detection using webcam.

3.2 Assembly Station

The assembly station is a prototype that employs the selective compliance articulated robot arm (SCARA) used for this station's pick & place and assembly operations workpiece. SCARA robot consists of two arms joined at the base and the intersection of arms one and two; it is used in assembly automation lines when coordinated with the control unit and other periphery gadgets. This station, SCARA robot, was mounted on a stable stand, pick and place robots are positioned to reach different areas to perform work. The operating status has been sent to the database and shown on the dashboard, as shown in Figure 5.

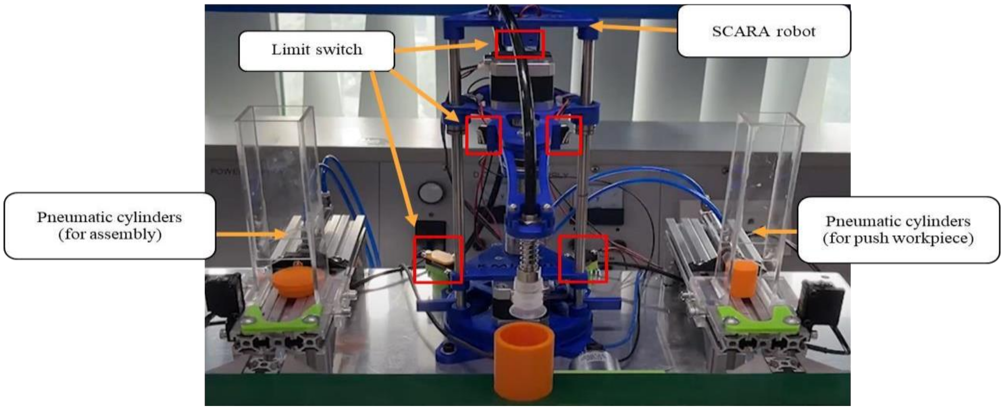

Figure 5. The structure of assembly station.

3.3 Warehouse Packing Station

The warehouse packing station is a prototype for storing goods that uses articulated robot arms with multiple joints and articulated robotic arms to move and lift items in the warehouse. It was used for moving things from pallets to racks with sensors fitted at intervals along the warehouse racking, and the system can track when the robot placed things on racks or not. The operating status has been sent to the database and shown on the dashboard, as shown in Figure 6.

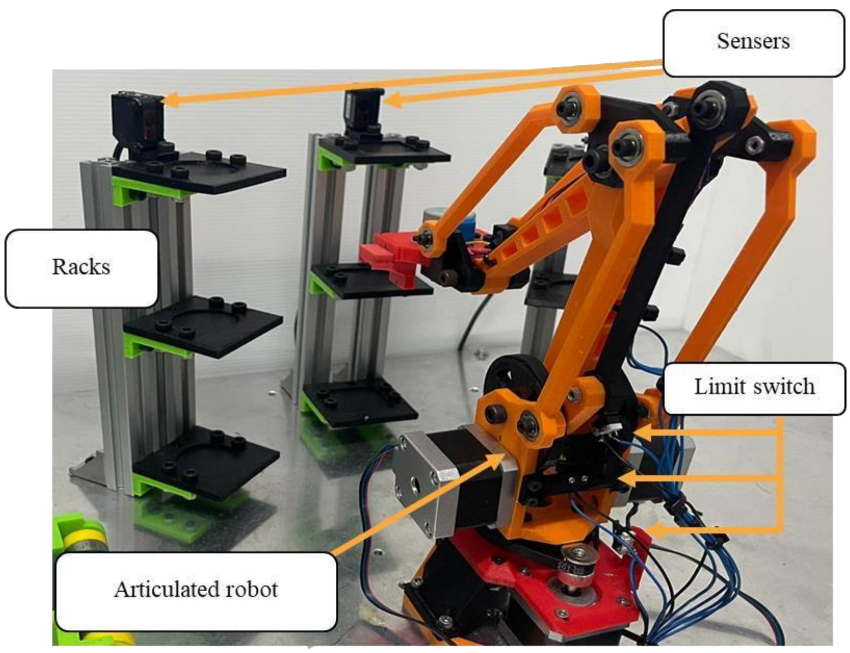

Figure 6. The structure of warehouse packing station.

3.4 Dashboard

In this work, we employ Node-RED programming tool to connect hardware devices and application programming interfaces and use database services. It can edit via the browser, making it easy to use and enter with https://nodered.org/. The information of industrial automation created in Node-RED and PLC are stored, imported, and exported for sharing information as a dashboard in the gateway connected with Open Platform Communications Unified Architecture (OPC-UA). It helps to create a live data dashboard quickly, as shown in Figure 7.

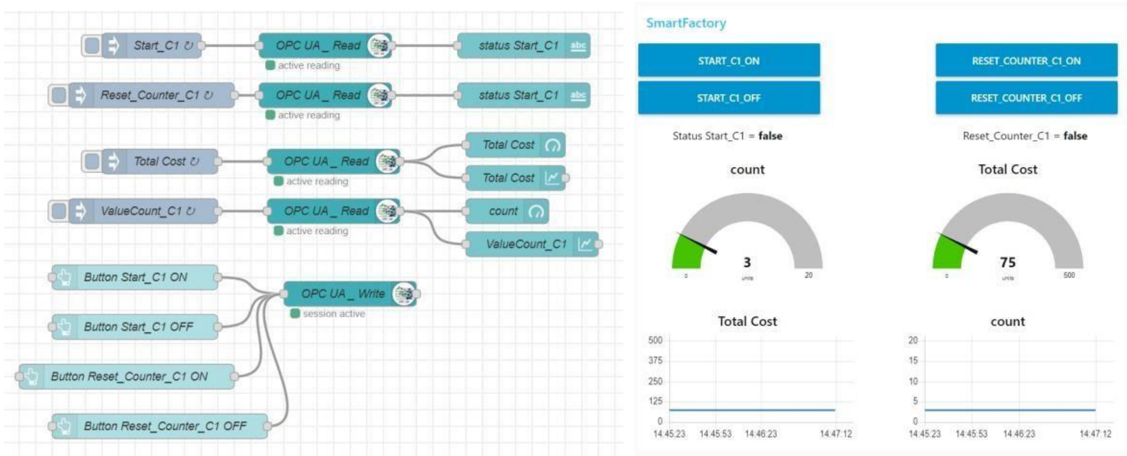

Figure 7. The illustrate of dashboard with Node-RED.

4. Conclusion and Future Work

This study offers the development of an automated manufacturing system learning kit that can be used to teach engineering education. It consists of three stations: loading, assembly, and warehouse packing. In addition, the learning factory ecosystem presented in this study aims at a much broader use of novel learning methods to introduce mechatronics engineering students to understand the new digital manufacturing process. The study results inspire instructors and educational institutions to prepare engineering students with the knowledge and practical skills based on the learning factory ecosystem. In terms of future study, to gain maximum benefit from this development in engineering education, appropriate enhancement might be to design research experiments to answer research questions and propose finding the result ultimately.

Acknowledgements

This research was funded by King Mongkut's University of Technology North Bangkok. Contract no. KMUTNB-65-BASIC-08.

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