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Implementing STEM Integrated Inquiry-Based Cooperative Learning of Smart Factory System

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Abstract: Nowadays, smart factory system learning has been increasingly mentioned in vocational education, considered guidelines to enhance students' understanding of a manufacturing situation in a realistic industry. However, it is challenging to teach the students to understand and practice. Thus, it should be cultivated in the curriculum of Technical Vocational and Training (TVET). This paper describes the STEM integrated inquiry-based cooperative learning approach of the smart factory system course. Forty first-year diploma students major in mechatronics and robotics engineering at TVET College in east Thailand participated in this study. This research finding shows the student's learning performance increasing and positive attitudes toward collaborative exploration learning management under the STEM study guidelines on a smart factory system course for TVET students.

Keywords: Inquiry based learning, smart manufactory, cooperative learning

1. Background and Motivation

Currently, the revolution of a new form of the industrial revolution is the form of digital networks (Digital networks), which are associated with intelligent operating systems in industrial plants, including design, development, and manufacturing, to installation and maintenance (Elvis, 2015) that enter the fourth industrial revolution or industry 4.0.

The technicians or workers are a critical force that will dramatically change the pattern of the industry. Especially the development of this group of craftsmen is significant, which must come from knowledge, experience, and technology. The number of workers in Thailand in the field of professional work with skills that meet the needs of the industry is only 30 million people out of a total workforce of more than 8-6 million people across the country or accounting for only about 15 percent to increase the workforce with such skills to reach the level of 40-45%. It is necessary to work together to accelerate the creation of 12-15 million professional workers into the system.

Therefore, Technical Vocational and Training (TVET) should have a system that aims to develop to meet the needs of the enterprise. Conducting practical training in laboratories with new technologies and collaborating with colleagues in the same line of work also increases the ability to engage in highly competitive careers. The curriculum of the vocational institutions must be improved to keep up with the rapidly changing industry conditions in the past few years. In addition, vocational graduates from industry 4.0 adaptation programs must have specializations such as software data analysis, cyber security, android application, and mechatronics discipline (Roll & Ifenthaler, 2021).

The 5E learning is a process that influences students' increased learning motivation and understanding of the concepts and participation in collective surveys and discussions. It also changes the learning environment, so students enjoy learning together (Daşdemir, 2016; Taengkasem et al.,2020; Chookaew & Panjaburee, 2022). Besides, it enables students to participate in practical learning through social skills that facilitate work; they can achieve better results when working together and understanding in teams and they can create a new body of knowledge by participating in carrying out activities.

Ali (2014) suggested that science educators encourage teachers to change teaching methods from teacher-centered teaching and focusing on the lectures in the textbooks to change to a quest-based method as 1) Emphasis on learners' interest in science, 2) Gives students opportunities to use practical techniques, 3) Allow learners to solve problems using logic and evidence, 4) Encourage students tostudy for more information to be able to find a way to explain more complex information, and 5) Paying attention to writing an explanation from the scientific evidence. This approach points to a classroom environment in which the community is seen working on a quest: science knowledge and the same proof-of-scientist process. It shows the importance in the future for driving the industrial system to keep up with new technologies (Zhang & Ming, 2021; Chookaew et al., 2021). The management can increase productivity for better efficiency, including personnel development skills following enterprises' needs in the industrial sector to keep up with the rapidly changing industry and support the industry 4.0 approach

Thus, TVET students should gain knowledge and expertise in industrial factory systems using information technology so that they will experience and be able to develop ideas, innovations, and professional skills. Mainly the high vocational certificate student level because learners at this level have skills and abilities. They have learned the concept of Introduction to tools and equipment, including basic knowledge related to industrial systems. In addition, it is the age when it is necessary to cultivate practice guidelines and attitudes to work with others to achieve the ability to perform the primary duties of the supervisor of entrepreneurship and be an innovator. This research aims to develop students' performance to learn industrial factory systems to meet the needs of the workplace and modern technology and to create an attitude to work together. Two research questions guided this study:

RQ: How does the STEM integrated inquiry-based cooperative learning to promote students' performance?

RQ2: How does students’ attitude participating in the STEM integrated inquiry-based cooperative learning?

2. Smart Factory System Learning

The researcher analyzes the smart factory system's behavioral objectives, knowledge, and skills that students must acquire and considers the learning process. They will receive both terms of knowledge understanding of the content and applying the skills learned to be tested for assessing learners' skills from studying in each unit. The student must learn conditionally from units 1-3. They can practice after completing the study according to the planned process and continue until the end of the lesson, as shown in Table 1.

According to the planning activities and lesson plan that focuses on collaborative learning processes using STEM education to integrate content and knowledge for learners, there are steps of activities for cooperative inquiry learning, as shown in Figure 1.

Table 1. *The behavioral learning objectives*

Unit	Topic	Behavioral learning objectives
1	- TCP/IP settings - Stack Magazine Station I/O map settings. - Conveyor Station I/O map settings.	1. Set the IP of the PLC to be able to connect to the computer. 2. Set the input and output of the Meclab training set in the I/O map correctly. 3. Define variables used for inputs and outputs of Meclab training sets used to connect to PLCs.

2	- Programming to control the operation of the Stack Station - Programming to control the operation of the Conveyor station.	4. Write a program to control the operation of the Stack Magazine Station. 5. Write a program to control the operation of the Conveyor Station.
3	- Creating a monitor to simulate the operation of the Stack Magazine Station. - Creating a monitor to simulate the operation of the Conveyor station.	6. Create a model on the monitor for controlling the Meclab operation. 7. Design a monitor for controlling Stack Magazine Station operation. 8. Design a monitor for displaying the performance of the Stack Magazine Station. 9. Design a monitor for controlling the operation of the Conveyor Station 10. Design a monitor for displaying the performance of the Conveyor Station.

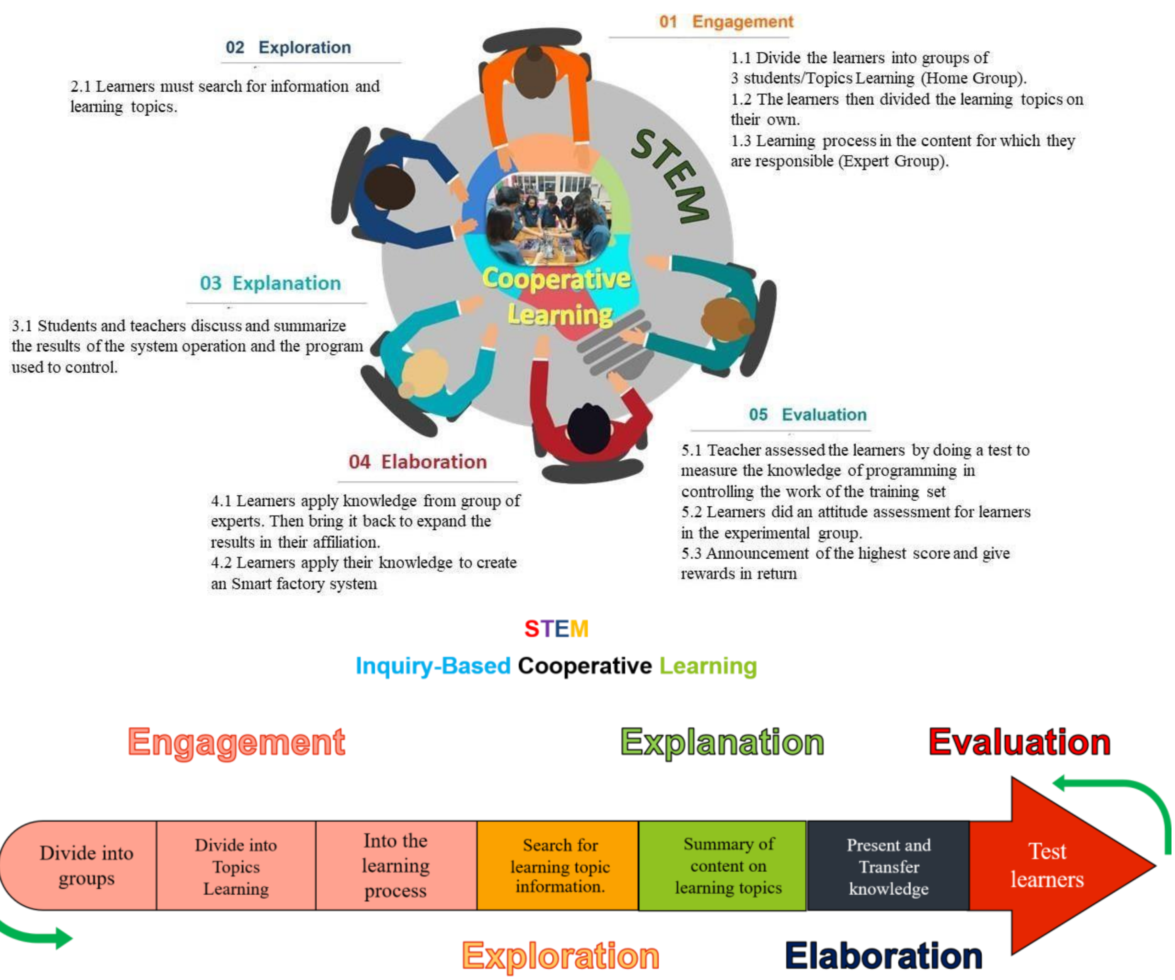

Figure 1. An overall structure of STEM Inquiry-Based Cooperative Learning.

In this study, we developed the training kit to simulate industrial factory systems consisting of workpiece distribution Pneumatics, a cylinder to push the workpiece, conveying to uses a DC electric motor system, and sorting workpieces to use an electric valve in the separation. After that, we combine two systems to create the initial simulation size industrial system. All device used to control the system's operation is the Programmable logic controller (PLC) (Omron: NX-series NX1P2 CPU Unit hardware), as shown in Figure 2.

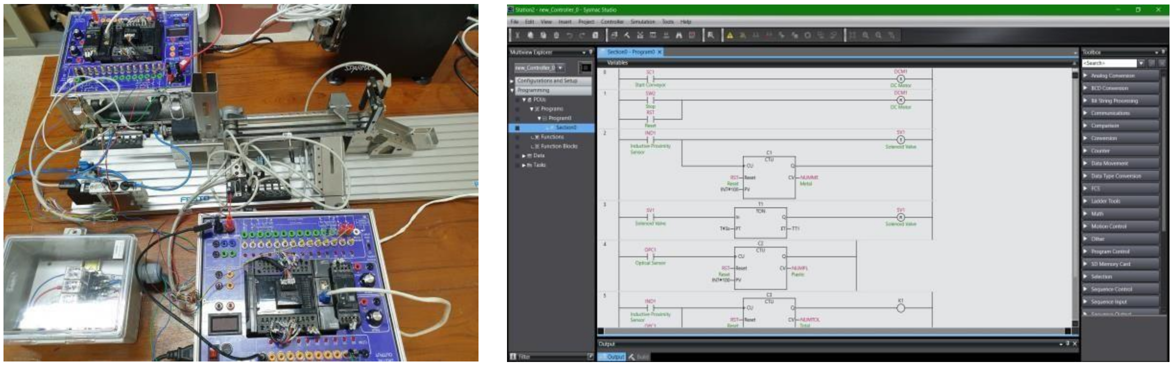

Figure 2. Smart factory system training kit (left) and PLC program in Sysmac Studio (right).

3. Methodology

3.1 Participants

This study was conducted at Thai-Austrian Technical Collage in east Thailand. Forty first-year diploma students majoring in mechatronics engineering and robotics at TVET College in east Thailand participated in this study. They registered for factory automation courses with a grade of 2.00 or higher. They were divided into 20 students in experimental and 20 students in control groups. The experiment group will use the cooperative inquiry learning teaching method, focusing on doing activities together among students.

Then, the students took the test to measure the practice skills assigned by the teacher. Afterward, they took the checklist assessment criteria for assessing the students' attitudes towards learning activities. In comparison, the control group will use traditional lecture-based learning. Then, the students took the test to measure the practice skills assigned by the teacher.

3.2 Learning Activities

The implementation of learning activities occurred during the three weeks in factory automation courses. The students in the experimental group will be divided into groups (each group of 3 students). Then, the instructor described the introduction to activity in the classroom and motivated related to the importance of industrial plant systems in the past from 1.0 to today's Industry 4.0. After that, the teacher explains the essential content and methods of operation of all learning units. All students participate in the learning activities and assignments. One of the students within the group appoints a representative to monitor all learning units within their group. The teacher uploads the content files that the students will have to study on their own through the students' Google Classroom. Then the representative students in each group disperse into their groups in each assigned unit.

The students have self-study with experiments following the operating methods of each unit. When a representative student completes the learning task, they will return to their original group to bring information that each person has studied in all learning units to transfer knowledge to members of their groups. Everyone in the group will receive complete details on all learning units through the transmission of information from members. Then, the students took the performance skill test (10item), as shown in Figure 3.

Figure 3. Students' learning activities.

4. Results

4.1 The Results of Students' Performance

The results of the self-assessment comparison before and after learning activity were in this study. The comparison results were shown in Table 2 and Table 3.

Table 2. *Results of pre-test comparison.*

Results of Pre-Test					
Group	n	X	S.D.	*t*	*sig*
Experimental group	20	7.05	4.22	-0.152	.88
Control group	20	7.30	6.04 $p > 0.05$		

Table 2 found that in the pre-study self-assessment of the students in the experimental group. The mean was 7.05 (S.D. =4.22), and in the control group, the mean was 7.30 (S.D. =6.04). The t-test results were not statistically different at 0.05; prior knowledge was no different.

Table 3. *Results of post-test comparison.*

Results of Post-Test					
Group	n	X	S.D.	*t*	*sig*
Experimental group	20	17.55	2.74	2.412	.02*
Control group	20	14.90	4.08		

* $p < 0.05$

Table 3, it was found that the self-assessment results after studying in the experimental group, the mean was 17.55 (S.D.= 2.74), and in the control group the mean was 14.90 (S.D.=4.08). The t-test results were significantly different at the 0.05.

The student's performance skills checklist of the smart factory system concept was used to evaluate students in both two groups, including ten items with a total score of 50. The assessment results were obtained from teachers as assessors. The results of the assessment of practical skills between the two groups of students are shown in Table 4.

Table 4. *The results of the student's performance skills.*

Results of Post-Test					
Group	n	X	S.D.	*t*	*sig*
Experimental group	20	41.08	11.22		
Control group					
20	23.73	14.27	4.273	.00**	

** $p < 0.01$

Table 4 shows that the mean of the learners in the experimental group was 41.08 (S.D.= 11.22), and the control group was 23.73 (S.D.= 14.27). The mean of the experimental group was higher than the control group. There was a statistically significant difference at 0.01.

4.2 The Results of Students' Attitude

The attitude assessment items divide into four dimensions are 1. Active participation within the group, 2. Interaction within the group, 3. The importance of members within the group, and 4. Skills and knowledge of working together in a group. We found that the assessment results of the students' attitudes by finding the average of the assessments were 4.32 (S.D.= 0.22). It can be considered that the student's positive attitude toward this approach is at a good level. In addition, the results from interviewing TVET students toward the STEM integrated inquiry-based cooperative learning are summarized in Table 5.

Table 5. *The Students' Attitude Interview*

Interview items	Students' Attitude Summary
When students participate in inquiry-based cooperative learning activity, how do students feel?	The students feel satisfaction when learning with friends within their group. They were an exchange of knowledge to complete the assigned tasks by doing group karmic activities. They can cooperate with the enthusiasm of the group members and mutual assistance so they can go through together.
When students work in a group, how do you communicate within the group?	The students want to communicate correctly, but some members may not have enough prior knowledge causing the misconception to be transmitted to other group members, especially difficult content that the student cannot understand.
When students work in a group, what are the student expectations?	The students expect to write programs following specified conditions. They want to gain more knowledge of PLC connection to the Internet of Things platform and use SCADA as an automated control system.

5. Conclusions

In the smart factory system course, it is sometimes difficult for students to understand the principles of writing programs following specified conditions with a PLC connected to the Internet of Things platform, especially when it is necessary to use SCADA as an automated control system. This paper describes the STEM Inquiry-based cooperative learning model of the smart factory system course. Forty first-year diploma students major in mechatronics engineering at TVET College in east Thailand participated in this study. The research found that the student's learning performance increasing and positive attitudes toward collaborative exploration learning management under the STEM study guidelines on a smart factory system course for TVET students.

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