So, H. J. et al. (Eds.) (2020). Proceedings of the 28th International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Implementation of Multimedia-based Inquiry Learning to Promote Students' Understanding of Automated Factory Systems and Their Perceptions

Sasithorn CHOOKAEW[a*], Supachai HOWIMANPORN[b] , Santi HUTAMARN[c]
Warin SOOTKANEUNG[d]
[a,b,c]Department of Teacher Training in Mechanical Engineering,
Faculty of Technical Education, King Mongkut's University of Technology North Bangkok, Thailand
[d]Department of Computer Engineering, Faculty of Engineering
Rajamangala University of Technology Phra Nakhon, Bangkok
*sasithorn.c@fte.kmutnb.ac.th

Abstract: With the introduction of the smart factory, automation systems have changed the factors and elements associated with traditional manufacturing systems. Smart factories incorporate the current features of smart systems so that they can compete in the future. It is important to determine industrial requirements, and provide students in higher education engineering programs with the necessary training. However, it is frequently the case that conventional automated factory learning focuses on lectures about automation systems without incorporating interesting learning materials. In addition, many students have trouble understanding the concepts and the new technologies associated with automation systems. In this study, we attempt to increase the students' understanding of the relevant subject content with the use of multimedia-based inquiry learning. This findings of this research study indicate that students gain better conceptual knowledge and understanding after participating in multimedia learning. Such an approach offers a medium gain in the progression of their understanding and also provides evidence of a positive increase in student perception.

Keywords: inquiry-based learning, mobile learning, engineering education

1. Introduction

Thailand is an emerging economy that is driven by its manufacturing sector. However, recent data has shown that not everything is going well. In response to this, the Thai government has attempted to promote engineering education to support Thai industry. The most important aspect of this has been how to change the engineering education learning process in such a way as to encourage industrial learning and training for the future. The so-called Fourth Industrial Revolution (Industry 4.0) is a collective term for technologies that will enable the manifestation of smart industry. The smart factory is part of Industry 4.0 that has rapidly grown and has become increasingly important, especially in the case of those companies pertaining to the engineering field (Prinz et al., 2002; Büchi et al., 2020) that incorporate five key components: Big Data, Cloud System, Internet of Things (IoT), Cyber-Physical Systems (CPS), and Smart Factory. Together, these make up the heart of Industry 4.0 (Mabkhot et al., 2018). The smart factory introduces the automated system changes to the factors and elements that make up traditional manufacturing systems, and incorporates the current requirements of smart systems so that it can compete in the future. It is important to look into the requirements of industry and impart the relevant training to students.

However, conventional automated factory learning often involves lectures about automation systems without incorporating any interesting learning materials. Consequently, many students have trouble understanding the relevant concepts and the new technologies relating to automation systems.

Automated factory systems require learning about two concepts in the form of servo motors controlled with the aid of the IoT, and integrating programmable logic controllers (PLCs) with SQL database topics. Both these aspects must be considered in order to prepare students for careers in smart factories. The students should understand the connection between machines and the automation process. However, many students lack the necessary comprehension and skills. In this study, we attempt to increase the students' understanding of the subject content with the use of multimedia-based inquiry learning. In this research we describe a method associated with teaching about an automated factory system that increases students' understanding. The study investigates the situation by asking the following research questions:

1. Do students who participate in multimedia-based inquiry learning have an understanding of the concepts associated with automated factory systems?
2. What are the students' perceptions of multimedia-based inquiry learning?

2. Related Study

2.1 STEM education in engineering curriculum

During this time of change, educational engineering has attempted to integrate features of the STEM (science, technology, engineering, and mathematics) discipline with engineering curriculum units in such a way that students are aware of the importance of understanding these disciplines in order to prepare themselves for the high technological present and future (Mathis et al., 2017; Fan & Yu, 2017; Siverling et al., 2019; Kajonmanee et al., 2020).

Yakimov & Iovev (2019) point out the main objectives with regard to the development of a learning environment for encouraging practice in the field of mechatronics and industrial automation. The use of real industrial devices provides an education in conditions close to reality. It is expected that this will lead to a successful education in the STEM field which will allow students to acquire sustainable theoretical knowledge and practical skills for the start of their career in factory automation.

However, some of the problems associated with such an acquisition is deciding how to apply the technology in such a way as to enhance learning when it comes to incorporating students' hands-on activities in engineering education. In this study, we focus on two student learning outcomes: 1) the extent to which students are able to understand how the servo motor process is controlled, and 2) the extent to which students are able to understand the integration of PLCs with SQL databases as part of the industrial automation system.

2.2 An automation factory system learning

Curriculum content related to automated factory systems is important for mechatronics, mechanical, and electrical engineering students. This content focuses on how factory equipment is connected in order to improve the efficiency and reliability of process control systems. Therefore, two important aspects for constructing multimedia learning approaches are as follows:

- Servo motor systems controlled with the use of the IoT: This content is related to a servo motor that is a rotary actuator. This allows for the precise control of speed, torque, acceleration, and angular and linear position. It uses several applications such as that every joint on the robot is connected by a servomotor in order to give the robot arm a precise angle, or using servo motors as part of the manufacturing process in order to start, move, and stop conveyor belts carrying products to various stages.
- Integrating PLCs with SQL databases: This content is related to using programmable logic controllers (PLCs) connected with a database such as the assembly line in the smart factory needing an easy and fast way to log or obtain data online about the production equipment.

2.3 Multimedia-based inquiry learning

Many studies have attempted to include an inquiry-based learning (IBL) approach in a variety of courses to increase students' conceptual understanding and increase their learning (Aboagye et al., 2018; Thongkoo et al., 2019). In addition, using multidisciplinary teaching which combines inquiry-based learning activities, the students are able to achieve real learning (Zhai, 2019).

Inquiry-based learning is a popular learning approach that is used to engage students in an authentic scientific discovery process, in order to develop their knowledge and play a positive role in training them in terms of innovation. It has obvious advantages in terms of the learning process, a process which includes 5 phases: Orientation phase: Stimulating curiosity about a topic and addressing a learning challenge through the provision of a problem statement; Conceptualization phase: Stating theory-based questions and/or hypotheses; Investigation phase: Planning exploration or experimentation, collecting and analyzing data based on the experimental design or through exploration; Conclusion phase: Drawing conclusions from the data and comparing inferences made based on the data with regard to hypotheses or research questions; and Discussion phase: Presenting the findings of particular phases or the whole inquiry cycle by communicating with others and/or controlling the whole learning process or its phases by engaging in reflective activities (Pedaste et al., 2020). Many studies have proposed the use of advancements in digital technologies for creating an effective tool in the form of an integrated inquiry-based approach through a technology-enhanced learning environment (Srisawasdi, 2018; Jaimeetham & Srisawasdi, 2018; Wongwatkit el al., 2017).

In this study, we propose the use of multimedia material or digital resources that are provided to support students' learning via mobile learning. The principle underlying the design of learning activities incorporating multimedia material is that it has to use QR code on student handouts that have learning content based on the concept of a servo motor controlled with the use of IOT, and integrating PLCs with SQL databases. Subsequently, the inquiry-based learning process is used to drive learning activities associated with multimedia materials as shown in Figure 1.

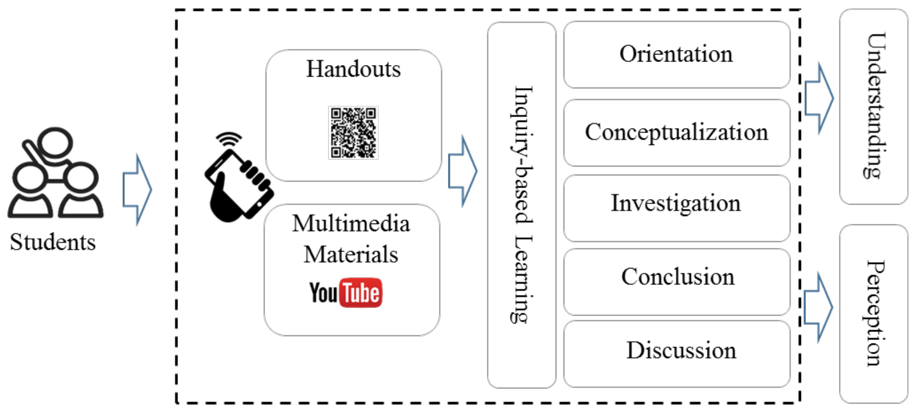

Figure 1. The structure of the multimedia-based inquiry learning

3. Method

3.1 Participants

The participants in this study consisted of 15 vocational education and training students (12 male and 3 female) whose ages ranged from 18 to 22. All of the students have experience of using a mobile device in their daily lives.

3.2 Procedure

The experiment data were conducted over a 4 week period (1 week / 3 hours total of 120 hours). A one group pre- and post-test research design was used to study the students' understanding. The learning materials for the topics, including handouts for the students, reading materials, and video presentations on YouTube, were prepared before the learning activity started, so that when the activity started all materials were ready to support student learning.

In a learning activity, the students were oriented by introducing a learning topic. All students took the pre-test which included 40 items and lasted about 40 minutes. The teacher then employed a questioning technique for generating interest in real problems in an industrial setting. The students then used a handout to investigate and synthesize new knowledge in order to solve practical problems. After the activities, all students took the post-test (40 items in about 40 minutes). Then, as shown in Figure 2, they completed the questionnaire on their mobile devices with regard to their perceptions regarding inquiry-based learning using multimedia materials.

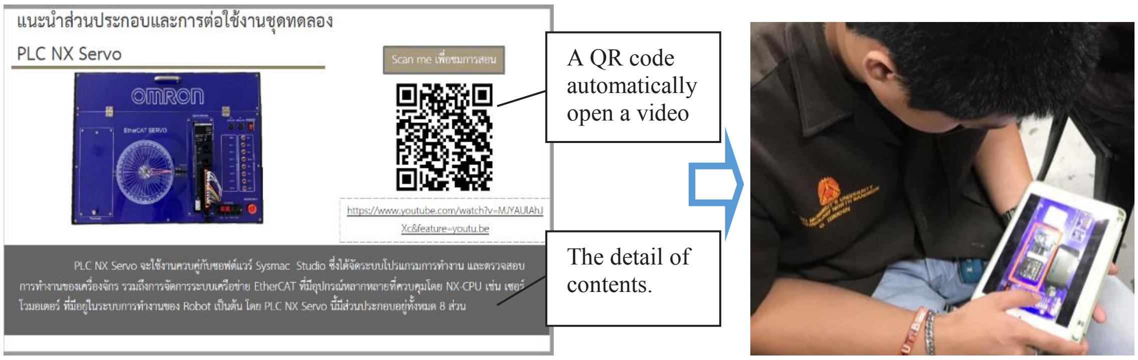

Figure 2. Illustrative examples of student learning

4. Results

4.1 The results in terms of student understanding

The data collected with regard to the students' understanding are as shown in Table 1. The paired-samples t-test showed that there is a statistically-significant difference ($t = 21.46$, $p < .001$) between the students' post-test scores and their pre-test scores on the test of conceptual understanding.

In addition, the normalized gain (Hake, 1998) was 0.62, indicating that the students achieved better conceptual knowledge and understanding after participating in the multimedia learning process and that the progression of their understanding indicated a medium gain.

Table 1. *Pre - and post- conceptual understanding test*

Test	N	Mean (SD)	*t*	p	Normalized gain
Pre-test	15	16.33 (2.65)	21.46	0.00*	<g> =0.62
Post-test	15	31.07 (2.49)			

$p < .001$*

4.2 The results in terms of student perception

A questionnaire was administered to investigate the students' perception of the multimedia learning process after participating in the learning activity. The questionnaire was adapted from Chookaew et al.'s (2015) attitude questionnaire, and employed a five-point Likert scale ranging from 1 'strongly disagree' to 5 'strongly agree'. This questionnaire consisted of eight items divided into three categories: perceived satisfaction, perceived usefulness, and behavioral intentions.

Table 2. *Means and SDs of the students' perception*

Questionnaire items	Mean (SD)	Remark
Perceived satisfaction:	*4.36 (0.70)*	*Agree*
1. I am satisfied with using the multimedia materials as a learning assisted tool	4.40 (0.71)	Agree
2. I am satisfied with the learning content	4.07 (0.68)	Agree
3. I am satisfied with the multimedia-based inquiry learning activities	4.60 (0.61)	Strongly Agree
Perceived usefulness:	*4.30 (0.53)*	*Agree*
4. I believe the multimedia materials act as a useful learning tool	4.13 (0.50)	Agree
5. I believe the multimedia-based inquiry learning activities are useful	4.47 (0.62)	Agree
Behavioral intentions:	*4.33 (0.63)*	*Agree*
6. I intend to use the multimedia materials to assist my learning	4.53 (0.62)	Strongly Agree
7. I intend to use the contents in the multimedia-based inquiry learning to assist my learning	4.40 (0.71)	Agree
8. I intend to use the multimedia-based inquiry learning activities as a supplementary learning tool	4.33 (0.71)	Agree

As shown in Table 2, the students' perception with regard to the inquiry-based learning approach using multimedia materials was deemed to be satisfactory with Mean = 4.36 and SD = 0.70, in terms of perceived usefulness with Mean = 4.30 and SD = 0.53, and in terms of behavioral intentions with Mean = 4.33 and SD = 0.63. These indicate a positive level of student perception with regard to learning with the use of multimedia materials.

5. Discussion and Conclusion

The advantages of using multimedia technology as a means of driving learning activities that relate to engineering content are consistent with the theoretical framework with regard to assisting students' understanding of automated factory systems as part of their engineering education.

This study examined the effectiveness of inquiry-based learning activities through the use of multimedia material in terms of supporting students' understanding and encouraging a positive perception of the approach. The activity systematically embedded domain knowledge in relation to STEM (science, technology, engineering, and mathematics) areas, and was especially successfully in merging the engineering content as a result of the learning environment. This study can play an important role in encouraging further research within engineering education with regard to this topic.

This study provides valuable insights for engineering educators and identifies a way forward for future research. Further studies might explore how best to access improved learning performance and skills. In addition, the integration of hands-on activities as part of the learning process should be considered as a means of encouraging engineering students' understanding and practice.

Acknowledgements

This research was funded by King Mongkut's University of Technology North Bangkok. Contract no. KMUTNB-63-DRIVE-19.

References

Aboagye, G. K., Ossei-Anto, T. A., & Ampiah, J. G. (2018). Combining Inquiry-Based Hands-On and Simulation Methods with Cooperative Learning on Students' Learning Outcomes in Electric Circuits. American Journal of Educational Research, 6(8), 1172-1181.

Chookaew, S., Wanichsan, D., Hwang, G. J., & Panjaburee, P. (2015). Effects of a personalised ubiquitous learning support system on university students' learning performance and attitudes in computer-programming courses. International Journal of Mobile Learning and Organisation, 9(3), 240-257.

Fan, S. C., & Yu, K. C. (2017). How an integrative STEM curriculum can benefit students in engineering design practices. International Journal of Technology and Design Education, 27(1), 107-129.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American journal of Physics, 66(1), 64-74.

Jaimeetham, D., Srisawasdi, N. (2018). Using mobile game-like simulation to promote inquiry-based laboratory learning in elementary school science. In proceedings of the 26th International Conference on Computers in Education, (pp.240-248). Manila, Philippines: Asia-Pacific Society for Computers in Education.

Prinz, C., Morlock, F., Freith, S., Kreggenfeld, N., Kreimeier, D., & Kuhlenkötter, B. (2016). Learning factory modules for smart factories in industrie 4.0. Procedia CiRp, 54, 113-118.

Büchi, G., Cugno, M., & Castagnoli, R. (2020). Smart factory performance and Industry 4.0. Technological Forecasting and Social Change, 150, 119790.

Kajonmanee, T., Chaipidech, P., Srisawasdi, N., & Chaipah, K. (2020). A personalised mobile learning system for promoting STEM discipline teachers' TPACK development. International Journal of Mobile Learning and Organisation, 14(2), 215-235.

Mabkhot, M. M., Al-Ahmari, A. M., Salah, B., & Alkhalefah, H. (2018). Requirements of the smart factory system: a survey and perspective. Machines, 6(2), 23.

Mathis, C. A., Siverling, E. A., Glancy, A. W., & Moore, T. J. (2017). Teachers' incorporation of argumentation to support engineering learning in STEM integration curricula. Journal of Pre-College Engineering Education Research (J-PEER), 7(1), 6.

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., ... & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. Educational research review, 14, 47-61.

Srisawasdi, N. (2018). Transforming Chemistry Class with Technology-Enhanced Active Inquiry Learning for the Digital Native Generation. In International Siverling, E. A., Suazo-Flores, E., Mathis, C. A., & Moore, T. J. (2019). Students' use of STEM content in design justifications during engineering design-based STEM integration. School Science and Mathematics, 119(8), 457-474.

Perspectives on Chemistry Education Research and Practice (pp. 221-233). American Chemical Society.

Thongkoo, K., Panjaburee, P., & Daungcharone, K. (2019). A development of ubiquitous learning support system based on an enhanced inquiry-based learning approach. International Journal of Mobile Learning and Organisation, 13(2), 129-151.

Yakimov, P. I., & Iovev, A. N. (2019). Development of a Modern Learning Environment for Education in Mechatronics and Industrial Automation. IFAC-PapersOnLine, 52(25), 441-444.

Wongwatkit, C., Panjaburee, P., & Srisawasdi, N. (2017). A proposal to develop a guided-inquiry mobile learning with a mastery learning mechanism for improving students' learning performance and attitudes in Physics. International Journal of Mobile Learning and Organisation, 11(1), 63-86.

Zhai, L. (2019). A Inquiry Teaching Mode Based on STEM Education. International Journal of Emerging Technologies in Learning (iJET), 14(17), 44-58.