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Research Article

Mastering Automation: Hands-On Learning With Factory I/O

Norhafzan Bariman[1,*], Khairil Che Mat[2], Masrul Nizam[3]

[1] Jabatan Kejuruteraan Mekanikal, Politeknik Muadzam Shah Pahang, Lebuhraya Tun Razak, 26700 Muadzam Shah, Pahang, Malaysia; norhafzan23@gmail.com[1]

[2] Jabatan Kejuruteraan Mekanikal, Politeknik Muadzam Shah Pahang, Lebuhraya Tun Razak, 26700 Muadzam Shah, Pahang, Malaysia; khairilchemat@gmail.com[2]

[3] Jabatan Kejuruteraan Mekanikal, Politeknik Muadzam Shah Pahang, Lebuhraya Tun Razak, 26700 Muadzam Shah, Pahang, Malaysia; masrul@pms.edu.my[3]

[1,2,3] Center of Technology ARCTech Politeknik Muadzam Shah Pahang, Lebuhraya Tun Razak, 26700 Muadzam Shah, Pahang, Malaysia.

* Correspondence: norhafzan23@gmail.com; 0197501066

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Abstract: *Industry 4.0 requires engineering students to master not only theoretical skills, but also more practical skills. The Teaching and Learning Aid "Mastering Automation: Hands-On Learning with Factory I/O" was developed to enhance teaching and learning for students in the fields of engineering and automation. It provides a comprehensive guide to help students learn basic automation systems, from Factory I/O simulation to implementation in real-world situations using PLC systems. This TLA was produced starting with completing a work process simulation using Factory I/O, then programming the PLC with STEP7 and designing the HMI interface through SKTOOLS. The results of the pilot test show that student engagement and understanding are increasing. Through this approach, students' Industry 4.0 skills can be improved to meet industry needs.*

1. INTRODUCTION

The rapid development of Industry 4.0 requires engineering students to have more knowledge in practical skills, especially in the field of automation (Hernandez-de-Menendez, Escobar Díaz, & Morales-Menendez, 2020). Teaching methods that only emphasize theory will limit the opportunities for students to translate engineering concepts into real job applications (Foster & Yaoyuneyong, 2016). Simulation-based learning combined with physical hardware has been identified as an effective approach to overcome this limitation (Elendu et al., 2024).

To address this gap, the Teaching and Learning Aid (TLA) has been developed. This TLA integrates Factory I/O simulation software with real PLC hardware to provide a real learning experience in industrial automation systems. Through the produced TLA, students will be more confident in facing real jobs in industries related to the Industry 4.0 environment (Aswardi et al., 2023).

2. LITERATURE REVIEW

Industry 4.0 places emphasis on workforce preparation, especially in the fields of automation, digital manufacturing, and industrial control systems Previous studies have reported that the combination of simulation with hands-on practical training, especially related to PLCs, has improved students' understanding of real automation processes (Marsono[1] et al., 2025). Factory I/O simulations have also been widely used as a virtual commissioning and learning platform. This method allows students to visualize processes occurring in the industry before actual implementation (Zheng, Yang, Lou, & Wang, 2024).

Studies have also shown that hands-on and real-world problem-based learning approaches can increase student engagement and motivation, thus retaining long-term knowledge compared to traditional lecture-based methods (Erickson, Marks, & Karcher, 2020). Nowadays, critical skills in automation, especially in PLC programming and HMI design, are essential in the implementation of Industry 4.0 (Garcia-Moran et al., 2021). This TLA was produced based on the finding that effective teaching and learning processes should integrate theoretical concepts with simulation and practical. Studies have also shown that linking theory with practice improves skills and prepares students for real industrial environments. In the implementation of this TLA, HMI interface design and PLC programming are identified as critical skills to prepare students for Industry 4.0. This TLA will serve as a reference and guide for instructors and students to understand the concept of Automation systems.

3. METHODOLOGY

This TLA was produced using a structured approach, starting with the creation of a simulation using Factory I/O software, followed by the installation of the PLC system, programming of the PLC using STEP 7, and the development of an HMI interface using SKTOOLS, as shown in Figure 1. Next, this system was integrated with a conveyor system as used in the industry. This TLA was used by students of the Diploma in Mechanical Engineering (Automation) at Muadzam Shah Polytechnic. A survey using a questionnaire was conducted to measure students' understanding, practical abilities and motivation.

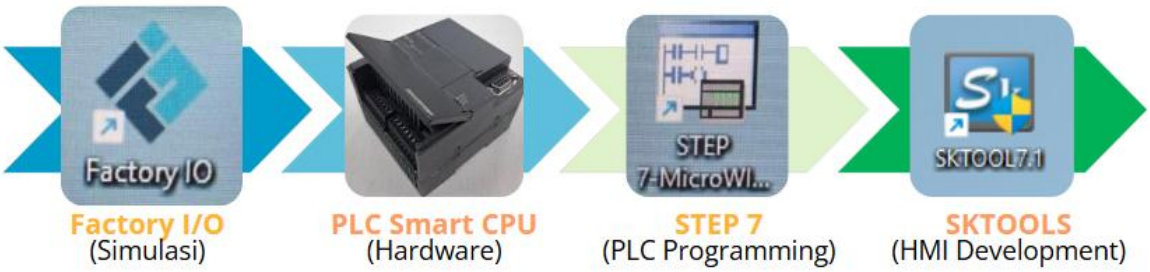

Figure 1. Steps to develop a Teaching and Learning Aid

4. FINDINGS

Based on the results of the questionnaire shown in Table 1, the produced TLA was able to improve students' understanding and practical skills. Engagement and motivation also increased compared to traditional teaching methods. All students successfully completed the simulation and hardware integration exercises. Students showed significant improvement in producing PLC programming, HMI interface design and troubleshooting in automation systems. The practical exercises allowed students to effectively translate the simulation exercises into real-world automation systems. Training with this TLA could provide immediate feedback on programming errors and system design, enabling students to continuously improve their skills. As a result, students demonstrated proficiency in PLC programming, HMI design, troubleshooting and integrating simulations with real systems.

Table 1. Finding on the Impact of Teaching & Learning Aid (Mastering Automation Hands-on Learning with Factory I/O)

No	Item	Mean	Standard Deviation
1	The manual content is organized systematically and is easy to understand.	4.41	0.71
2	The step-by-step instructions in the manual help me understand how to use Factory I/O with Siemens PLC.	4.37	0.73
3	The illustrations, diagrams, and screenshots in the manual help me understand concepts more clearly.	4.32	0.69
4	The language and terminology used in the manual are suitable for diploma-level students.	4.44	0.64
5	This manual helps me understand the relationship between Factory I/O software and Siemens S7-200 Smart PLC hardware.	4.51	0.62
6	Using this manual improves my skills in solving automation-related problems.	4.43	0.69
7	I feel more confident in carrying out practical activities after following the guidelines in this manual.	4.41	0.66
8	The teaching method using this manual makes it easier for me to follow the learning process step by step.	4.51	0.62
9	The learning activities using this manual encourage me to be more active and independent.	4.43	0.73
10	This manual helps lecturers deliver the lesson content in a more organized and effective manner.	4.33	0.72
11	Overall, this manual enhances my understanding and skills in PLC applications and industrial automation.	4.49	0.63

Total	**4.42**	**0.68**

5. DISCUSSION

The analysis of the findings from the questionnaire conducted on students who have used this TLA is shown in Table 1. Table 1 shows the level of effectiveness of the produced TLA, where the findings show that students can master the course taught with the findings showing an overall mean score of 4.42 with a standard deviation of 0.68. This finding shows that students generally strongly agree that the produced manual can support their teaching and learning process in mastering PLC applications and automation systems.

The high mean values on all items between 4.32 to 4.51 show very positive feedback from students with the use of this TLA. Items 5 and 8 recorded the highest mean score of 4.51 with a standard deviation of 0.62, it shows that this manual really helps students understand the integration between factory /O software and Siemens S7-200 Smart PLC hardware. Through the using of this manual, students can follow the learning process in a structured way, step by step. This shows the strength of using the manual book in connecting theoretical knowledge with practical applications, which is important in engineering education.

The relatively low standard deviation value between 0.62–0.73 indicates that students' responses to the produced TLA are consistent, further strengthening the reliability of the findings. The produced manual is also user-friendly and suitable for diploma-level students, as shown in Item 4 with a Mean of 4.44. With the use of clear language, and supported by illustrations and step-by-step instructions, this TLA can improve understanding and subsequently promote students' self-learning, as shown in Item 9 with a Mean of 4.43 (Eltahir & Babiker, 2024).

The findings of the study show that the TLA as shown in Figure 3 can bridge the gap between theoretical knowledge and practical skills of automation systems. Findings from previous studies show that integrating simulation-based learning methods with real PLC hardware allows students to better visualize the movement of an automation system in the industry (Xu, Zheng, & Zhang, 2024). This approach supports experiential learning, where students can learn by experiencing it themselves rather than by observation alone.

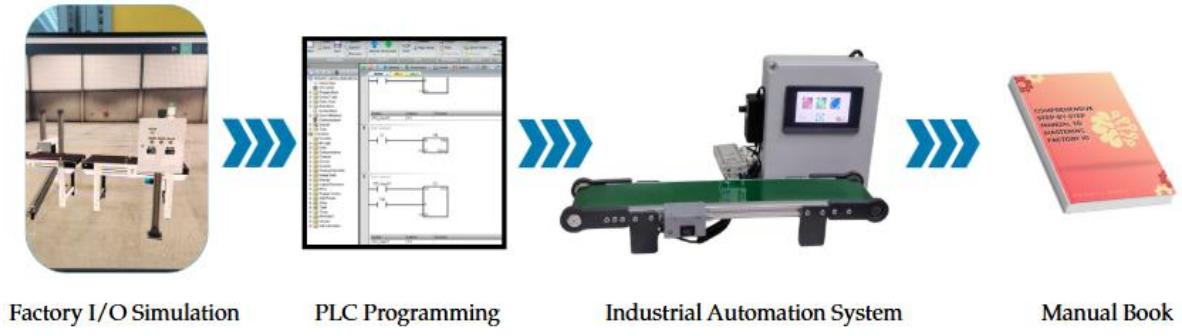

Figure 3. Automation Teaching and Learning Aid (ATLA)

The increase in student engagement and motivation is consistent with research highlighting the benefits of hands-on, problem-based learning in engineering teaching and learning (Pantzos, 2025). By using the Factory I/O, STEP7 and HMI TLAs, students are exposed to workflows that are similar to real industry practices, thus increasing student readiness for work in Industry 4.0 (Kirchner, 2017). Previous teaching and learning constraints have been reduced through the production of this TLA. Overall, this TLA promotes self-directed learning, critical thinking and problem-solving skills, which are essential elements for aspiring automation engineers (Kataria, Sanchez, & Govindasamy, 2024).

6. CONCLUSION

The produced Teaching and Learning Aids (TLA) show significant potential in improving students' understanding, engagement and competence in learning automation systems. In line with previous studies, the integration of simulation and real hardware can improve students' practical skills and preparation in Industry 4.0 (Bondin & Zammit, 2025). This TLA can also help students develop PLC programming systems, design HMIs and integrate automation systems in a hands-on manner (Vargas, Heradio, Donoso, & Farias, 2023). Overall, the findings support the application of simulation-based and hands-on teaching methods in engineering education (Singh-Pillay, 2024). This TLA also contributes to sustainable and industry-relevant teaching and learning practices.

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