

# Development and validation of an interactive skill training kit for enhancing mechatronics professional competencies in industrial production processes

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## Abstract

This study aimed to design and assess a skill training kit for industrial production processes to improve undergraduate mechatronics engineering students' professional competencies. The learning activities provided in the kit were designed using the ADDIE instructional design model's stages, Analysis, Design, Development, Implementation, and Evaluation, to promote active participation, critical thought, experimentation, and ongoing assessment. The aim was to: (1) develop a skill training kit for industrial production processes, (2) assess the effectiveness of the skill training kit for industrial production processes, (3) analyze the difference in professional competencies of learners in the experimental group as compared to control group, and (4) determine the level of

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satisfaction experienced by learners using the industrial production process skill training kit. A purposeful sample of 28 undergraduate students enrolled in the first semester of the 2025 academic year participated in this study. All students had obtained prior instruction in Programmable Logic Controllers and Sensors, and Control Devices. The study instruments included the training kit, instructional manuals, work checklists, performance tests, competency tests, and satisfaction questionnaires. Data were analyzed using descriptive statistics (percentages, mean, and standard deviations). The study showed: (1) that the training kit had a very high quality (mean = 4.63), (2) the learning efficiency was above the threshold benchmark, (3) that students in the training kit experimental group significantly improved overall and domain-specific professional competencies (better outcome) than students in the control condition at the 0.05 statistically significant level., and (4) students had a high level of satisfaction with the training kit (mean = 4.49). Overall, a training kit systematically designed with improvement could enhance students' practical skills, professional competencies, and learning satisfaction in a mechatronics engineering course.

### **Keywords**

Skill training kit, industrial production process, mechatronics professional competency

## **Introduction**

With the introduction of Industry 4.0 and Industry 5.0, which have had a significant impact on contemporary manufacturing processes, industrial technologies are developing quickly. In order to satisfy new industrial demands, engineering education must therefore change concurrently. The interdisciplinary field of mechatronics engineering, which combines mechanical, electrical, and computing principles, is essential in giving graduates the theoretical knowledge and practical skills they need to succeed in modern industrial settings. Training centers and educational initiatives must therefore create cutting-edge teaching materials that successfully close the gap between theoretical pedagogy and practical industrial application. Nevertheless, current instructional materials and training kits frequently highlight discrete technical skills without being integrated with the larger framework of industrial production processes. The intricacy and interconnectedness of actual manufacturing environments are not replicated by these traditional systems, which limits learners' ability to develop comprehensive professional competencies. A significant gap in competency-based technical education is also maintained by the static and non-interactive character of traditional training systems, which restricts their ability to adjust to the quickly shifting needs of contemporary industry. The use of interactive and digital technologies to improve engineering education has been the subject of recent research. Immersion teaching strategies, like those that use Digital Twin (DT)-based learning environments, have shown promise in simulating real-world industrial situations and enhancing learning effectiveness and skill acquisition.<sup>1</sup> In a similar vein, Learning Factory (LF) models that emphasize both technological and human-centric proficiencies

have been used to promote Industry 5.0-oriented capabilities.<sup>2</sup> It has also been demonstrated that combining Industry 4.0 technologies with sophisticated mechatronic systems enhances smart manufacturing education and gets students ready for the complexity of contemporary production systems.<sup>3</sup> When taken as a whole, these tactics show how physical, digital, and assessment elements can be combined to create learning ecosystems that are more efficient and flexible. Comprehensive, interactive training platforms that combine competency-based learning approaches with real-world industrial processes are still desperately needed, notwithstanding these developments. These kinds of tools are crucial for encouraging critical thinking, experiential learning, and the development of quantifiable skill outcomes that meet industry standards. By creating and assessing an interactive training kit for industrial production process skills tailored for undergraduate mechatronics engineering students, the current study fills this knowledge gap. The training system's development, validation, and optimization are guided by the ADDIE instructional design model. This model makes it easier to systematically evaluate the learner competencies attained through structured assessments as well as the skill performance outcomes. This study has four goals. Its first goal is to create a modular skill training kit that will improve students' comprehension of industrial production processes. The second goal of the study is to assess how well the developed kit teaches both conceptual and practical skills associated with industrial production. Third, it aims to examine how learners who use the training kit (experimental group) and those who receive traditional instruction (control group) differ in their professional competencies. Lastly, the study seeks to ascertain how satisfied learners are with the industrial production process skill training kit's usability, functionality, and overall learning experience. There are two main theories put forth: 1. Its ability to enhance practical proficiency and learning motivation in mechatronics education will be confirmed when the developed training kit meets the established standard of effectiveness (85/85) in skill performance. 2. Students in the experimental group will have substantially greater professional competencies than students in the control group. To meet the changing needs of contemporary industrial ecosystems, this research thus offers a scalable competency-based training model that incorporates real-world process simulation, practical experimentation, and systematic performance evaluation. This is how the rest of the paper is organized. The literature on competency-based learning, industrial training kits, and the application of Industry 4.0 and Industry 5.0 technologies in engineering education is reviewed in Section "Experimental procedure". The design of the interactive training kit, the ADDIE-based instructional framework, and the assessment techniques used are all covered in detail in Section "Research results" of the research methodology. The outcomes of the training kit's implementation and effectiveness analysis are shown in Section "Discussion". The findings, the implications for mechatronics education, and future research directions are finally covered in Section "Recommendations".

### *Literature review*

The main ideas and theoretical frameworks about industrial production process skills, skill-training package development, instructional design, and experiential learning

through training systems are covered in this section. The following is a summary of the reviewed literature.

### *Skills in the industrial production process*

The theoretical knowledge, technical expertise, and practical skills necessary to operate efficiently in contemporary manufacturing settings are all included in the industrial production process. In mechatronics engineering, the integration of mechanical, electrical, and control systems calls for the creation of training kits that replicate authentic industrial settings. One prominent illustration of the hierarchical structure and complexity of industrial operations is the automatic height-sorting system put forth by Khwanmuang<sup>4</sup>. Three fundamental modules—packaging, weighing, and sealing—that are indicative of an entire production line were identified in this study. To allow for real-time control and monitoring of these processes, a Human–Machine Interface (HMI) program was created, giving students a genuine and engaging experience. A hands-on learning strategy utilizing training kits, industrial tools, and simulation environments is crucial to developing such competencies in undergraduate mechatronics students.<sup>5</sup> Students performed hands-on activities under the guidance of an instruction manual that came with the training kit. Designing control interfaces and programming automation tasks that replicated actual industrial production processes were part of these activities. The purpose of the kit was to improve the fundamental abilities needed to program and manage agricultural automation systems that use Programmable Logic Controllers (PLCs). The Mitsubishi Electric GX Works3 environment was used for programming tasks, and GT Designer3 was used to create HMI interfaces. Students had to do the following learning tasks: 1. Process input signals from analog and digital devices; 2. Manage a simulated industrial conveyor system; 3. Control output operations; and 4. Gather data using the RS-485 communication protocol. Learners can connect theoretical concepts with actual production dynamics thanks to this integrated training approach, which fosters both technical fluency and cognitive comprehension.

### *Development of skill training kits*

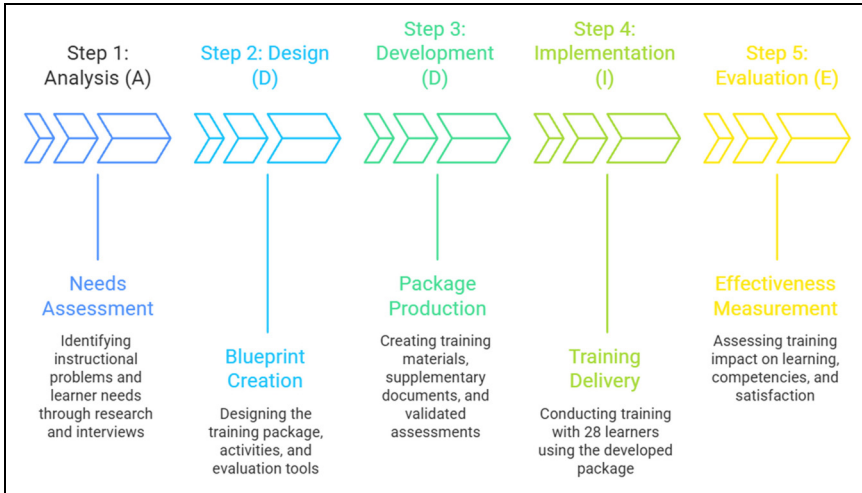
Because of its systematic, iterative, and extensively validated use in basic, higher, and vocational education as well as industrial training environments, the ADDIE model of instructional design was chosen for this study.<sup>6</sup> To guarantee pedagogical rigor and compliance with professional standards, the model provides an organized framework for creating, implementing, and assessing educational resources. By defining the instructional problem and determining the traits, requirements, and past knowledge of the learners, the Analysis phase serves as the cornerstone of the ADDIE model. Important questions are now addressed: What particular skills or knowledge should students acquire? How can learning objectives and instructional goals be developed to support these results? This stage serves as a guide for later stages of design and development. Setting deadlines and performance standards may also be part of it.<sup>7</sup> As highlighted in earlier research, a comprehensive analysis guarantees that the training kit is suited to learner needs as

well as industry demands.<sup>8,9</sup> This kind of alignment highlights how crucial it is for industrial education to link teaching resources with practical operational contexts and pedagogical standards. Determining the logical order and complexity of the learning materials, creating instructional plans, choosing suitable assessment techniques, and establishing learning objectives are the main goals of the design phase.<sup>10</sup> Project-based learning frameworks,<sup>11</sup> which support progressive skill development and guarantee cognitive and technical coherence throughout the training process, are frequently used to inform this phase of mechatronics education. Training kits, instruction manuals, videos, and simulation software are among the digital and tangible learning resources produced during the development phase. During this phase, formative testing is frequently carried out to improve usability and refine materials.<sup>6,8</sup> The next step is implementation, which entails distributing the created materials to students to assess their usefulness, efficacy, and level of engagement. Lastly, the evaluation phase incorporates both formative and summative assessments to gauge student achievement and assess the caliber of instructional materials. The E1/E2 efficiency standard, a commonly used benchmark in Thai technical and vocational education,<sup>10,12,13</sup> was used in this study to assess the effectiveness of the instruction. Here, E1 stands for the effectiveness of the learning process, which is evaluated by how well students complete tasks during instruction, and E2 stands for the effectiveness of learning outcomes, which is evaluated by assessments conducted after instruction, such as practical exams. In technically or practically complex learning systems, an 85/85 standard ( $E1/E2 \geq 85/85$ ) is widely accepted as the cutoff point for instructional effectiveness, denoting accuracy and learner performance mastery.

By integrating feedback at every stage of development, the ADDIE model's iterative nature promotes continuous improvement. The skill training kit successfully connects theoretical learning and industrial application thanks to this iterative refinement process, which encourages evidence-based instructional innovation. The E1/E2 framework was initially created in Thailand, but its concepts of competency-based evaluation, process efficiency measurement, and iterative design are generally applicable in higher education contexts around the world, especially in engineering, technical, and vocational fields.

### *Instructional design*

The methodical process of organizing, planning, and structuring learning experiences in order to guarantee successful and quantifiable learning outcomes is known as instructional design. Typically, this process entails establishing methods of assessment, choosing suitable instructional strategies, deciding on the content to be delivered, and defining learning objectives. It has been shown that applying active learning concepts to the ADDIE framework greatly improves learner motivation, skill acquisition, and the transfer of knowledge to real-world applications, especially in the Thai educational context.<sup>14</sup> With an emphasis on learner-centered pedagogy, this integrated approach promotes student engagement via problem-solving, exploration, and teamwork. Additionally, ADDIE's context-based and iterative design frameworks facilitate ongoing improvement of teaching resources, guaranteeing that learning interventions continue to be flexible enough to meet the demands of both industry and academia.



**Figure 1.** The ADDIE instructional design process for developing and implementing the industrial production skill training kit.

### *Learning through training kits*

Skill training kits are organized collections of teaching aids and resources intended to support experiential, hands-on learning. In order to facilitate the acquisition and application of technical competencies through active experimentation, these usually integrate tangible equipment, simulation tools, and instructional manuals. Research has repeatedly shown that well-crafted training kits can be modified to satisfy particular learner needs while adhering to industry standards, improving both practical proficiency and cognitive understanding.<sup>15</sup> Furthermore, it has been demonstrated that industry-aligned teaching resources significantly enhance students' technical proficiency and familiarity with actual production settings.<sup>16</sup> These results highlight the pedagogical benefits of interactive, contextually relevant training programs in closing the knowledge gap between theory and real-world skill development. Such kits are very effective media for competency-based learning in engineering and vocational education, giving students the technical confidence and professional skills that are in high demand in today's labor markets. Figure 1 Systematic ADDIE model stages.

## **Experimental procedure**

### *Ethical considerations*

The present study was ethically approved by the Human Research Ethics Committee of Sirindhorn College of Public Health, Yala Province (Approval No. SCPHLIRB-2568/579) under the project titled Development of Learning Innovation to Enhance

Professional Competence in Automatic Control Systems among the students of Mechatronics Engineering and Industry 4.0. Every procedure was carried out in compliance with the current ethical standards, and informed consent of each participant was taken with full consideration of the individual rights.

### *Population and sample*

The study's participant sample consisted of 28 third-year undergraduate students who were enrolled in the Bachelor of Engineering program in Mechatronics in the first semester of the 2025 academic year. All were previously enrolled in courses on Programmable Logic Controllers and on Sensors and Control Devices. The sample was selected using purposive sampling and created two 14-student samples: one experimental and one control group.

### *Research instruments*

A specially created Modular Industrial Production Process Training Kit (MIPPTK) was the research tool utilized in this investigation. In order to promote hands-on learning in mechatronics and industrial automation, the design adhered to instructional design principles.

Deficits in current instructional media were found during the preliminary analysis, specifically their incapacity to integrate multiple production phases, replicate real-world industrial environments, or evaluate learning using observable performance outcomes. Learning objectives centered on Industry 4.0-related competencies, such as programming Programmable Logic Controllers (PLCs), sensor integration, conveyor control, and process-level solutions, were established to fill these gaps. The MIPPTK was designed as a three-module system that replicated actual industrial processes: box sealing, weighing, and product wrapping. PLCs, sensors, conveyors, and Human-Machine Interface (HMI) control features were used in each module (Figure 2). Worksheets (Figure 3), performance tests, proficiency rubrics, and user manuals were examples of supporting instructional materials.

Three primary assessment tools were used:

1. A training quality evaluation form based on a five-dimensional, five-point Likert scale that was validated by three experts (Index of Item–Objective Congruence,  $IOC = 0.60–1.00$ ); 2. A professional competency assessment that uses a rubric and includes five performance dimensions ( $IOC = 0.60–1.00$ ); and 3. A student satisfaction questionnaire with 19 items that covers four dimensions ( $IOC = 0.60–1.00$ ). Fourteen students in an experimental group participated in three successive phases of the MIPPTK's implementation. The kit's structure and working procedures were first explained during an orientation session. Second, with the help of task sheets, active learning sessions allowed participants to practice hands-on in simulated industrial settings. In order to show their learned competencies, students lastly finished performance-based practical exams using the MIPPTK. By emphasizing experiential and performance-based learning, the implementation made sure that students successfully applied their theoretical knowledge to real-world industrial tasks, improving their professional competence in production systems and automation.

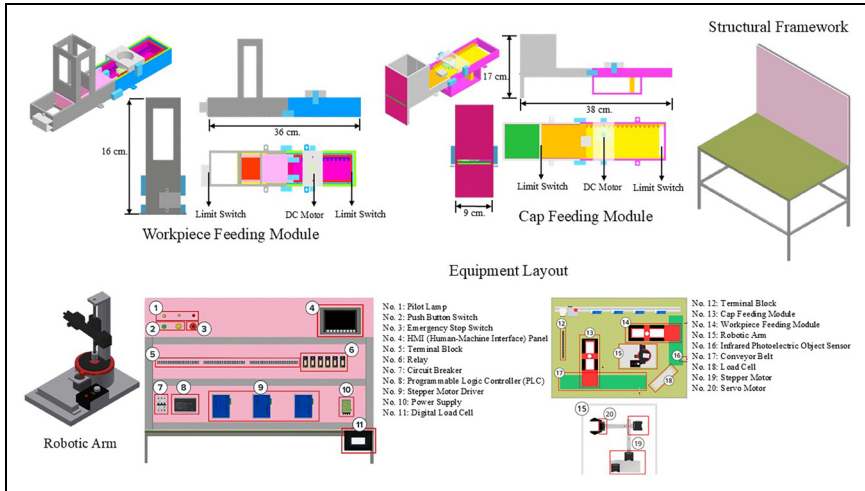


Figure 2. Example of training kit design.

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**Details of the Skill Training Set**

- No. 1: Pilot Lamp
- No. 2: Push Button Switch
- No. 3: Emergency Stop Switch
- No. 4: HMI (Human-Machine Interface) Panel
- No. 5: Terminal Block
- No. 6: Relay
- No. 7: Circuit Breaker
- No. 8: Programmable Logic Controller (PLC)
- No. 9: Stepper Motor Driver
- No. 10: Power Supply
- No. 11: Digital Load Cell
- No. 12: Terminal Block
- No. 13: Cap Feeding Module
- No. 14: Workpiece Feeding Module
- No. 15: Robotic Arm
- No. 16: Infrared Photoelectric Object Sensor
- No. 17: Conveyor Belt
- No. 18: Load Cell
- No. 19: Stepper Motor
- No. 20: Servo Motor

Figure 3. Supporting documents for the training kit.

### Data collection procedure

The researcher initiated the teaching process by informing the students about the instructional approach that involved the industrial production process skills training kit, in order to clarify for the learners the learning objectives and the purpose of instruction. Fourteen students comprising the experimental group were taught using active learning activities with the industrial production process skills kit that included eleven interconnected tasks that focused on circuit connection, sensor installation, PLC programming, and HMI

design for process control. The students participated as a class in making seven small groups to complete task requirements, documenting their activities on work instruction forms. Instructional efficiency during learning (E1) was determined from the task completion data. After completing the learning tasks, performance testing in the experimental and control groups included four performance tests related to industrial process control, such as sensor installation, motor and light control using PLC programming, load cell positioning and application, and HMI design. Data from the performance testing performed after learning was used to assess the efficiency of instruction after learning (E2). Each student's professional competency was measured based on five behavioral measures. The experimental group also completed a satisfaction survey to reflect on their learning experience utilizing the kit as an intervention. All data were analyzed using both descriptive and inferential statistics to assess the impact of the developed training kit on learning outcomes, which included values of E1/E2 after learning for each task, competency results, and satisfaction ratings.

### *Data analysis*

Data were analyzed in the following manner. The quality of the industrial process skills training kit was analyzed using means ( $\bar{x}$ ) and standard deviations, categorized across five levels ranging from needs improvement (1.00–1.49) to excellent (4.50–5.00). Instructional efficiency of the PLC-based motor control training kit was calculated using the formula for efficiency described by Promwong<sup>17</sup>. E1 is process efficiency, and E2 is outcome efficiency, with an efficiency criterion of 85/85 for both. Professional competency was analyzed between the experimental group and the control group using an independent t-test analysis at the 0.05 significance level. Student satisfaction with the training kit was analyzed using a five-point Likert scale,<sup>18</sup> which ranged from very low (1.00–1.50) to very high (4.51–5.00).

## **Research results**

### *Development of the industrial production process training kit*

The Industrial Production Process Training Kit was assessed by experts in five areas: (1) instructional documentation, (2) structure, (3) support for professional skill development, (4) usability, and (5) overall appropriateness. Table 1 summarizes the evaluation results, which show that the kit's overall quality was rated as very good ( $\bar{x} = 4.63$ , S.D. = 0.53). The dimensions that scored the highest were instructional documentation ( $\bar{x} = 4.71$ , S.D. = 0.46), closely followed by structure, materials, and equipment ( $\bar{x} = 4.70$ , S.D. = 0.47). Additionally classified as very good were ratings for overall appropriateness ( $\bar{x} = 4.65$ , S.D. = 0.59), usability ( $\bar{x} = 4.56$ , S.D. = 0.65), and support for professional skill development ( $\bar{x} = 4.50$ , S.D. = 0.51). These results show that the training kit has strong structural integrity, extensive and well-structured instructional materials, and a high level of relevance to the development of industrial competencies. This study adds to the body of knowledge in instructional design from an academic perspective by showing how

**Table 1.** Quality evaluation results of the industrial production process training kit.

Item	$\bar{x}$	S.D.	Quality level
1. Structure, Materials, and Equipment	4.70	0.47	Very good
2. Instructional Documents	4.71	0.46	Very good
3. Support for Professional Skills	4.50	0.51	Very good
4. Usability	4.56	0.65	Very good
5. Overall Appropriateness	4.65	0.59	Very good
Overall Quality	4.63	0.53	Very good

**Table 2.** Efficiency of the industrial production process training kit in terms of skill performance (n = 14).

Assessment type	Full score	Mean score	Efficiency (%)
Practice during learning (E1)	165	144.92	87.83
Practical post-test (E2)	80	68.71	85.89
E1/E2	–	–	<b>87.83/85.89</b>

creative training tools can be methodically created and verified using expert-based standards like the Index of Item–Objective Congruence (IOC). Practically speaking, the training kit advances the fields of industrial education and training pedagogy by acting as an efficient pedagogical link between theoretical instruction and industrial practice.

### *Efficiency analysis of the training kit*

An experimental implementation with 14 students was used to assess the Industrial Production Process Training Kit's effectiveness. Students received an average practice performance score (E1) of 144.92 out of 165 points (87.83%) and a post-test performance score (E2) of 68.71 out of 80 points (85.40%), as indicated in Table 2. By surpassing the predefined standard criterion of 85/85, the computed efficiency ratio ( $E1/E2 = 87.83/85.40$ ) validated the training kit's instructional efficacy. The use of E1/E2 efficiency metrics as reliable measures of instructional quality is empirically supported by these findings. The results also provide fresh perspectives on how to incorporate hands-on learning into industrial production processes. By confirming a performance-based training framework that improves cognitive and psychomotor learning outcomes, this study makes scholarly contributions to the fields of industrial education and technology.

### *Professional competence of students*

Five key indicators were used to assess the learners' professional competencies. Overall, the competency level was rated as very good (S.D. = 0.23,  $\bar{x} = 4.64$ ). With a mean score of 4.79 for equipment installation and 4.54 for practical operation, both indicators fell into

**Table 3.** Presents the comparison of students' professional competencies between the experimental group and the control group.

Competency indicator	Group	n	M	SD	t	df	Sig																																																								
1. Problem analysis and task design	Experimental	14	4.64	0.25	3.03*	23	0.000																																																								
	Control	14	3.93	0.53				2. PLC programming	Experimental	14	4.57	0.26	2.47*	22	0.000	Control	14	3.93	0.69	3. Equipment installation	Experimental	14	4.79	0.18	8.57*	23	0.000	Control	14	3.07	0.38	4. System testing and troubleshooting	Experimental	14	4.64	0.25	4.71*	22	0.000	Control	14	3.50	0.58	5. Practical operation	Experimental	14	4.57	0.26	8.50*	23	0.000	Control	14	3.14	0.13	Overall	Experimental	14	4.64	0.23	10.52*	117	0.000
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	Control	14	3.93	0.69				3. Equipment installation	Experimental	14	4.79	0.18	8.57*	23	0.000	Control	14	3.07	0.38	4. System testing and troubleshooting	Experimental	14	4.64	0.25	4.71*	22	0.000	Control	14	3.50	0.58	5. Practical operation	Experimental	14	4.57	0.26	8.50*	23	0.000	Control	14	3.14	0.13	Overall	Experimental	14	4.64	0.23	10.52*	117	0.000	Control	14	3.51	0.57								
3. Equipment installation	Experimental	14	4.79	0.18	8.57*	23	0.000																																																								
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	Control	14	3.51	0.57																																																											

\*Statistically significant at the 0.05 level ( $p < 0.05$ ).

the very good range. The robustness of the developed training approach was confirmed by the high ratings given to problem analysis, programmable logic controller (PLC) programming, and troubleshooting skills. These results show that the Industrial Production Process Training Kit successfully improved learners' professional preparedness and applied technical skills, especially in industrial settings related to mechatronics. At the 0.05 level of statistical significance, students in the experimental group demonstrated significantly higher levels of both overall and domain-specific professional competencies than those in the control group, as shown in Table 3. The pedagogical value of experiential and hands-on learning approaches included in the training kit is highlighted by this result. It emphasizes how these methods can support the development of new skills, the cognitive fusion of theory and practice, and sophisticated problem-solving skills that are in line with Industry 4.0 competency frameworks.

### *Learner satisfaction with the training kit*

Four aspects of learner satisfaction with the Industrial Production Process Training Kit were assessed: overall satisfaction, instructional design, content, and usability. Table 4 summarizes the overall satisfaction score, which was rated as high ( $\bar{x} = 4.52$ , S.D. = 0.50). With respect to the system's ease of use, the efficient integration of automation components (such as PLCs, sensors, and conveyors), and the lucidity of instructional manuals, the usability dimension was evaluated the highest ( $\bar{x} = 4.79$ , S.D. = 0.41). With an overall satisfaction rating of  $\bar{x} = 4.55$  (S.D. = 0.54), learners also demonstrated a high degree of confidence in their capacity to apply the knowledge and skills they had learned to actual industrial settings. From an academic standpoint, these results provide fresh empirical support for the learner-centered assessment of training kit efficacy, which was previously neglected in favor of expert-based evaluations. The kit's

**Table 4.** Learners' satisfaction with the training kit for industrial production process skills (n = 14).

Category	$\bar{x}$	S.D.	Level of satisfaction
Aspect 1: Content and Appropriateness of the Training Kit	4.39	0.49	High
Aspect 2: Learning Activity Design	4.36	0.48	High
Aspect 3: Usability of the Training Kit	4.79	0.41	Highest
Aspect 4: Overall Satisfaction	4.55	0.54	Highest
Overall Average	<b>4.52</b>	<b>0.50</b>	<b>Highest</b>

value as a sustainable instructional innovation that improves learner engagement, confidence, and readiness for industrial employment is practically confirmed by the high satisfaction levels.

In every evaluation dimension, the Industrial Production Process Training Kit performed exceptionally well. It met the highest quality standards, outperformed the E1/E2 efficiency benchmark, successfully improved learners' professional competencies, and got the highest participant satisfaction ratings. All of these results support the instructional innovation's theoretical validity and real-world relevance. The results provide fresh empirical support for the methodical planning, execution, and assessment of innovative teaching strategies in industrial and vocational education. The study also creates a scalable and replicable instructional model that combines learner-centered pedagogy with technical rigor, which has wide adoption potential in both academic institutions and industrial training settings. The theoretical underpinnings of Industrial Education and Technology are thus reinforced by this research, which also offers practical insights that complement global trends in competency-based and Industry 4.0-oriented learning frameworks. Table 5 provides a comparison of these results with those of earlier research.

## Discussion

To support professional skills of the students learning the mechatronics engineering, an Industrial Production Process Training Kit was created and tested. The interpretation of the findings as applied to the study purposes shows a theoretical development along with a positive impact on the sphere of industrial education and technology.

To start with, the development of the training kit that was structured according to the ADDIE model (analysis, design, development, implementation and evaluation) delivered excellent outcomes in all the dimensions considered by the experts. The kit was rated very high in terms of overall suitability, professional skills support, instructional documentation, usability and structural integrity. As per the evidence of Umpornpaiboon<sup>8</sup> and Branch<sup>10</sup> who similarly also reported good instructional results in learning modules which relied on the ADDIE, the results validate the role of systematic instruction design methods. Such continuity goes to show how the ADDIE model remains relevant and flexible when it comes to guiding the development of practice-driven, industry-based educational materials.

**Table 5.** Comparative analysis of mechatronics and PLC training kits for enhancing student competencies (2020–2025).

Previous report / author	Finding	Limitation	Application	Ref.
Sanit Khwanmuang (2021)	Created a PLC training kit that combined pneumatic and motor systems; assessed the effectiveness of the instruction (E1/E2).	limited to simple control functions; it lacked process interconnection and modularity.	PLC and pneumatic training that is introductory.	Khwanmuang <sup>19</sup>
Wisn Wangworawong et al. (2024)	Engineering Design Process The Engineering Design Process was used to design and test a pneumatic kit with sensor based on PLC and practical industrial control.	focused on running one subsystem as opposed to a complete manufacturing system.	On-job training on simple automated pneumatic systems.	Wangworawong et al. <sup>20</sup>
Piyawat Sritram et al. (2021)	Created an automated system of material-sorting kit based on R&D with the help of PLC-controlled DC motions and pneumatic actuators, combined with FluidSIM and Ladder Diagram software.	Only able to simulate single sub systems; did not have a complete replication of an industrial process.	Only able to simulate single sub systems; did not have a complete replication of an industrial process.	Sritram et al. <sup>21</sup>
Boonkert Sontipan et al. (2021)	Developed a PLC programming kit that was tested using role-playing simulations with real learners.	concentrated primarily on programming; there was no integrated workflow for design and production.	PLC programming using simulated tasks and fundamental management modules.	Sontipan et al. <sup>22</sup>

(continued)

Table 5. Continued.

Previous report / author	Finding	Limitation	Application	Ref.
Bunjittum et al. (2020)	Developed a PLC-sensor control kit with experimentation and assessments; a notable improvement in learning proved by the E1/E2 efficiency of 84.50/82.25.	Limited to simple PLC-sensor integration; it lacked an industrial context and modular scalability.	PLC-sensor control teaching aid for electrical and electronic education.	Bunjittum et al. <sup>23</sup>
Rusimamto et al. (2021)	Created a PLC training module and kit using Thiagarajan's 4D (Define-Design-Develop) model as a basis. Experts and students verified the high viability of the Omron CPIE PLC-based traffic light, parking gate, and lamp control simulation (validity 85.18%; module 83.33%; response 85%/82.17%).	There was no long-term learning assessment, validation was based on a small trial group, and the dissemination phase was skipped.	Instructional media for PLC competency in electrical engineering education.	Rusimamto et al. <sup>24</sup>
Artiyasa et al. (2020)	Used the Omron GPM1A PLC and NB7W HMI to create a portable PLC-HMI kit that included practical exercises (such as heating and mixing water). showed high learner satisfaction and notable learning gains (pretest 52.7 → posttest 85.6).	SCADA integration was absent, the I/O capacity was limited to 10 channels, and it was not appropriate for complex or networked automation.	PLC-HMI exercises for basic training in industrial automation.	Artiyasa et al. <sup>25</sup>
Figan Dalmış (2022)	Built a PLC-based system with real-time Modbus RS485 control	Limited to basic automation and position control; neither	PLC/HMI automation training at the university	Dalmış et al. <sup>26</sup>

(continued)

**Table 5.** Continued.

Previous report / author	Finding	Limitation	Application	Ref.
	and position monitoring that integrated a linear motion system, servo motor, HMI, and pneumatic cylinder.	quantitative learning evaluation nor IoT/SCADA integration are available.	level that facilitates modular growth.	
This work (2025)	Using the ADDIE model with iterative E1/E2 and satisfaction evaluation, a modular automated manufacturing training kit was developed that integrates PLC, sensors (proximity, IR, ultrasonic, and loadcell), DC/stepper motors, and HMI-conveyor systems.	Needs long-term usability testing and extensive validation.	An extensive automation training kit that is compatible with Industry 4.0 for the development of professional skills.	–

Second, the efficiency analysis verified that the training kit exceeded the generally recognized benchmark of 85/85 with an E1/E2 efficiency ratio of 87.83/85.89. In this case, E1 stands for learning process efficiency, and E2 for learning outcomes after instruction. This result shows that active, hands-on participation produces greater cognitive and psychomotor gains than theoretical instruction alone, which empirically supports the efficacy of experiential learning approaches.<sup>5</sup> The outcome is also in line with,<sup>12,17,18</sup> which found that motor control training based on Programmable Logic Controllers (PLCs) produced similar E1/E2 efficiencies (87.43/85.12). When taken as a whole, these results demonstrate how simulation-supported and experience-based learning can routinely outperform efficiency standards in industrial education settings.

Third, students exposed to the training kit showed noticeably greater proficiency in equipment installation, system operation, problem analysis, and PLC programming, according to a comparison of professional competencies between the experimental and control groups. This demonstrates how well the training kit fosters practical technical knowledge and system-level problem-solving skills. Realistic industrial scenarios and experiential learning techniques, which together close the gap between theoretical instruction and real-world application, are what give the kit its superior competency outcomes.

Fourth, the usability dimension received the highest mean score ( $\bar{x}=4.80$ ), while learner satisfaction was rated at a high level ( $\bar{x}=4.49$ ). Students said the kit was easy to use, useful, and efficient at helping them learn automation systems. The effectiveness of the ADDIE-based instructional structure, which emphasizes sequential organization, logical content flow, and learner-centered interaction, is attested to by such positive feedback. These results support those of Umpornpaiboon<sup>8</sup> which discovered that when instructional tools were created to incorporate interactive and applied learning components, students' satisfaction levels were similarly high.

Overall, by offering empirical support that methodically created industrial training kits not only produce measurable gains in learning performance but also raise learner engagement, motivation, and satisfaction, the study contributes to the body of current literature. The created kit is positioned as an example of scalable instructional innovation for technical education and workforce development due to its integration of usability, industrial relevance, and pedagogical coherence. All things considered, the created training kit showed excellent quality, effectiveness, and learner impact while offering fresh perspectives on methodical and experiential instructional design. It is distinct from other studies in that it incorporates real-world industrial production processes into a practical learning environment designed for mechatronics students, expanding both theoretical knowledge and pedagogical practice. This study theoretically confirms that complex, skill-based, and industry-driven training contexts can be successfully adapted to systematic design frameworks like ADDIE. In practice, the training kit promotes scalability and interdisciplinary application by acting as a prototype model for creating educational resources across multiple engineering and technology disciplines. The work's theoretical and practical merits make it a potential benchmark reference for future research and innovation in the field of industrial education and technology. It is renowned both domestically and abroad for its academic rigor and practical relevance.

## Recommendations

The study's conclusions support the Industrial Production Process Training Kit's academic and applied value. The kit should be carefully incorporated into classes covering automation systems, mechatronics, and industrial production processes in order to optimize its educational impact. This strategy will align learning objectives with Industry 4.0 skills and strengthen students' practical competencies. To improve learner engagement, encourage critical and analytical thinking, and fortify higher-order problem-solving skills, it is also advised to integrate the training kit into active learning and project-based learning frameworks. Incorporating the training kit into capstone projects and internship programs can also help students become more prepared for the workforce by bridging the gap between academic theory and real-world industrial settings. Instructors should participate in professional development workshops that emphasize the use of the kit in both teaching and assessment procedures in order to guarantee pedagogical consistency and efficient use. Broader studies that include participants from various academic institutions and business sectors are advised for future research to evaluate the training kit's generalizability and contextual adaptability. The sustainability of learning outcomes, especially with regard to the long-term retention of technical competencies and problem-solving abilities, should also be investigated through longitudinal studies.


Also, further studies are required to examine the digitization of the training kit by using virtual or augmenting reality-based simulations so that they can support scalable, flexible, and intermingling learning design appropriate to present engineering training. The integration of the 21st century skills such as creativity, critical thinking, teamwork and communication will also make the results of training more relevant to the changing industrial and technological environment.

In summary, these suggestions serve as a blueprint to the further growth of the theory along with the practical application in the sphere of technology and industrial education. The present research provides a new criterion of integrating practical training and systematic teaching design in technical education. It is a convenient resource to the researchers, educators and business people that wish to create innovative, scalable and contextually relevant training systems. In the future, it can be a model in terms of national and international appreciation of its capabilities in industrial and educational innovation projects.

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### Data availability statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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