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Implementation of IoT-Based Human Machine Interface-Learning Media and Problem-Based Learning to Increase Students' Abilities, Skills, and Innovative Behaviors of Industry 4.0 and Society 5.0

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***Abstract* – This research aims to discover students' increase abilities, skills, and innovative behaviors after being taught using a problem-based learning model using IoT-B-HMI-LM in the form of Trainer Kit. The study was conducted using quantitative methods on 69 students and eight teachers with electrical engineering expertise at vocational high schools in East Java, Indonesia. The stratified simple sampling technique was used to determine the research sample. Data analysis used descriptive statistics and paired sample t-test.**

The sample is determined by stratified random sampling. Data analysis with descriptive statistics and paired t-test. The results of the study show an increase in students' abilities, skills, and innovative behavior after being taught a problem-based learning model using the IoT-B-HMI-LM in the form of a Trainer Kit.

***Keywords* - Media, human machine interface, internet of things, student skills, industrial era 4.0.**

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1. Introduction

Vocational high schools (VHS) aim to purvey students ready to work in the industry [1]. Competencies of graduates are expected to have a high level of skills or HOTS, including critical, collaboration, creative dan innovative, communication skills-4C. Teachers must prepare students to enter The Fourth Industrial Revolution (4IR), marked by the change of digital systems to intelligent automation systems connected to all activities via the internet.

Society 5.0 aims to increase specific points in the future significantly. Five crucial aspects of Society 5.0 include diversity, decentralization problem solving, resilience, environmental harmony, and sustainability [2]. Ideally, Society 5.0 is changing contemporary manufacturing so that humans and machines can work together, bringing together the specific cognitive potential of employees and the engineering proficiency of robots in accurately producing innovative behaviors in the workplace [3].

Society 5.0 provides added value to the production by creating products based on consumer needs so that customers are satisfied to enjoy product results that focus on the interaction of machines and humans [2]. Integrating technology, people, virtual spaces, real states, and virtual worlds realizes a real collaborative network [4]. The characteristics in the working world now certainly affect the changing availability of types of work [5].

Graduates must possess new skills to fill the needs of the new type of work. Ten skills relevant to Industry 4.0 [6] are active learning, creativity, critical, , social management, negotiation quality control, judgment and decision making, coordinating with others, and complex problem-solving service orientation.

Twenty-first-century skills must integrate into education because the 4C ability to apply soft skills to real life is more useful than just having hard skills [7]. Global market requires an innovative workforce [8]. Innovation consists of behavioral innovation and technological innovation [7], [8]. Innovation towards technology is marked by the development of behavior and has innovative put on of increase [9], [10]. Innovation is a process that involves an element of initiation and ideas [9]. Self-innovation is a tiered process of identifying problems, coming up with ideas and solutions, combining supportive ideas, creating support networks, and realizing ideas [9], [11]. Innovating and executing new ideas is an innovation of individual behavior [12].

Generating ideas to develop products, provide new services, update work processes, combine concepts to solve problems are individual innovative behaviors [12]. Individual innovation behavior, both managerial and non-managerial can be a fundamental trigger for organizational innovation [13].

Teachers and students are challenged to adaptation, by increasing competence to use digital and android technology-based learning methods appropriately, so that students think critically, competitively, creatively, and innovatively [14]. VHS needs to develop Human Resources (HR), curricular arrangements, rejuvenation of practical facilities and infrastructure, including learning media or Human Machine Interface (HMI) and Internet of Thing (IoT)-based trainer kits, and robotics. Teachers and students are expected to be able to think critically, innovate, have creativity, be communicative, cooperate, and have self-confidence [15].

VHS teachers, at this time, have not all prepared plans and implemented learning, including 4C, and have not implemented much problem-based learning (PBL). Learning tends to be more teacher-centered. The impact is that the quality of education is less than optimal. People can learn well if they are actively involved, not passive recipients of information [15], The Electrification Study Program for Vocational High Schools in East Java Indonesia, is limited in providing a Programmable Logic Controller-Based Trainer Kit. Not all have developed an IoT-Based HMI-Learning Media (IoT-B-HMI-LM) with the form of Trainer Kit. IoT-B-HMI-LM can be a reference that the VHS must have a PLC for training. The number of PLCs often does not match the number of user students. Many learners, including those in vocational high schools, still do not know about virtual remote control in educational institutions [16]. The reasons are high prices and limited human resources. The percentage of VHS teachers who create or modify lesson props and practice is 30.30%, and the highest medium rate is in the form of PowerPoint [17].

The preliminary survey results showed that companies with large numbers of Industry 4.0 concepts had recognized it but did not yet know how to implement it [18]. As a result, few companies invested in training using automatic and modern machines for their employees. Training has an important role for the academic world in preparing workforce competencies which are often known as the concept of education 4.0 [19]. Equipment must also have industry standards for students to be accustomed to using industrial equipment [21].

HMI is a connecting system between machine and human technology. The increase in HMI also has an impact on the development of automation technology initially in the form of buttons and indicators, now it is capable of monitoring and analyzing complex processes and procedures [24]. HMI functions to visualize in real time. The design is easy to customize, making it easier for physical work [22]. HMI system as an electric motor monitoring using the software. The type must be compatible with the PLC so that the data matches the design. The HMI system has been able to work online and is real-time in identifying the eroded data sent to the Input/Output (I/O) port of the controller system.

IoT is a concept to expand expediency through continuous connections on the internet, controlling electronic equipment over long distances [23]. Each part of it uses wireless devices and their control over the internet [24]. IoT can transfer data over the network without needing interaction between people. In its application, IoT identifies, tracks and monitors objects and triggers accurate times and automatic events [25].

Everything that is the carrier of information from the source to the recipient is the definition of the media [26], [27]. The media's focus is the use of technology plus concepts and contexts [27]. Learning media in terms of their usefulness in the actual object, a model object, or an artificial object in a trainer kit [28]. The VHS trainer kit consists of imitations of real objects accompanied by instructions for use in the form of worksheets or modules.

IoT-based HMI media such as trainer kits using PLC, HMI, and IoT main components can be used for automatic control learning technology. Product trainers from existing automation manufacturers such as Siemens [29], Omron [30], Schneider [31], Raspberry Pi uses HMI GUI using python as its program language [32], and others utilize Arduino in designing and building independently [33]. Student skills according to the relevan of EI 4.0 and ES 5.0 before and after learning with PBL material Phase Alternating Line (PAL), Proportional Integral Derivative (PID), and Fuzzy Control model Trainer Kit [34].

The IoT-B-HMI-LM, developed as a trainer kit, uses industry-standard equipment and materials. PLC combined with HMI, IoT, and internet wireless devices can control a process remotely. This media can maintain various equipment, such as equipment in parking lots and electric motors in the production process. IoT uses the TPACK approach, PBL model and problem solving assignment method.

There are demands for learning needs and demands for innovative competencies in the EI 4.0 and ES 5.0, while the limitations of the existence of IoT-based HMI learning media that VHS still has. For this reason, it is urgent to study "Implementation Of Iot-Based Human Machine Interface Learning Media And Problem-Based Learning To Improve Students' Abilities, Skills Innovative And Behaviors Of Industry 4.0 And Society 5.0". This research aims to find out students' increased abilities, and skills, and innovative behaviors after being taught using a problem-based learning model using IoT-B-HMI-LM in the form of a Trainer Kit.

2. Method

This development research used the ADDIE model. The core of development in the ADDIE was to analyze students' background and needs, a set of effective, efficient, formative and summative tests, relevant environmental, material needs and learning arrangements independently, and learning outcomes [35]. The ADDIE model was appropriate for this study because it adapts well to various conditions. The degree of flexibility of this model is high and effectively used. The ADDIE model provides structured framework for instructional development interventions, evaluation, and improvement according to the available stages.

The IoT-B-HMI-LM development uses the ADDIE stages: analyzing, designing, developing, implementing, evaluating, and perfecting [35]. The analysis includes an analysis of the student's initial ability and the competence expected to be possessed by the student. Students studied the Expertise Competency of Electrical Power Installation Engineering (ECEPIE). The initial ability that students must have is understanding and analyzing the control of electromagnetic electric motors. Students are expected to have competencies that are understanding, skilled, and innovation behavior in designing, manufacturing, implementing, and assessing HMI-IoT-PLC-based motor control. Design stages, the design form of the IoT-B-HMI-LM as Figure 1.

Figure 1. Front view IoT-B-HMI-LM

IoT-B-HMI-LM specifications in trainer kits, components, and tools are assembled on boxes from the main material acrylic packed like luggage bags.

The implementation was carried out on 69 students and 8 ECEPIE VHS teachers in East Java, Indonesia. The determination is by stratified random sampling implementation to determine the feasibility of the developed IoT-B-HMI-LM. The feasibility of learning media is reviewed from the validity, practicality, and effectiveness of [36].

The validity aspect is in the form of validity of the contents of IoT-B-HMI-LM in the form of a Trainer Kit, media components, and materials are linked in a consistent manne. Validity is refers on expert validation results. The practical aspect shows that learning media can be used under normal conditions, according to experts and practitioners, and can be applied by teachers and students [36]. Practicality is based on the response of teachers and students to the media and learning. Indicators of response to IoT-B-HMI-LM include ease of understanding, clarity of instructions or information, display, motivating, interesting, arousing curiosity, and making the active ask, answer, and practice. Indicators of implementing PBL phases using IoT-B-HMI-LM. The steps in PBL are giving students problems, grouping them to solve problems, helping them carry out investigations independently and in groups, developing - presenting their work, evaluating the results of problem-solving, and reflecting [37].

Effectiveness shows effective media according to experts based on experience and then used the results are as expected [36]. Effectiveness is based on the significance of differences in innovative behaviors of skills, and abilities, before and after being taught using PBL using developed IoT-B-HMI-LM. The indicators are the ability of students to make program design, leader diagram, simulate, implement using the trainer kit on Three-Phase Electric Motor Control Problems (3P-EMC-P), Skills, including active problem solving, critical thinking, designing and executing programs, implementing programs created, working with strategies, monitoring work and teams, leadership in groups, caring and having influence, working together to solve problems, having a perspective and orientation, social, analyze, evaluate, evaluate, assess and decide.

Innovation behavior during learning, includes exploring new ways, adopting new products, generating new ideas, fighting for new ideas, solving problems with new ideas, implementing new ideas, completing tasks using new ways, working in teams with new ideas, defending new ideas, and form a work network..

Before the implementation stage, the researchers conducted expert validation of media experts, evaluation, and material content. Validation aims to determine the validity of IoT-B-HMI-LM, teacher response questionnaires and student responses, observation sheets on learning implementation, and pretest-postest of students' skills, abilities, and innovation behaviors. When the instrument measures against what is measured according to the established design, then it is valid [38]. In quantitative research, validity shows a measuring instrument capable of measuring what it should measure. Instruments other than reliable must also be valid [39]. Validity rating is based on V Aiken [40], invalid if the value < 0.3 and valid if > 0.3. Assessment sheets or instruments are also tested before use at the implementation stage to determine their reliability. A measure of reliability using the Cronbach Alpha coefficient on instruments with a Likert scale [41]; Low reliability 0.00-0.50, medium 0.50-0.70, high 0.70-0.90, very high 0.90–1.00 [42].

Data on the validity and practicality of learning media were analyzed with descriptive statistical techniques. T-test paired samples explore the significance of differences in pretest-postest results with a significance level of 5%. IoT-B-HMI-LM feasibility indicator if valid, practical, and effective [36]. Effective if, at the time of implementation of the paired sample t-test results, the results differ significantly between the initial ability and the final ability, between the initial skill and the last skill, and between the initial individual innovation and the final individual innovation. Evaluation stage, analyzing deficiencies that occurred during the research process, correcting them, and continuing to compile reports.

3. Results and Discussions

The developed and implemented media is the IOT-B-HMI-LM with the Trainer Kit dimension and uses PBL in its implementation.

Results of Media Development

The system on the media works in real-time, by reading data that has been sent at the input/output port controller. What HMI reads is on the port com, serial port, RS232 port, and USB port. HMI creates visualizations based on natural systems or technologies.

To design HMI can be done easily to adjust to facilitate the physical condition of the work done. The HMI system is used to monitor 3 phasa electric motors using Cx-designer software. The OMRON NB7W TW00B HMI type is compatible with the PLC used (CP1E type), so the data obtained follows the design.

The controller port read by HMI is in the form of a port com, USB port, and RS232 port. HMI monitors understand a process's flow and can supply audio video and alarm notifications in the incident of an strange state of the production process. IoT components in each part use wireless devices and are controlled over the internet.

Media validation is put on the results of three experts. Aspects and validation results of IoT-B-HMI-LM are presented in Figure 2, with an average value of 86.50 or 0.8650 with valid categories [40]. These results prove that the IoT-B-HMI-LM is feasible to implement in PBL learning with control 3P-EMC-P subject matter.

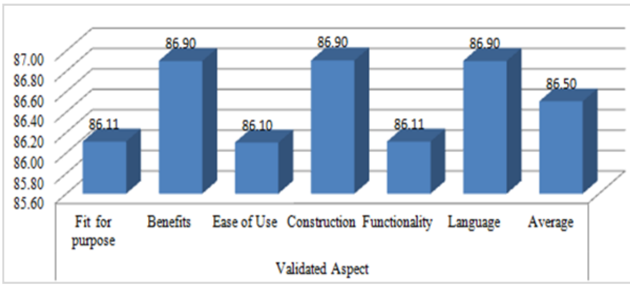

Figure 2. Aspects and results of IoT-B-HMI-LM validation

Research Instruments

Aspects of the teacher and student response questionnaire were validated early to understand information clarity, display suitability, motivation, and attractiveness, cultivate curiosity, actively ask, answer, and practice with an average of 86.58% % or

86,58 valid categories [40]. Validated aspects of the observation sheet for learning purpose fit, apperception, main activities, and activities, spend of time, display, language with an average of 86.40% (0.8640) valid categories.

Validated aspects on the instrument or assessment sheet of the ability to make 3P-EMC-P concept truth, relevance of question, assessment rubric, suitability variable ability, language, format quality, contains hots, EI 4.0 and society 5.0. An average of 87.96 % (0.8796) of categories is valid [40]. Validated aspects of the observation assessment instrument of student skill concepts truth, relevance to purpose, relevance to purpose, time allocation accuracy, appropriate grading rubric, language, constraints, form at quality, skill EI 4.0, and society 5.0, average 88.10% (0.8810) valid categories [40]. Aspects validated for the innovation behavior assessment instrument include suitability for purpose, quality of format, concept correctness, language, scoring rubric, accuracy of time allocation, contains life skills P21, EI 4.0, ES 5.0, average 85.71% (0 ,8571) valid category.

The reliability of each instrument was calculated using the Cronbach Alpha formula, content validity was determined by the day of expert validation. A summary of the validity and reliability values for each research instrument is described in Table 1.

Table 1. Reliability and Validity of instruments

Instrument	Validity	Alpha Cronbach
Teacher/student response	0.8658/V	0.74/H
Implementation of learning	0.8640/V	0.77/H
Ability	0.8796/V	0.78/H
Innovation behavior	0.8571/V	0.74/H
Skills	0.8810/V	0.74/H

Note: V:Valid, H:High

It can be seen that the reliability value is > 0.70, meaning that it is reliable [42] and valid because each instrument has V Aiken is > 0.3 [40]. All instruments can be used in research because they are reliable and valid [39]. The average response of teachers and students is 86.58% or very high (Figure 3) [43].

The implementation of the teacher in carrying out learning was observed by two observers, indicating that the teacher had carried out learning according to syntax PBL uses IoT-B-HMI-LM. The aspect of implementing PBL learning using the IoT-B-HMI-LM averaged 86.40% in the very high category [43].

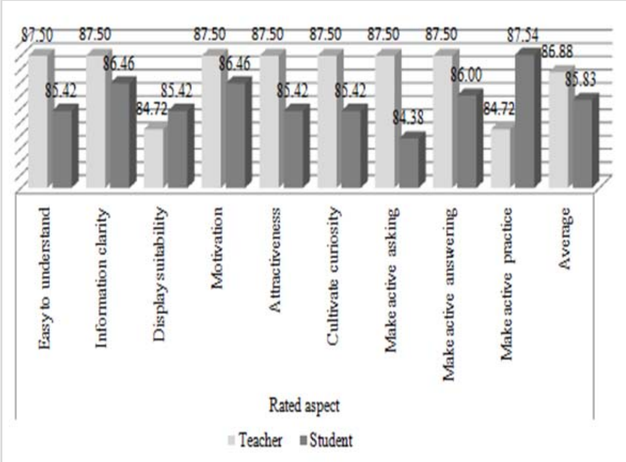

Figure 3. Student and teacher response to IoT-B-HMI-LM

Learning Outcome

The troubleshooting topics of the 3P-EMC-P consist of various problems for the make process or system applications, including design of controlling the starting current, reversing the direction of rotation, several motors rotating alternator, motors rotating sequentially, constant rotating, rotating and automatic stops, using the IoT-B-HMI-LM. The analysis of the implementation of learning averaged 83.57 (Figure 4).

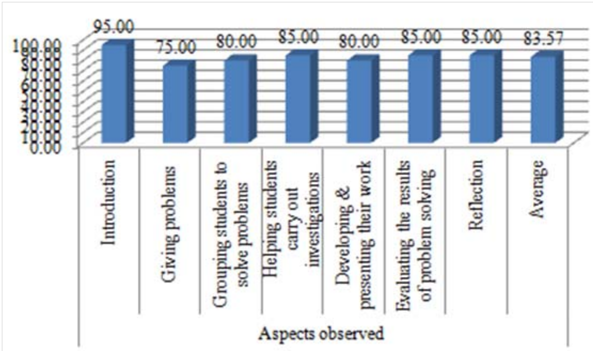

Figure 4. Learning implementation

The descriptive statistics at the pretest average is 41.217, increased to 77.170 at the post-test or final ability time (Table 2).

Table 2. Descriptive statistics

Statistic	Ability		Innovative Behavior		Skills	
	Initial	Final	Initial	Final	Initial	Final
Mean	41.217	77.170	47.681	77.864	44.368	81.290
Median	41.000	79.000	48.000	79.000	45.000	83.000
Variance	58.320	46.731	77.603	44.251	76.877	50.544
SD	7.367	6.836	8.809	6.652	8.868	7.102
Min.	20.000	56.000	20.00	62.00	61.000	60.000
Max.	57.000	91.000	64.00	93.00	44.000	97.000
Range	37.000	37.000	40.00	31.00	12.000	37.000

In contrast, the innovative behavior of individuals at the pretest increased from an average of 47.681 to 77.864 at the post-test. Initial skills at the pretest time averaged 44.368, increasing to 80.362 at post-test or final skills

Normality test results with Kolmogorov Smirnova and Shapiro-Wilk for initial abilities obtain 0.199 and 0.137, while final abilities are 0.570 and 0.152. The initial skills are 0.176 and 0.126; the final skills are 0.070 and 0.492; the initial individual innovative behavior is 0.183 and 0.126; the final individual innovative behavior is 0.068 and 0.593. It is all sig > 0.05, meaning that each data is normally distributed [42]. The homogeneity of variances test results for the ability of the sig value is 0.155, individual innovative behavior is 0.070, and skill is 0.159. Sig values, all > sig 0.05, indicate homogeneous data variance [36].

Thus, the distribution is normal and homogeneous, then an average difference test is carried out, and the results are in Table 3.

The difference in students' abilities on the pretest and posttest was sig <0.0001 or significantly different. Pretest-posttest skill value sig <0.0001 means a significant difference in students' early and late skills [42]. These results show that learning with PBL using the IoT-B-HMI-LM Trainer Kit is effective.

There were significant differences in initial abilities, individual innovative behaviors, and the skills of students implementing 3P-EMC-P before and after being taught the PBL model using the IoT-B-HMI-LM.

There are significant differences in abilities, individual innovative behavior, and student skills in controlling 3P-EMC-P before being compared after being taught with PBL using the IoT-B-HMI-LM Trainer Kit.

Table 3. Paired sample T-Test

	Mean	t	df	Sig. (2-tailed)
Pretest-Postest Ability	-3.600	-59.528	68	.0001
Pretest-Posttest Skills	-3.595	54.307	68	.0001
Pretes-Postest Innovative Behavior	-3.020	-42.028	68	.0001

The aspects studied are based on the skills requirements of EI 4.0 and ES 5.0, P21 learning, and the demands of EI 4.0-ES 5.0.0. The aspects studied are based on the learning demands of P21 and the skills of EI 4.0 and ES 5.0. Everyone must have the skills of technology literacy, human literacy, data literacy, and be able to adapt to the EI 4.0 - ES 5.0 workflow side by side.Technology in life supports humans [5]. The IoT-B-HMI-LM Trainer Kit implemented with PBL can improve students' abilities, individual innovative behavior, and skills in dealing with EI 4.0 and ES 5.0.

The following relevant research results support this research. Student responses are good to the HMI Trainer Kit learning media subject matter of automation techniques, valid and good performance according to experts[44]. IoT properly combines PLC in remote pneumatic labs and students become more skilled in dealing with EI 4.0 [45]. The IoT Trainer Kit can be used formally for practical work related to the EI 4.0 automation industry[46]. The Trainer Kits can influence the student's process of obtaining a student learning experience [29]. Learning using a PLC Trainer Kit can improve student achievement [47]. There is a significant effect PBL on learning outcomes. [48]. The PLC based Electric Machine Training Kit performs satisfactorily. [30].

Effective media used by teachers makes students' attitudes more positive, encourages students' self-motivation, demonstrates factors and ideas related to important topics and concepts, encourages relevance and credibility, and improves understanding [49]. Student learning outcomes can be improved by using IoT-based learning support media [50]. improving learning outcomes effectively can be done by implementing IoT-based learning media [51]. Students who learn to organize a product or service problems collaboratively can increase flexibility, motivation, engagement, self-esteem, achievement orientation, self-management, future orientation, content knowledge, thinking skills, creativity, social, creating and managing problems [52].

Virtual laboratories and remote control in education are increasingly important and relevant for students in the 21st century [16]. Measurement data detected by IoT sensors from three locations can be a basis for collaborative learning. Teachers' creativity can improve students' ability to think critically in determining learning strategies in several subjects [53]. PBL influences learning learning achievement, motivation, critical thinking skills [54], PBL positively influences student learning outcomes [20], and learning outcomes outing network are taught with PBL better than direct-instruction, and there is motivation interaction and PBL on learning outcomes [20].

4. Conclusion

There are increases and significant differences in abilities, individual innovative behavior, and students' skills in solving problems controlling electric motors before and after being taught with PBL using the IoT-B-HMI-LM Trainer Kit. Learning with the PBL model using IoT-B-HMI-LM in a Trainer Kit could improve students' abilities, innovative behaviors, an skills in EI 4.0 - ES 5.0. These findings have implications for learning innovation in enhancing students' abilities, creative behaviors, and skills. In the future, teachers can consider these findings in efforts to improve student competence in Industry 4.0 and Society 5.0.

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