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Development of a hybrid training model based on the Internet of things and problem-based learning to enhance technicians' competency in vehicular air conditioner repair

Desarrollo de un modelo de entrenamiento híbrido basado en el internet de las cosas y el aprendizaje basado en problemas para mejorar la competencia del técnico en la reparación del aire acondicionado vehicular

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Abstract
The objectives of this research were the following: 1) to develop a hybrid vehicular air conditioner repair training model based on Internet of Things for technicians; 2) to compare their competency and achievement in vehicular air conditioner repair to those of the control group. The samples were 260 technicians, selected by a Multi-stage Random Sampling method. They were divided into two groups: 130 technicians in an experimental group and 130 technicians in a control group. The research instruments were as follows: (1) a Hybrid training model based on Internet of Things and problem-based learning; (2) a competency test; and (3) a achievement test. Data analysis was conducted using means, standard deviation, and one-way MANOVA. The results of the study were as follows: 1) A hybrid training model consisting of 3 components—1) hybrid online and face to face training, 2) Internet of things, and 3) problem-based Learning; 2) The experimental group of technicians achieved significantly higher scores in the competency and achievement tests than those achieved by the group control, at .05 level.
Keywords hybrid training, internet of things, problem-based learning

Resumen
Los objetivos de esta investigación fueron los siguientes: 1) desarrollar un modelo híbrido de reparación-entrenamiento de aire acondicionado vehicular basado en Internet de las cosas para los técnicos; 2) para comparar su competencia y logros en la reparación de aire acondicionado vehicular con los del grupo de control. Como las muestras fueron 260 técnicos, seleccionados por un método de muestreo aleatorio de etapas múltiples. Se dividieron en dos grupos: 130 técnicos en un grupo experimental y 130 técnicos en un grupo de control. Los instrumentos de investigación fueron los siguientes: (1) un modelo de capacitación híbrido basado en Internet de las cosas y el aprendizaje basado en problemas; (2) una prueba de competencia; y (3) una prueba de rendimiento. El análisis de los datos se realizó utilizando medias, desviación estándar y el análisis multifactorial dispersivo (MANOVA) unidireccional. Los resultados del estudio fueron los siguientes: 1) un modelo de capacitación híbrido que consta de 3 componentes: 1) capacitación híbrida en línea y formación presencial, 2) Internet de las cosas y 3)

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aprendizaje basado en problemas; 2) El grupo experimental de técnicos logró puntuaciones significativamente más altas en las pruebas de competencia y rendimiento que las obtenidas por el grupo de control, en el nivel 05.
Palabras clave: Entrenamiento Híbrido, Internet de las Cosas, Aprendizaje basado en Problemas

1. Introduction

Technician training centers have a role in the development of technicians in automotive service centers in Thailand. Therefore, the objective of the training is not only to educate and update technicians, but also to focus on the use of technology for training to continually be upgraded with automotive technology and evaluate the course for training the technicians in the service centers.

However, the use of the technology for training still lacks its full capacity, which is necessary for the technicians to be trained online and face to face (Sahin, 2010). The training of technicians at service centers also faces the problem of training in real-time interaction for the trainers and technicians, as well as the lack of information exchange, which is necessary for technicians that may affect the quality of the training.

Hence, the researchers decided to examine and develop a hybrid training model based on the Internet of Things (Wu et al., 2010) in order to increase the professional competency of automotive air conditioning repair technicians. Furthermore, the improvement of the training competency and achievement (Baartman & de Bruijn, 2011) of the technicians in the center by using Internet technology was conducted to help with the training in the form of real-time interaction (G´omeza et al., 2013). The research results were applied in the development of the training to ensure that the technicians were of equal quality in every service center. Moreover, the modules promoted self-learning (Chancharoen et al., 2014) and saved the budget for training by using technology as the media, as well as used technology to help technicians easily access the required knowledge.

2. Literature Review

The literature review briefly describes the concepts of hybrid online and face-to-face training, the Internet of Things used for training technicians, and problem-based learning (PBL), as reported in current research.

Table 1
The synthesis of hybrid training.

	Hybrid Training	Carman (2005)	Sahin (2010)	Singh (2003)	Bonk & Graham (2004)	Lungu (2013)	Sriarunrasmee, et al.	Total
1	e- Learning	/	/	/	/	/		5*
2	Collaborative Learning	/	/	/	/	/		5*
3	Learning Management System	/	/	/	/	/		5*
4	Web		/			/		2
5	Face-to-face Learning	/	/	/	/	/	/	6*
6	Live	/		/			/	3
7	Self-paced Learning		/	/			/	3
8	Assessment	/			/			2
	Total	6	6	6	5	5	3	

Hybrid training (Table 1) as applied in the researchers' development of an integrated training model for professional air conditioner technicians included the following concepts: 1. e-Learning, 2. collaborative learning, 3. Learning management system, and 4. face-to-face learning.

Table 2
The synthesis of the Internet of Things.

No	Internet of Things	Huansheng Ning & Sha Hu (2012)	Wu et al. (2010)	G´omeza et al. (2013)	Kang et al. (2015)	Khodadadi & Buyya (2015)	Kortuem et al. (2013)	Total
1	IoT Application	/	/	/	/	/	/	6*
2	Analytics	/	/	/	/	/	/	6*
3	Cloud	/	/	/	/	/	/	6*
4	Connectivity	/	/	/	/	/	/	6*
5	Device	/	/	/	/	/	/	6*
6	Security					/		1
7	Data Analytics	/						1
8	Service Platforms						/	1
9	Big Data		/					1
	Total	6	6	5	5	6	6	

The Internet of Things as applied in the researchers' development of an integrated training model for professional air conditioner technicians included the following concepts: 1. IoT application, 2. analytics, 3. cloud, 4. connectivity, and 5. Device (Table 2).

Table 3
The synthesis of problem-based learning.

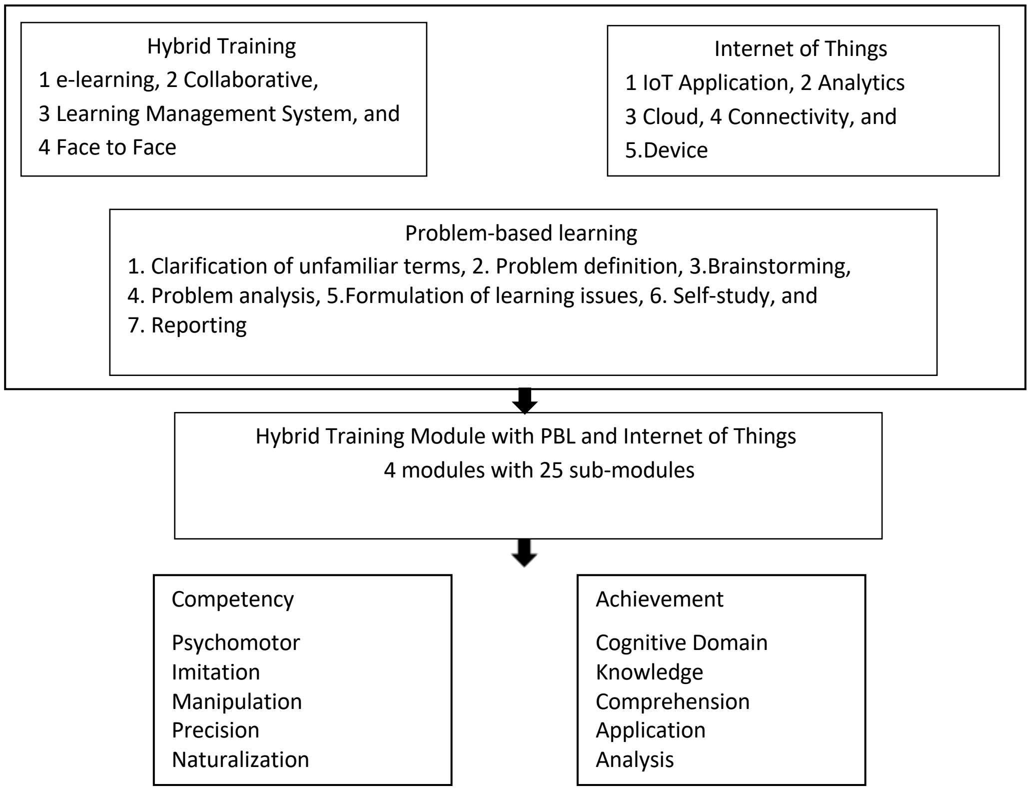
No	Problem-based learning	Newman et al. (2001)	Kilroy (2015)	De Graaff & Kolmos (2003)	Adiga & Adiga (2015)	Dammer et al. (2001)	Schmidt (1983)	Total
1	Clarification of Unfamiliar Terms	/	/	/	/	/	/	6*
2	Problem Definition	/	/	/	/		/	5*
3	Brainstorming	/		/	/	/	/	5*
4	Problem Analysis	/	/	/	/	/	/	6*
5	Formulation of Learning Issues	/	/	/	/	/	/	6*
6	Self-study	/	/		/	/	/	5*
7	Reporting	/	/	/		/	/	5*
	Total	7	6	6	6	6	7	

Problem-based learning applied in the researchers' development of an integrated training model for professional air conditioner technicians included the following concepts: 1. clarification of unfamiliar terms, 2. problem definition, 3. brainstorming, 4. problem analysis, 5. formulation of learning issues, 6. self-study, and 7. Reporting (Table 3).

2.1. Conceptual framework

The researchers reviewed the principles, concepts, and theories about hybrid training, the Internet of Things, and problem-based learning to create the following conceptual framework (Fig.1). The system consisted of content, activities, channels to exchange knowledge in the online system, testing, online interaction practice, and training without any restrictions in terms of time and place. It also enabled the trainers and technicians to interact through the program. Long distance learning and practice were enabled by the IOT. In the training practice, technicians conducted the practice according to the instructions in their work sheets that were constructed based on problem-based learning principles.

Figure 1
Conceptual framework of the study



2.2. Research objective

1. To develop a hybrid training model based on the Internet of Things and problem-based learning to enhance the technicians' competency skill in vehicular air conditioner repair.

2. To compare the scores from the competency and achievement tests of the technicians in the experimental group to those in the control group.

3. Methodology

The study was conducted in two parts: the development of the model and the experiment.

3.1. Model development

Step 1: The concepts, theories, and research data on hybrid training design, Internet of Things, and problem-based learning were reviewed and analyzed (Fig. 2).

Step 2: The information gained from the review and analysis was synthesized into a draft of the hybrid training model.

Figure 2
Draft of the hybrid training model (HIP model).

Step3: The research instruments for evaluating the model draft were developed and three experts were asked for their feedback.

Step 4: A focus group of five experts was organized to discuss the draft of the model, as to whether it was appropriate, and asked to provide suggestions.

Step 5: The efficiency of the model was statistically analyzed with the mean (x) and standard deviation (SD). Five levels of efficiency were assigned following the concept of the Likert scale as follows (Brown, 2001):

4.50 - 5.00 indicated the highest efficiency;

3.50 - 4.49 indicated a high efficiency;

2.50 - 3.49 indicated a medium efficiency;

1.50 - 2.49 indicated a low efficiency;

1.00 - 1.49 indicated a very low efficiency.

Step 6: The draft of the model was improved according to the suggestions from the panel of experts.

3.2. The experiment

3.2.1 Sample

The samples in this study were 260 technicians from a number of Toyota service centers in Thailand. The participants in this study were selected by using a multistage random sampling method, and were divided into the experimental group and the control group with 130 technicians each.

3.2.2 Instruments

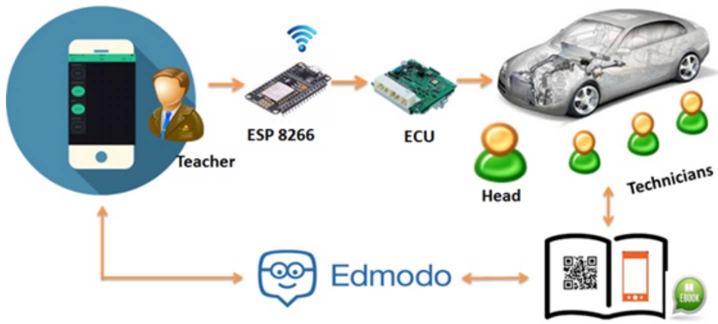
1. Hybrid training modules: There were four modules evaluated by five experts Fig3. The evaluation results had five levels: 4.50-5.00 (highest), 3.50-4.49 (high), 2.50-3.49 (medium), 1.50-2.49 (low), and 1.00-1.49 (very low), respectively.

2. Achievement test: The test included 40 multiple-choice questions; each with four choices. The Index of Item Objective Congruence (IOC) was calculated from the three experts' evaluations. The IOC obtained was between

0.67 – 1.00, the difficulty value was between 0.50 – 0.75, and the discrimination value was between 0.20 – 0.40. The reliability of the test was based on Cronbach's alpha coefficient, which was 0.75.

3. Competency Test: The test of the competency skill comprised 24 questions. Its IOC was calculated from the evaluations from the three experts that gave a result of between 0.67 – 1.00. The inter-rater reliability (Gwet, 2014) of the test was 0.85.

Figure 3
Hybrid training model based on the Internet of Things.



3.3.3. Data collection

The steps for the collection of the data were as follows:

1. Introduced the hybrid training model based on the Internet of Things and problem-based learning to the trainers and technicians, as well as informed them of their roles in the course.

2. Conducted the HIP model training with 130 technicians in the sample group for 60 hours.

3. After all the training sessions were completed, the technicians from the experimental group and the control group were tested with the 24-question competency test for two hours and the 40-question achievement test for one hour.

4. The test scores were collected for data analysis with one-way MANOVA.

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4. Results

The results were presented in two parts as the hybrid training model and the experimental results.

4.1. The hybrid training model based on the Internet of Things and problem-based learning

Figure 4
Comparing the previous and current hybrid training models.

Previous hybrid training model Current hybrid training model

The previous and current hybrid training models consists of three elements.1) Hybrid Training 2) Internet of Things and 3) Problem-based Learning . Previous hybrid training model is Asynchronous system including practice worksheets for laboratory work and Current hybrid training model is synchronous system (real-time) including module consisted of the training content and activities, online practice exercises, and a test (Fig 4) .

Table 4
Elements of the "HIP model".

Element	Details
Hybrid Training (H)	Hybrid training is a combination of two approaches - online learning and face-to-face classes. The four features of hybrid or blended learning include 1) e-Learning 2) Collaborative Learning 3) Learning Management System , and 4) Face-to-face Learning
Internet of Things (I)	IoT and smartphone were used to control an air conditioner repair training kit via a Wi-Fi interface (ESP 8266). The training kit, in turn, commanded the electronic control unit (ECU) of the vehicle to act as if there was a certain kind of defect in the air conditioner, e.g., triggered by a command from a smartphone, the ECU would break the circuit into an open circuit according to the command. These commands were documented in a worksheet prepared by the trainers.
Problem-based Learning (P)	Problem-based learning applied in the development of the integrated training model included the following concepts: 1. clarification of unfamiliar terms, 2. problem definition, 3. brainstorming, 4. problem analysis, 5. formulation of the learning issues, 6. self-study, and 7. reporting.

Table 4 shows the HIP model consists of three elements: 1) Hybrid Training (H) is the training course consisted of learning activities in online format; however, offline classes were still necessary. 2) Internet of Things (I) is a huge collection of connected devices and networks that can be managed via the Internet. It can provide real-time data exchange. 3) Problem-based learning (PBL) is a teaching method in which complex real-world problems are used as a vehicle for promoting technicians training of concepts and principles as opposed to direct presentation of facts.

4.2. Experimental results

The researchers analyzed the data collected from the competency and achievement tests. First of all, the researchers assessed the assumptions of MANOVA as applied to this study. The results are shown in Table 5.

Table 5
The results of the MANOVA assumption assessment.

	Normal Distribution		Pearson's Correlation	Box's M Test (Sig.)	Bartlett's Test (Sig.)	Levene's Test (Sig.)
	Experimental	Control				
Competency	0.082	0.124	.172**	0.21	0	0.2
Achievement	0.116	0.247				0.176
Result	Normality	Normality	.172 < .80	Sig. > α	Sig. < α	Sig. > α

α = .05

From the data in Table 5, when the dispersion was calculated with the Shapiro-Wilk technique, the result showed a normal distribution of data in all four groups with a level of significance of .05. As for the equality of the covariance matrices calculated in Box's M test, the results showed no significant differences. The correlation between the dependent variables, competency and achievement test scores, was .172, which did not exceed .80, indicating that MANOVA could be validated.

Table 6
Comparison of the mean and SD of the competency and the achievement test scores between the experimental and control group

Dependent Variable	Independent Variable	N	$\overline{x}$	SD	F	Sig
Competency	Experimental	130	49.02	4.58	22.8	0.00
	Control	130	46.01	5.83		
Achievement	Experimental	130	29.05	3.04	43.87	0.00
	Control	130	26.12	4.03		

α = .05

As can be seen in Table 6, the competency and achievement test scores accomplished by the experimental group were significantly higher than those achieved by the control group (p < .05). The average competency score of the experimental group was 49.02 (SD = 4.58), which was higher than that of the control group at 46.01 (SD = 5.83). Similarly, the average achievement score of the experimental group was 29.05 (SD = 3.04) that was higher than the average achievement score of the control group at 26.12 (SD = 4.03).

5. Discussion and conclusion

5.1 Discussion

The technicians in the experimental group who were trained with the hybrid training model based on the Internet of Things and problem-based learning achieved significantly higher competency and achievement test scores than the technicians in the control group who were taught by a conventional approach. The level of significance was p < .05. These results were possibly because of the good quality of the hybrid training model that had been positively verified by experts in vehicular air conditioner repair.

The Internet of Things (Kang et al., 2015) was instrumental in this training course because it enabled the trainers to provide any kind of common defects that might occur in a vehicle's air conditioner for the technicians to train. Furthermore, this was based on Huansheng Ning and Sha Hu, (2012) who explained that the IoT could be used for the hybrid training module for the online training of technicians. The researchers believe that the hybrid training module could be applied quite reliably in other training contexts resulting in a significant higher performance. The researchers' future hybrid training model based on the IoT and problem-based learning would mainly cover the Arduino program (Chancharoen et al., 2014; Louis, 2016; Javier et al.,2018), a more advanced software that could be applied in hybrid training.

The hybrid training model involved using the IoT to turn a perfectly working IoT-connected air conditioner training kit into an air-conditioner with a certain type of defect. This allowed the technicians to analyze that defect. Moreover, a QR code (Yue Liu et al., 2008) was used for technicians to link to a video training clip for solving a particular type of defect, making it easy for them to learn. All of the clips were constructed to be easy to understand according to the principles of the Learning Management System (LMS) (Park, 2011). The course consisted of four competency modules. Each module consisted of the training content and activities, online practice exercises, and a test. According to the LMS, there should be a variety of communication channels between the trainers and technicians. The researchers provided both face-to-face communication and online communication via a PC and smartphone.

The researchers' hybrid training course consisted of online learning activities and face-to-face classes. Both kinds of activities were based on problem-based learning (Newman et al., 2001). Problem-based learning is a teaching method in which complex real-world problems are used as a vehicle for promoting technicians learning of concepts and principles as opposed to the direct presentation of facts. In this study, the IoT was used in conjunction with PBL in order for the trainers and technicians to be familiar with the activities in the lessons because they could teach and learn with real objects and defects in a training kit triggered by the IoT.

5.2 Conclusion

The hybrid training model based on the Internet of Things and problem-based learning to enhance technicians' competency in vehicular air conditioner repair is a method that can improve the training competency and achievement of technicians. The hybrid training model used the Internet of Things to support a problem-based learning process that encouraged interactions between technicians themselves and the trainers. The hybrid training model developed proper skills, knowledge, and attitudes, as well as saved the budget for training and used technology to help technicians easily access the required knowledge**.** Therefore, technicians could access the training course anytime and anywhere as they demanded (Sriarunrasmeea et al., 2015).

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