The Development of Online Training Modules and Internet of things on Vehicle Air Conditioner

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Abstract

The objectives of this study were the following: 1) to develop online training modules and use the internet of things(IoT) to enhance technicians' competency on fixing vehicle air conditioners; the modules were evaluated by 5 experts who were selected by purposive sampling and 2) to evaluate the effectiveness of the training modules and the IoT. The participants were 40 Toyota service center technicians selected by cluster random sampling. The statistics used for analysis were mean, percentage, and standard deviation. The tools used were the following: 1) Four training modules (25 sub-units) and the IoT; 2) an achievement test consisted of 3 parts and 40 questions; and 3) A test on repair practice consisted of 20 questions. The following results were obtained: 1) The training modules in combination with the IoT were rated as High quality ($\bar{X}$ = 4.45, S.D.= 0.47) and 2) The effectiveness of the training modules as shown by the results of the during-the-training test and after-the-training test were 84.63 : 87.71, exceeding the passing criterion of 80 : 80. The developed training course should benefit working technicians of every Toyota service center in Thailand in their diagnosis and repair of vehicle air conditioners.

Keywords: Training Modules, Internet of Things, Problem-Based Learning, Online Training, Vehicle Air Conditioner

Introduction

In the 21st century, Information and Communication Technology (ICT) started to get applied in education. At present, we have an information society. Tools, technologies, and learning methods are various and sufficient for training. However, the ability to apply tools or technologies for optimum benefit is still lacking in terms of quantity, quality, and the value of investment.

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. The new air-conditioning technologies are introduced at a fast pace; therefore, technicians need to be trained constantly on these technologies. Our developed training modules and the IoT for enhancing the competency of technicians' in repairing vehicle air conditioners involved face-to-face and online trainings. For face-to-face training (Sahin, 2010), the modules included both theory and practice and were conducted in a laboratory. Similarly, for online training, there were modules for learning theory and how to practice. Moreover, the IoT has revolutionized the use of computers and training methods. The goals of IoT were to connect all electronic devices surrounding us into a huge network and allow us to access the desired information anywhere, anytime. This goal has been progressively realized so that, currently, there are many devices that can connect to the internet efficiently and intelligently. Nowadays, even electrical appliances are equipped to work with the IoT (Ning & Hu, 2012). One of the advantages of IoT in training technicians is that we can use IoT to trigger an intended defect in a connected air-conditioner repair training kit. The triggering can be at any time and from anywhere so that the technicians can practice on any kinds of defects at their convenient time.

The importance of constant, up-to-date technician training cannot be understated. The author was interested in developing training modules in combination with the IoT to enhance technicians' competency on repairing vehicle air conditioners.

Objective

1. To develop training modules for course for training technicians at Toyota service centers in Thailand; the course would be enhanced by the use of IoT that would make online practice, anytime and anywhere, on repairing vehicle air conditioners possible.
2. To evaluate the efficiency of the training modules and IoT in training those technicians to repair vehicle air conditioners.

Conceptual Framework

1. The training course consisted of learning activities in online format; however, offline classes were still necessary. Moreover, the activities were based on problem-based learning (PBL). There were 7 steps to the PBL that we used (Camp, van het Kaar, van der Molen, & Schmidt, 2014)

   a) Clarifying unfamiliar terms,
   b) Defining the Problem,
   c) Brainstorming theories related to the problem,
   d) Analyzing the problem,
   e) Formulating learning issues,
   f) Self-studying,
   g) Reporting.

The training course involved using IoT to turn a perfectly working IoT-connected air conditioner training kit into an air-conditioner with a certain type of defect. This allowed a technician to analyze that defect. Moreover, QR code (Liu, Yang, & Liu, 2008) was used for technicians to link to a video training clip for fixing 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 training content and activities, online practice exercises, and a test. According to LMS, there should be a variety of communication channels between teachers and technicians. We provided both face-to-face communication and online communication via a piece of PC and smartphone software called Edmodo which featured all required LMS communication specifications. The training course had no limitation of time and place for learners to engage in a learning session. Therefore, technicians can access the training course anytime and anywhere as they demanded. Moreover, they can interact within their group by using their computer or smartphone and the Internet as the medium. The course used the Internet to support a cooperative learning process that encouraged interactions between technician themselves and between them and the teachers, promoting development of proper skills, knowledge, and attitudes. Therefore, the competency modules truly helped enhancing the technicians' work competency. The training course development was based on the following concepts: 1. E-learning, 2. Collaboration, 3. Learning Management System, and 4. Face-to-face communication (Lungu, 2013; Bonk & Graham, 2004).

2. The competency modules included relevant knowledge, skills, and integrated attitude. The technicians under training possessed all preliminary requirements for working on air-conditioner of Toyota cars. At the end of the training course, it was expected that they would become highly professional in air-conditioner repair. The development of the competency modules was done by converting professional standard requirements to learning standards. The training modules covered the training of all aspects of air-conditioner repair competency. Conversion from the learning standards in a competency module into a training module was straightforward, as shown in Table 1. This facile conversion ensured that, after being trained, the technicians would acquire adequate knowledge, skills, and attitudes up to the professional standards. The knowledge, skill, and attitudes altogether would be evaluated professionally and at the same time.

3. IoT is a huge collection of connected devices and networks that can be managed via the Internet. It can provide real-time data exchange. Therefore, it was suitable for the development of the training course (Kortuem, Bandara, Smith, Richards, & Petre, 2013; Ning & Hu, 2012; Gómez, Huete, Hoyos, Perez, & Grigori, 2013).

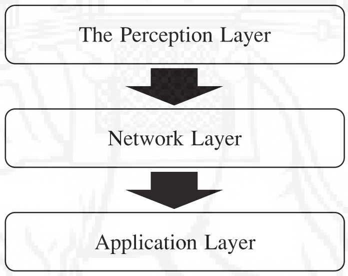

Figure 1 Structure of IoT (Wu, Lu, Ling, Sun, & Du, 2010)

The input layer of IoT is called a perception layer. Mostly, it is for identification of the objects of which data are to be collected. Examples of a perception layer are barcode readers, RFID tags and readers, cameras, GPS, sensors, and sensor networks.

The second layer, a network layer, consists of neural networks, the brain of IoT. The main duty of this layer is to transfer the data from the perception layer to the neural networks which process the data.

Finally, the third layer is called an application layer. After collected data was processed by neural networks in the network layer, the outcomes of the processing are transferred to this layer that control output devices such as relays, or magnetic switch such as those in an electronic controller.

Literature Review

Our literature review briefly describes the concepts of training, IoT used for training technicians, and problem-based learning (PBL).

Training Modules

Training modules is a combination of two approaches: online learning and offline classes. According to (Şahin, 2010), three features of blended learning include 1) Face to face learning, 2) Self-paced learning, and 3) Live e-learning.

Technologies and their applications are relevant to learning. According to studies by (Lungu, 2013), five main areas of training are the following: (1) technologies in the classroom such as power point and interactive whiteboard; (2) virtual communication tools such as discussion boards, chat room and podcasting; (3) social networking software such as blogs and wikis; (4) e-learning systems such as group collaborative software; and (5) mobile learning.

According to studies by (Akyüz & Samsa, 2009; Picciano, 2009), using training in Information Literacy Skills course can effectively support students to engage them in a more self-directed learning. Training also encouraged discussion between instructors.

Internet of things (IoT) Used for Training Technicians

According to a study by (Ning & Hu, 2012), internet of things is a huge collection of connected devices and networks that can be managed via the Internet. IoT involves every field of science and technology, hence it may be used to solve all kinds of problems in the future.

According to a study by (Gómez et al., 2013), IoT is a good tool for supporting a teaching process and improving student academic performance. In particular, IoT can be used by instructors and learners to interact with real objects in their training. It is a valuable learning resource.

According to a study by (Kang, Han, Han, & Kim, 2015), IoT focuses on service and application. There are a lot of works that have been developed to enable people to interact with it, and it still poses a lot of interaction questions to be solved in the future.

Problem-Based Learning (PBL)

Our training course consisted of online learning activities and offline classes. The activities were based on problem-based learning (PBL). Problem-based Learning (PBL) is a teaching method in which complex real-world problems are used as a vehicle for promoting student learning of concepts and principles as opposed to direct presentation of facts.

According to a study by (Kilroy, 2015), PBL relies on the components of this theory. It differs from more ‘‘traditional’’ approaches to teaching in that the participants are encouraged to use self directed learning skills to analyze a given clinical scenario, formulate and prioritise key learning objectives within that scenario, and then collect whatever additional information they think will be needed to address those objectives. Crucially, all this takes place within a group setting, so that each individual member of the group contributes to the learning process at every stage.

According to studies by (Newman et al., 2001), Problem based learning has been adopted around the world as a philosophy and method for teaching and learning in professional education in particular. IoT was used in conjunction with PBL in order for the teachers and students to feel familiar with the activities in the lessons.

According to studies by (De Graaff, & Kolmos, 2003), Problem-based learning is an instructional method that is said to provide students with knowledge suitable for problem solving. PBL identify characteristics at the levels of the oretical learning principles, educational models and educational practices.

Research Methodology

Training modules for repairing vehicle air conditioner enhanced by the use of IoT were developed in this study. There were five steps to this study.

Step 1: Reviewing the literature: analyzing previous studies and concepts on training, applications of IoT, and problem-based learning (PBL).

Step 2: Developing the training modules for technicians on repairing vehicle air conditioner as follows:

2.1 Converting competency units into training modules

Table 1 Conversion of the Requirements in the Competency and Sub-Competency Units into Details in the Training Modules

Competency Unit	Module Details
Competent unit name	Training module name
Sub-competency	Training result
Work standard	Evaluation criteria
Work scope	Content scope
Evaluation guideline	Evaluation method

Four training modules based on IoT were achieved, consisting of 25 units. Module1, Equipment inspection, had 7 units; Module 2, Equipment disassembly, had 6 units; Module 3, Electrical circuit analysis, had 7 units; Module 4, Problem condition analysis, had 5 units. The modules and the names of those units are listed in Table 2.

2.2 Constructing the details of each module: Those details are shown in Table 2. The training was in the form of competency-based training, a part of Learning System Management (LMS). Next, we embedded the obtained training modules into LMS and employed Edmodo software in the LMS system. 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, i.e., triggered by a command from a smartphone, the ECU would break the circuit into an open circuit according to the command. Those commands were documented in a worksheet prepared by the teachers.

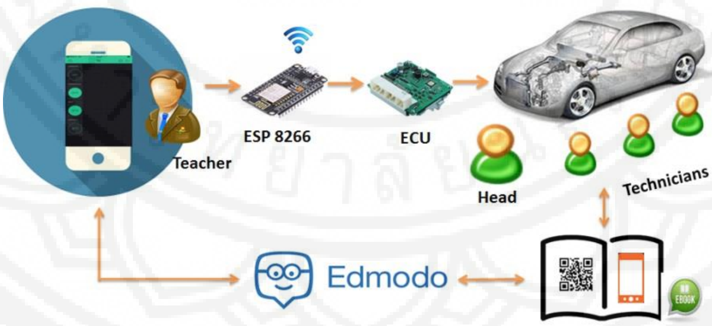

Figure 2 Training Course Based on the IoT

2.3 Evaluating the effectiveness of the training modules and IoT in technician competency enhancement: three untrained technicians with varying initial capabilities acted as the subjects for this evaluation, and the teachers provided the evaluation of the effectiveness of the training modules and IoT.

The scoring rubric for the evaluation is shown in Table 3. Some disadvantages of the modules found from this evaluation round were improved. The improved modules were evaluated in the next step.

2.4 Evaluating the effectiveness of the improved training modules and IoT: Six untrained technicians with varying initial capabilities acted as the subjects for this round of evaluation, and the same teachers in 2.3 provided the evaluation. Also, the same scoring rubric was used.

2.5 Evaluating the effectiveness of the improved training modules and IoT with a large sample size. Forty untrained technicians with varying initial capabilities acted as the subjects for this final round of evaluation, and the same teachers provided the evaluation. The evaluation results together with the training modules were presented to a panel of five experts—the head of the Toyota Automotive Technological College and four education technology instructors: two from King Mongkut's University of Technology Thonburi and another two from Srinakharinwirot University-for them to find out whether there were anything in the modules that would need further improvements and make suggestions.

Step 3: Organizing a focus group of a panel of five experts in educational technology: presenting the training modules obtained from step 2.5 and their evaluation results to the panel and seeking their advice for improvement. The panel also evaluated the modules. Their evaluation results are reported in Table 2.

Step 4: Developing two final tests for evaluating the knowledge and skills of technicians in vehicle air conditioner repair: one was for testing their theoretical knowledge, and the other was for testing their practical knowledge and skills. The former was a multiple-choice test containing 40 questions with a total score of 40 points, and the latter was a practical test containing 20 questions with a total score of 60 points.

4.1 The multiple-choice test was constructed as follows:

1) Analyzing the content and behavioral objectives of each training unit;

2) Testing the modules' content validity and finding their index of congruence (IOC) which turned out to be 0.67-1.00; the testing was done by three experts—the head of Toyota Automotive Technological College and two instructors from the institute.

The achievement test was administered to 20 technicians at the Cha-cherng-sao Toyota center. The technicians came from several Toyota service centers in Thailand.

4.2 The practical test was constructed as follows:

1) Gathering information on the process of test development from related documents and theories, then determining the format of the test questions;

2) Analyzing the content and behavioral objectives of each training unit;

3) Testing the content validity of every unit and finding its IOC, which turned out to be 0.67-1.00. The test was conducted by the same panel of three experts that tested the multiple-choice test.

Step 5: Formulating the criteria for evaluating the efficiency of the training modules and IoT. The evaluation scores were statistically manipulated into means ($\bar{X}$) and standard deviations (S.D.). The criteria were translated into 5 Likert levels (Brown, 2001).

4.50 - 5.00 indicates highest efficiency

3.50 - 4.49 indicates high efficiency

2.50 - 3.49 indicates medium efficiency

1.50 - 2.49 indicates low efficiency

1.00 - 1.49 indicates very low efficiency

Results

This section presents the results in 2 parts as follows.

Part 1: The results from the evaluation by 5 experts of the efficiency of the training modules. These are shown in Table 2 below.

Table 2 The Evaluation Results by the Experts on the Efficiency of the Training Modules

Training Modules	$\overline{x}$	S.D.	Efficiency
Module 1 Equipment Inspection			
A111 Condenser inspection	4.20	0.45	High
A112 Compressor inspection	5.00	0.00	Highest
A113 FCU inspection	4.20	0.45	High
A114 Blower motor inspection	4.40	0.55	High
A115 Blower resistant inspection	4.60	0.55	Highest
A116 Temperature sensor inspection	4.20	0.45	High
A117 Amplifier current inspection	4.40	0.55	High
Total	**4.43**	**0.43**	**High**
Module 2 Equipment Disassembly			
A121 Condenser disassembly	4.20	0.45	High
A122 Compressor disassembly	4.40	0.55	High
A123 FCU disassembly	4.80	0.45	Highest
A124 Blower motor disassembly	4.40	0.55	High
A125 Temperature sensor disassembly	4.80	0.45	Highest
A126 Amplifier current set disassembly	4.40	0.55	High
Total	**4.50**	**0.50**	**Highest**
Module 3 Electrical Circuit Analysis			
A131 Amplifier current set circuit	4.60	0.55	Highest
A132 Compressor circuit	4.00	0.00	High
A133 Blower motor circuit	4.40	0.55	High
A134 Blower resistant circuit	4.40	0.55	High
A135 Crank circuit	4.80	0.45	Highest
A136 Center processor circuit	4.20	0.45	High
A137 Temperature sensor circuit	4.40	0.55	High
Total	**4.42**	**0.44**	**High**
Module 4 Problem Condition Analysis			
A141 Air conditioner system is broken	4.20	0.45	High
A142 Blower motor does not work	4.40	0.55	High
A143 Blower motor does not change status	4.40	0.55	High
A144 Cool air is not released	4.80	0.45	Highest
A145 Compressor does not work	4.60	0.55	Highest
Total	**4.48**	**0.51**	**High**
Grand Total	**4.45**	**0.47**	**High**

The experts had an opinion that the training modules had a high efficiency for training technicians on vehicle air conditioner repair ($\overline{x}$ = 4.45, S.D.= 0.47). The total score for the equipment disassembly module was highest ($\overline{x}$ = 4.50, S.D.= 0.50); the total score for the problem condition analysis module was high ($\overline{x}$ =4.48, S.D.= 0.51); the total score for the equipment inspection module was high ($\overline{x}$ = 4.43, S.D.= 0.43); and the total score for electrical circuit analysis module was high ($\overline{x}$ = 4.42, S.D.= 0.44). All of these show that these learning modules are suitable for enhancing the air conditioner repair competency of technicians.

Part 2: The results from the evaluation of the efficiency of the final training modules and IoT after they were used for an actual training are shown in Table 3 below.

Table 3 Results of the Evaluation of the Final Training Modules and IoT

Test	Full Score	$\overline{x}$	Percentage
During the training (E1)	100	84.63	84.63
After the training (E2)	100	87.71	87.71

(The passing criterion for each module was a score of 80% or higher)

The mean score achieved by the technicians for during-the-training tests (E1) was 84.63%, while the mean score achieved by the technicians for an after-the-training test (E2) was 87.71%. These results indicate that the vehicle air conditioner training modules had the effectiveness (E1 : E2) of 84.63:87.71 passing the criterion of 80 : 80.

Discussion and Conclusion

Our developed training modules based on IoT (Wu et al., 2010) was satisfactory. They achieved a high mean efficiency evaluation score of $\overline{x}$ = 4.45 with an S.D. of 0.47. These results were possibly because of the good quality of the training model that had been positively verified by experts in vehicular air conditioner,which was expected and in full agreement with a high mean efficiency score achieved by LMS-based training modules in a study by (Baartman & de Bruijn, 2011) even though those modules were off-line training modules for medical students.

Moreover, The effectiveness of the training modules and IoT for during the training tests and after the training tests were 84.63 : 87.71, meeting the requirement of 80 : 80 and agreeing well with the results of a study by (Banyen, Viriyavejakul, & Ratanaolarn, 2016). The author of that study proposed a blended learning model for learning achievement enhancement of Thai undergraduate students.

One of the reasons that the modules were successful was that they can be accessed both online and offline (Park, 2011) making them conveniently available to the trainees anytime and anywhere.

IoT was instrumental in this training course (Kang et al., 2015) because it enabled the teachers to provide any kinds of common defects that might occur in a vehicle air conditioner for the technicians to train on. Thanks to (Gómez et al., 2013) for providing us with a successful example of using IoT for online training of technicians. We think that IoT can be applied quite reliably in other training contexts without a significant degradation in performance. Our future training modules based on IoT would mainly cover Arduino program, a more advanced piece of software that works with IoT (Chancharoen, Sripakagorn, & Maneeratana, 2014; Louis, 2016).

Suggestions

Our future training modules based on IoT would mainly cover Arduino program, a more advanced piece of software that works with IoT.

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