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Energy Management Competency Development based on the Internet of Things (IOT)*

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This study identified the competencies requirement for university students in energy management based on the Internet of Things (IOT) technique. First, three experts in the energy management and IOT field were interviewed, and a list of professional competencies was concluded. Then, 11 field experts were invited as subjects. Using the Delphi technique, questionnaires were designed to assess competency indicators for energy management based on IOT. The data collected from the questionnaires were analyzed using a non-parametric Wilcoxon signed rank test. Finally, this study concluded 34 professional competencies under five dimensions for energy management based on IOT. The findings could provide a valuable reference to educators in the field of engineering and technology education who are involved in training and development programs.

Keywords: energy management; Internet of Things (IOT); competency analysis

1. Introduction

Energy management is a systematic strategy for controlling a building's energy consumption. It builds and keeps an efficient balance between a building's annual functional energy requirements and actual energy consumption. It is intended to reduce energy waste to a minimum as permitted by the climate where the building is located, through its functions, occupancy schedules, and other factors. University is an eclectic mix of building styles and construction, including research facilities, libraries, offices, auditoriums, dormitories, classrooms, dining halls, a central steam-heating plant, individual building chillers for air conditioning, thousands of lighting fixtures, and exit lights [1]. Therefore, energy management is a concerned topic on university campuses.

Baytiyeh [2] applied the Internet of Things (IOT) to benefit greatly from the foresight and predictability afforded by the technique to all fields. The technique to code and track objects has allowed universities to become more efficient, speed up processes, reduce error, prevent theft, and incorporate complex and flexible systems through IOT. IOT is a technological change that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields that can access the internet in any point of time and space [3]. IOT architecture aims to achieve an open infrastructure with scalability, flexibility and security for people. It is designed to be user-centered and customized as 'Web of Things' which includes interaction possibilities for the benefit of society. In addition, IOT adopts new dynamic business concepts, including flexible billing and incentive capabilities to promote information sharing [4].

Competency requirements refer to the expected capability standards or goals of a specific category of professionals and form the basis for capability assessment [5, 6]. Competency refers to the ability to achieve an outcome in a specific situation. The industrial requirements for energy management based on IOT must be examined to ensure the validity of the items and standards used in the measurement of competency. A curriculum must be implemented according to industry requirements, and the process of analyzing competencies should determine whether students have attained the required standards. The main purpose of analyzing competency is to verify whether an individual possesses the knowledge, attitudes, and skills required in the workplace.

The aim of the study is twofold: first, to identify the competencies required for university students in energy management based on Internet of Things (IOT); and second, to determine whether the identified competencies are of equal importance. With these two targets in mind, this study formulates the following research questions.

(1) What competencies are considered essential for energy management based on IOT?
(2) What is the relative importance of those competencies as perceived by field experts?

2. Literature review

2.1 Internet of Things (IOT) concept

The Internet of Things (IOT) is a concept of a network for information exchange and communica-

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tion [7]. IOT enables a set of things/objects to be [8]: (1) Pervasive: IOT devices are able to interact with the environment by sensing and reasoning certain data that have been produced. They may be connected through wired or wireless networks to exchange information and interact with the environment for making the best real-time decision. (2) Identified via a unique address. This desirable characteristic is obtained by Internet Protocol Version (IPV), which grants an expanded addressing space. (3) Cooperative with other things by granting them an access to the local information to create new applications or services.

The integration of sensing and actuation systems with Internet monitoring is likely to optimize energy consumption as a whole. It is expected that IOT devices will be integrated into lighting energy consuming devices and be able to communicate with the utility supply company in order to effectively balance power generation and energy usage. Such a system also offers the opportunity for users to remotely control their devices or centrally manage them via a cloud-based interface and enable advanced functions like scheduling [9].

Smart buildings and green buildings are two topics of great importance currently in architecture/engineering education [10]. Between them, green buildings are capable of saving energy, saving water, protecting the environment, and helping people to ensure sustainable development, while smart buildings are green buildings with better performance enabled by using information and communication technology (ICT), Internet of Things (IOT), and other advanced technologies [11, 12]. Based on the literature review, the structure of the IOT technique in this study includes (1) perception layer, (2) equipment layer, (3) control layer, (4) application layer, and (5) network layer.

2.2 Energy management concept

Smart buildings and green buildings are two recent topics of great importance in architecture/engineering [13]. Green buildings are capable of saving energy and water, protecting the environment, and ensuring sustainable development [14]. Smart buildings can be considered green buildings with better performance enabled by information and communication technology (ICT), IOT, and other advanced technologies. Smart buildings integrate a wide variety of fields such as architecture, energy management, safety monitoring, energy-saving household appliances, automatic control, air-conditioning energy conservation, indoor environment quality, water conservation, and lighting management [15]. Therefore, in addition to equipping students with architectural knowledge, it is important for a traditional university education in architecture to cover the emerging technologies used in smart buildings as well.

2.3 Competency analysis concept

The term competency has been defined in the literature from a range of perspectives. McClelland [16] suggested the term as a criterion for judging the success of performance. Autio and Hansen [17] specifically defined technological competence as an interrelationship between technical abilities in psychomotor, cognitive, and affective areas. Competencies are clusters of related knowledge, skills, and abilities that correlate with effective performance in the task or role at hand. Competency frameworks have been used in various settings as training tools [18], for educational professionals in recruiting and developing staff, and for designing a curriculum [19]. Specifically, competency refers to the capability of employees to work effectively and perform the role they have been assigned [20].

3. Methodology

3.1 Research design

The research design of the study includes the following procedures.

(1) Identifying desired professional competencies required for students in energy management based on IOT (by reviewing the literature and interviewing field experts);
(2) forming a competencies analysis group;
(3) designing a professional competencies questionnaire to collect data;
(4) distributing the questionnaire to 11 field experts (Delphi group) three times;
(5) conducting data analysis (descriptive statistics, Kendall coefficient of concordance, and nonparametric Wilcoxon signed rank test);
(6) identifying, reviewing, and integrating those required professional competencies as perceived by field experts.

3.2 Questionnaire design

To fulfill the research objectives, the questionnaire was designed to collect data for professional competencies in 5 layers: (1) perception layer, (2) equipment layer, (3) control layer, (4) application layer, and (5) network layer; and for 34 professional competencies in energy management based on IOT. Each competency was rated by its importance to job performance in the IOT industry. A Likert scale was used in this questionnaire. Eleven members of the Delphi group were asked to assess each competency according to the following five-point scale: 5-very important, 4-more important, 3-some-what important, 2-less important, and 1-least important in their job performance.

Competencies were classified using cumulative percentages calculated from the importance ratings provided by respondents, as follows: (1) Essential (must have) with 90% of the responses indicating 4 or 5; (2) Important (should have) with 90% of the responses indicating 3, 4, or 5; and (3) Unimportant, as indicated by a failure to meet the above criteria [21, 22].

3.3 Participants

The three-round Delphi technique questionnaire used in this study was distributed to members of the Delphi group in June, July, and August 2016. These 11 Delphi group members included 9 field engineers in energy management and the IOT industry and 2 scholars at a technology institute.

Table 1. Kendall coefficient of concordance test

N	11
Kendall's W[a]	0.208
Chi-square	75.532
df	33
Asymp. Sig.	0.000

[a] Kendall's coefficient of concordance.

3.4 Data analysis

A goodness-of-fit test was used to confirm that participants were consistent in their responses. Means were identified as was the standard deviation (SD), and appropriate non-parametric Wilcoxon signed rank test was used [23].

4. Results

After the questionnaires were received, the Kendall coefficient of concordance test was applied to evaluate the relationship between the Chi-square ($\chi 2$) value of 75.532 (see Table 1) and those competencies indicators that the participants considered important.

Table 2 to Table 6 displays the ranked results, including the mean values of the scores and SD. All mean scores of the 34 competencies were above 4.27, indicating that the Delphi group considered the included competencies as "essential".

As seen in Table 2 to Table 6, using analysis based on the five layers of capability indices proposed, the layers deemed to be of greatest importance were the control layer (M = 4.88), followed by the application layer (M = 4.87), network layer (M = 4.66), perception layer (M = 4.65), and equipment layer (M = 4.50); however, little difference was observed between the five. The competency perceived to

Table 2. Analysis of consistency related to competency in perception layer

Capability Indices	Mean	SD	Wilcoxon signed-rank test
1. Perception layer	4.65		
1-1 Applying sensor technologies	4.91	0.30	–3.207*
1-2 Operating microelectromechanical systems	4.36	0.50	–3.035*
1-3 Applying radiofrequency identification (RFID) technologies	4.36	0.50	–3.035*
1-4 Applying multimedia technologies (such as image recognition and human motion recognition technologies)	4.73	0.47	–3.071*
1-5 Operating wireless sensor networks (WSNs)	4.82	0.40	–3.127*
1-6 Operating wired networks	4.73	0.47	–3.071*

*$p < 0.05$.

Table 3. Analysis of consistency related to competency in equipment layer

Capability Indices	Mean	SD	Wilcoxon signed-rank test
2. Equipment layer	4.50		
2-1 Operating mobile communication devices	4.55	0.52	–3.017*
2-2 Operating digital home appliances	4.27	0.65	–2.889*
2-3 Installing and maintaining lighting devices	4.45	0.69	–2.889*
2-4 Installing and maintaining air-conditioning equipment	4.36	0.67	–2.879*
2-5 Installing and maintaining power supply	4.55	0.52	–3.017*
2-6 Using embedded technologies	4.64	0.50	–3.035*
2-7 Maintaining and troubleshooting for operating equipment	4.45	0.52	–3.017*
2-8 Installing and maintaining sensor controllers data devices	4.82	0.40	–3.127*
2-9 Assembling and operating operational circuitry	4.45	0.52	–3.017*
2-10 Long-term support for battery power supplies	4.45	0.52	–3.017*

*$p < 0.05$.

Table 4. Analysis of consistency related to competency in control layer

Capability Indices	Mean	SD	Wilcoxon signed-rank test
3. Control layer	4.88		
3-1 Monitoring brightness sensing signals sent to system controller	4.91	0.30	–3.207*
3-2 Monitoring human body sensing signals sent to system controller	4.73	0.47	–3.071*
3-3 Monitoring temperature sensing signals sent to system controller	4.91	0.30	–3.207*
3-4 Monitoring voltage and current signals sent to system controller	5.00	0.00	–3.317*
3-5 Monitoring image recognition signals sent to system controller	5.00	0.00	–3.317*
3-6 Analyzing, sending, and monitoring network management alerts	4.73	0.47	–3.071*

*$p < 0.05$.

Table 5. Analysis of consistency related to competency in application layer

Capability Indices	Mean	SD	Wilcoxon signed-rank test
4. Application layer	4.87		
4-1 Realizing smart living spaces	4.91	0.30	–3.207*
4-2 Implementing energy management	4.82	0.40	–3.127*
4-3 Realizing smart grids	4.91	0.30	–3.207*
4-4 Implementing security surveillance	5.00	0.00	–3.317*
4-5 Analyzing and applying big data	4.73	0.47	–3.071*

*$p < 0.05$.

Table 6. Analysis of consistency related to competency in network layer

Capability Indices	Mean	SD	Wilcoxon signed-rank test
5. Network layer	4.66		
5-1 Applying wireless communication technologies (such as Bluetooth, WiFi, and ZigBee)	4.82	0.40	–3.127*
5-2 Applying high-speed internet technologies (such as IPv6, IPv4, and ICMP)	4.45	0.52	–3.017*
5-3 Applying information security technologies (such as firewalls)	4.64	0.50	–3.035*
5-4 Applying multimedia technologies (such as streaming technologies and image acquisition/integration technologies)	4.73	0.47	–3.071*
5-5 Applying web servers and relevant information technologies	4.82	0.40	–3.127*
5-6 Applying programming languages	4.82	0.40	–3.127*
5-7 Planning and controlling virtualization hosts (such as Vmwell)	4.36	0.67	–2.879*

*$p < 0.05$.

have the greatest importance in control layer was 3-4 *"Monitoring voltage and current signals sent to system controller"* (M = 5.00), 3-5 *"Monitoring image recognition signals sent to system controller"* (M = 5.00), and in application layer was 4-4 *"Implementing security surveillance"* (M = 5.00). Finally, based on the results of the above-mentioned analysis for sorting by perceptions of importance, it was learned that the perception of highest importance expressed concerned the competencies requirement for university students in energy management based on the Internet of Things (IOT) technique.

5. Discussions

Each indicator is given in Table 2 to Table 6, and by using the Wilcoxon Signed Rank test the authors evaluated whether there exists a statistically significance difference between the hypothesized mean of 3 (neutral). All 34 indicators showed a statistically significant difference ($p < 0.05$) through the Wilcoxon Signed Rank test. In Table 2 to Table 6, since these *p*-values were very small, this implies that the mean is sure to be larger than three. Nonparametric tests often are used in conjunction with small samples [24]. In the majority of the applications, the hypothesis is concerned with the value of a median, the difference between medians.

This study was limited to a select Delphi group of Taiwanese participants who are well in energy management and the IOT industry. The results of Delphi procedures depend on the knowledge and cooperation of the experts who are likely to contribute valuable ideas are essential to include. Because the number of experts is usually small, Delphi technique does not produce statistically significant results. The Delphi technique has also some limitations, such as results are dependent on the quality of the participants, results can be influenced by the researcher, and the top experts may be difficult to recruit.

6. Conclusion

Table 2 to Table 6 shows the results of three rounds of Delphi technique expert questionnaire, including perception layer (6 competencies), equipment layer (10 competencies), control layer (6 competencies), application layer (5 competencies), and network layer (7 competencies); and considered essential for the energy management based on IOT were proposed. The appropriate non-parametric Wilcoxon signed rank test was used, which was helpful to understand the results.

This study aimed to identify the competencies required by university students in energy management based on the Internet of Things (IOT). Based on the literature review, interviews with field experts, and the Delphi technique, 34 competencies considered essential for the effective performance design of energy management based on IOT were identified. In short, the results of this study include the following: (1) Analyzing the practical competencies required for energy management based on IOT, and (2) those competencies were considered to be of equal importance; in other words, all essential as perceived by field experts.

The implications of the results in this study are dependent upon the degree to which those findings can be extrapolated. This level of specificity was a requirement of the Delphi procedures to ensure that the competencies identified were an accurate and comprehensive reflection of all aspects of effective performance.

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