International Journal of Engineering Education Vol. 30, No. 2, pp. 312–318, 2014
Printed in Great Britain
0949-149X/91 $3.00+0.00

A Gesture-Based Learning System with a Concept Map-Oriented Approach in a Basic Engineering Circuit Course*

SHENG-WEN HSIEH, TZONG-SONG WANG** and MING-CHIA HSIEH
Department of Management Information Systems, Far East University, No. 49, Zhonghua Rd, Xinshi Dist., Tainan City 74448, Taiwan (R.O.C.). E-mail: onyx@cc.feu.edu.tw

The main particularity of gesture-based learning is that users interact in the learning process in the same way as they interact in the non-digital world. It can also support kinesthetic pedagogical practices to benefit users with strong bodily-kinesthetic intelligence. However, without proper assistance or guidance, the performance of gesture-based learning is usually not satisfied. To cope with this problem, the aim of this paper is to propose a concept map-oriented approach with a gesture-based learning system in the basic engineering circuit course. There were ninety-three participants in the experiments designed with the three learning approaches: concept map-oriented gesture-based learning, conventional gesture-based learning, and traditional e-book learning. The experimental results showed that the concept map-oriented learning approach with the gesture-based learning system increased the learning performance of the students in the basic engineering circuit course more than traditional e-book learning and the conventional gesture-based learning approach did.

Keywords: gesture-based learning; concept maps; embodied interaction; basic engineering circuit course

1. Introduction

Learners study a learning content well when they are exposed to the subject matter with a variety of instructional methods. Most engineering education students obtain the best learning performance through experimentation and active involvement [1]. Nevertheless, the traditional lecture mode of engineering education provides only a little experimentation, active involvement and other learning activities. To complement the lack of learning activities in the traditional classroom, the interactive Computer Assisted Engineering Education Software (CAEES) provides students with supplementary exposure to the fundamental concepts in engineering education to enhance the learning content [2]. Since computers have become available, various designs of CAEES user interfaces have been researched and developed. There are two categories of CAEES interfaces. One is the conventional interface category, such as the Graphical User Interface (GUI), which is based on a keyboard and mouse [3]. The other is the non-conventional interface category, such as the Natural User Interface (NUI), which is based on gesture and a voice-based interface. It does not require users to have any prior knowledge of technology and enables users to interact with computers in the way that people interact with real objects. For example, Kinect is a motion sensing input system designed by Microsoft for the Xbox 360 video game console, with the devices of a Charge-coupled Device (CCD), a 3D depth CCD and multi-array microphones; user movements, gestures and voices are able to be captured and traced [4].

It provided a new and revolutionary way of interaction and has turned it into a naturally sophisticate user interface. Nowadays, the Kinect sensor is applied in many professional areas, including medicine, entertainment, education, and many other fields [5]. Some of the scholars maintain that to apply the technical innovation of Kinect is of educational assistance, but there is a lack of proper strategies or tools to assist learning. Therefore, aside from the fact that this research is mainly technically conducted with gesture-based computing, the teaching strategies are also considered.

In some abstract learning content, such as science or mathematics, learners might lose interest in learning without any support [6]. Researchers have indicated that students' learning achievements could be disappointing unless effective learning strategies or tools can be provided [7–9]. To help students to organize information, concept mapping provides a learning strategy that shows a diagram linking with related nodes to display the relationships between concepts. Concept mapping is the most frequently used learning strategy [10] with visual aids to support information organization. Via qualitative and quantitative studies, researchers

** Corresponding author.

* Accepted 30 October 2013.

have pointed out that a concept map can increase meaningful learning, which promotes positive effects on the learning performance [9]. In the last decade, it has also played important roles in many professional fields of applications, including knowledge construction and organizing tools [11], knowledge structure measuring tools [12], and learning guidance tools [13]. Consequently, concept maps provide a visualized cognitive tool for learners to organize their knowledge and enhance their learning experiences and, through reflective thinking, the self-awareness of the learner can be increased [14].

In this study, a gesture-based computer assisted engineering education approach based on using a concept map-oriented mind tool in the basic engineering circuit course is proposed. An experiment has been conducted to investigate the following research questions.

1. Is the concept of a map-oriented gesture-based computer assisted engineering education system in the basic engineering circuit course helpful to students in improving their learning achievement?
2. Do the students have a better performance in basic engineering circuit learning through the concept maps approach?
3. Do the students have a better performance in basic engineering circuit learning through the gesture-based computer assisted engineering education approach?

2. Literature review

2.1 Computer assisted engineering education

Various designs of computer assisted engineering education systems have been researched and developed. Generally, there are two categories of system interface. One is graphical user interface computer assisted engineering education, which is based on a keyboard and a mouse, such as an online laboratory framework for the control of engineering courses [2]. Some paper presented a user-friendly finite difference time domain algorithm that uses the graphical property editor in MATLAB to study and model electromagnetic fields and the media [15]. Some paper presented a Web-based learning package, which is called the Construction Contracts Information Service (CCIS), for the teaching of construction contracts to Construction Engineering students [16]. All these papers focused on the graphical user interface that is based on a keyboard and a mouse.

Today, the natural user interface based on gesture-based technology is getting more popular than in the past, since it does not require users to have any prior knowledge of technology and enables users to interact with computers in the way that people interact with real objects. Also, there are only a few papers on research about the natural user interface in the domain of engineering education. Therefore, the aim of this paper is to inquire as to the learning performance of engineering education with the adopted gesture-based technology in the natural user interface.

2.2 Gesture-based technology

With bodily-kinesthetic intelligence, gesture-based computing can be considered to be an innovative educational development. Gesture-based technology includes devices controlled by natural movements of the finger, hand, arm, and body [17]. With Microsoft Kinect, a motion sensing device that performs controllerless interaction for the Xbox 360, game console user movements are able to be tracked and translated into interactions. Kinect is a multi-sensor input system with the devices of a video camera, a 3D depth camera and an array of microphones [4]. It is a sophisticated natural user interface for users to control and interact with the game console through gestures and voice commands instead of touching any game controllers. Hsu [18] showed that the kinesthetic features of Kinect and the gesture-based interaction will definitely encourage educators to dedicate themselves to kinesthetic pedagogical exercises in indoor instruction. It not only offered a new and revolutionary way of interaction but also had the attention of researchers and product developers in many areas.

The gesture-based technology is applied in divergent realms. For example, Gordon et al. [19] used Nintendo Wii to increase pediatric constraint-induced movement therapy and indicated that bimanual training, viewing video gaming and virtual reality training will be important in future rehabilitation efforts. Lee et al. [20] built a novel air painter system with Wii Remote, which involves basic painting functions, free sketching, and Chinese, English and Japanese recognition. Grieser et al. [21] used Selected Wii Fit Activities in College Aged Individuals to define Intensity Levels. The result showed that Wii Fit can effectively promote the physical activities of college aged individuals. Chang et al. [22] tried to use a Kinect-based system to cure two young adults with motor injuries. Data demonstrated that the motivation for physical therapy of the two participants is significantly enhanced, thus their exercise performance is promoted in the intervention phase. Vernadakis et al. [23] indicated that the use of the Nintendo Wii gaming console will effectively help undergraduate Physical Education students, especially in their physical performance related balance ability.

However, the current experiments and developments with Kinect still remained in a primitive state. Some of the scholars emphasize applying the technical innovation of Kinect as an educational assistant, but there is a lack of proper strategies or tools to assist learning. If Kinect can be operated with some helpful software for teachers to develop their control over computers, it would definitely be turned into an efficient interactive educational technology (Hsu 2011[P1]). Therefore, aside from the fact that this research is mainly technically conducted with gesture-based computing, the teaching strategies are also considered. This study has developed a gesture-based learning system to support a basic engineering circuit course by providing supplementary learning materials to complement the content, and building learners' facilities in concept mapping to help them organize their knowledge.

2.3 Concept maps

To observe and understand children's scientific conceptual change processes, the concept map learning approach was proposed [10]. Concept mapping provides a learning strategy that displays a diagram linking with related nodes to enable students to organize information through visual aid support. There are two concept mapping approaches. One is the learner-constructed concept map, and the other is the expert-constructed concept map. The expert-constructed concept map shows a teaching–learning strategy, which is used to develop learning in reading comprehension and to save time for instructors in teaching [24]. Novak and Gowin [10] found that meaningful learning can be built when learners link their original cognitive structures with the new ones in the teaching process. Researchers have indicated that a concept map can effectively help learners to construct knowledge and restructure their old knowledge with new information [25].

Various kinds of concept mapping strategy have been developed in recent years. Concept mapping provides a learning strategy that shows a diagram linking with related nodes to display the relationships between concepts. It is the most frequently used learning strategy [10]. It selects one concept as the center, and associates the related concepts and details as the mapping developed from the center to the outside [26]. When information is processed with concept mapping, learners' meta-cognitive awareness is enhanced to support them to build a proper monitoring strategy and to promote their use of retrieving and memorizing knowledge [10, 27–28]. Lipson [29] and Guastello [30] demonstrated that concept mapping strategies provided more learning assistance to students with low proficiency. Chiang et al. [31] also indicated that middle and lower-ability learners had a higher learning performance in information organization and comprehension when they used different concept mapping strategies instead of traditional reading strategies. Researchers have showed that there is no demonstrated change in learning performance when learners do not perceive their shortcomings [32]. Hwang et al. [33] further pointed out that such a problem could get worse for mobile learning activities when learners stayed in the field with their learning tasks in a disturbed status without effective and prompt hints or guidance being provided. Therefore, it is crucial to offer instant learning hints or guidance for complicated learning tasks to support learners to modify and reflect on their knowledge structures [33, 34]. In this study, an interactive concept map approach is proposed to support gesture-based learning activities for basic engineering circuit courses.

3. Research methodology

3.1 Experiment design

This paper uses the Kinect sensor to develop a gesture-based learning system to support the learning in a basic engineering circuit course; the system functions include speech recognition, gesture recognition, instant quizzes and concept mapping learning guidance. With the use of the concept map learning approach (Fig. 1), students are able to organize the information, define the important concepts and the relationships between concepts,

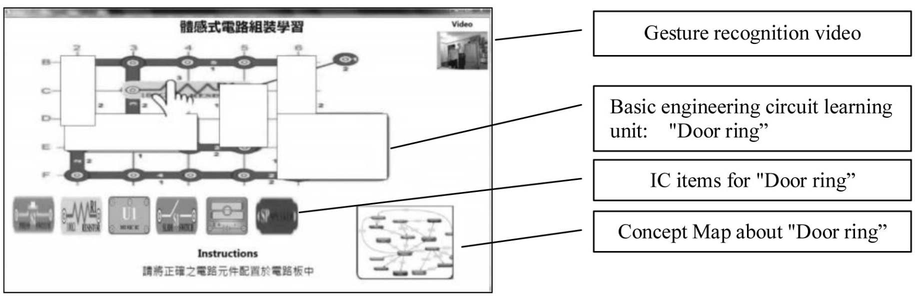

Fig. 1. Concept map-oriented gesture-based learning.

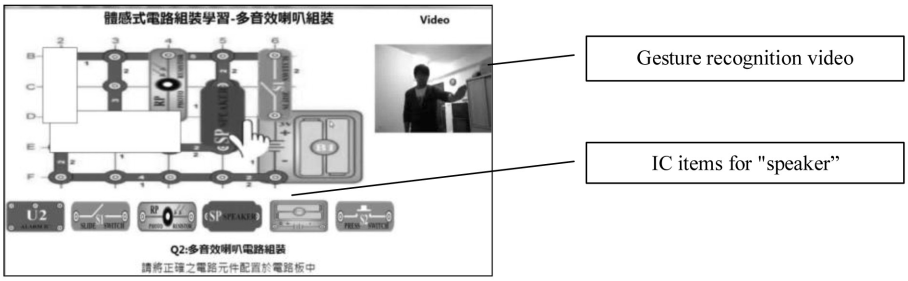

Fig. 2. Conventional gesture-based learning.

Fig. 3. Traditional e-book learning.

and identify their learning status related to the "door ring" unit in the basic engineering circuit course via visualizing the learning content and learning status information. The supplementary learning materials as well as the demonstrative concept maps were developed by consulting two teachers who have more than five years experience in teaching engineering circuit courses. They were informed of the importance of designing phenomenon explanations and providing more realistic illustrations.

Accordingly, to help learners comprehend the learning material, additional learning tools with phenomenon explanations and realistic illustrations were developed, which include digital text and images. Learners can learn a basic engineering circuit by gesture recognition and voice recognition, just like they interact in the non-digital world. However, when learners get confused understanding, caused by a wrong judgment, the system will provide immediate concept mapping learning guidance to make learners revise their knowledge structures. Figure 2 is conventional gesture-based learning, and Fig. 3 is traditional e-book learning.

3.2 Participants

The participants were 93 college students. They were assigned to an Experimental group A (N = 31), an Experimental group B (N = 31), and the Control group (N = 31). The difference between the three groups is the method of learning. The students in Experimental group A were instructed and guided by the Gesture-based Learning System with the Concept Map-oriented learning approach; those in Experimental group B were instructed and guided in the Conventional Gesture-based Learning System without access to concept maps; and those in the Control group were guided with the Traditional E-book Learning.

3.3 Experimental procedure

The experimental procedure consists of three stages, the conduction of the pre-tests, introduction to the tools and learning missions, and the conduction of the post-tests. In the first stage, the students took the basic engineering circuit course pre-test in 30 minutes. In the second stage, it took 10 minutes to instruct the students about the tools and missions of the learning activity. After the instruction, a 20 minute learning activity was conducted. During the learning activity, the students in Experimental group A were guided to the gesture-based learning system with the concept map-oriented learning approach through access to the corresponding concept maps and supplementary learning materials via Kinect sensor. The students in Experimental group B were instructed and guided through conventional gesture-based learning via the Kinect sensor. The students in the Control group used the traditional approach of e-book reading. In the final stage, the students completed the basic engineering circuit course post-test in 30 minutes.

The pre-test was conducted to evaluate the students' prior knowledge before the basic engineering circuit learning. It consisted of five true–false questions and five multiple-choice questions, giving a total score of 100. The post-test aimed to evaluate the learning achievements of the students after

Table 1. Pre-test results of the basic engineering circuit

Experimental group	*N*	Prior-test mean/S.D.	*F*
A	31	19.16/6.14	0.831
B	31	20.35/5.68	
C	31	18.42/6.05	

Table 2. ANOVA result of learning achievement on the post-test scores of the three groups

	Group	*N*	Mean	S.D.	*F*
EA	Experimental group A	31	67.94	8.54	8.91***
EB	Experimental group B	31	61.48	9.89	
C	Control group	31	56.61	12.89	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3. Pairwise comparisons of the three groups

					95% Confidence interval	
(I) Post-test	(J) Post-test	Mean difference (I–J)	Std. error	Sig.	Lower bound	Upper bound
EA	EB	6.45*	2.69	0.019*	1.11	11. 80
	C	11.32*	2.69	0.000**	5.98	16.67
EB	EA	–6.45*	2.69	0.019*	–11.80	–1.11
	C	4.87	2.69	0.074	–0.47	10.22
C	EA	–11.32*	2.69	0.000**	–16.67	–5.98
	EB	–4.87	2.69	0.074	–10.22	0.47

receiving different approaches to learning the basic engineering circuit. It also consisted of five true–false questions and five multiple-choice questions, with a total score of 100. The post-test was developed by consulting two teachers who had taught the engineering circuit course for more than four years.

4. Research result and discussion

Before the experiment, a test of basic engineering circuit knowledge was conducted to identify the differences in basic engineering circuit cognition between the three groups. The descriptive statistics of the pre-test are presented in Table 1. The result shows that their prior knowledge was not significantly different ($F = 0.831$, p-value = 0.439).

Table 2 shows the ANOVA result of the post-test scores of the three groups. The means and standard deviations of the post-test scores were 67.94 and 8.54 for Experimental group A, 61.48 and 9.89 for Experimental group B, and 56.61 and 12.89 for the Control group. It is found that the post-test scores of the three groups are significantly different ($F = 8.91$, $p < 0.001$).

The pairwise comparisons (Table 3) show that there is a significant difference between EA and EB, and a significant difference between EA and C. In other words, the students in Experimental group A had a significantly better learning achievement than the students in both Experimental group B and the Control group. Consequently, it is concluded that a gesture-based learning system with the concept map-oriented approach was more helpful to the students in terms of learning achievement in the basic engineering circuit course than the conventional gesture-based learning approach and the traditional e-book learning approach.

5. Conclusion

This study investigated the effects on students' learning achievement of the gesture-based learning system with the concept map-oriented approach in the basic engineering circuit course. The experimental results showed that the gesture-based learning system with the concept map-oriented approach had significantly better effectiveness in improving students' learning achievements than the conventional gesture-based learning approach and the traditional e-book learning approach. Regarding the effectiveness of the concept maps, the experimental results had indicated the effectiveness of employing concept maps in helping students organize the acquired knowledge. Regarding the effectiveness of providing supplementary learning materials, the experimental results showed no significant difference between Experimental group B and the Control group.

Acknowledgement—This paper was partially supported by the Research Grant NSC 101-2511-S-269 -001 -MY3 from Taiwan's National Science Council.

References

1. R. M. Felder and L. K. Silverman, Learning and teaching styles, *Engineering Education*, 1988, pp. 674–681.
2. B. Duan, K. V. Ling, H. Mir, M. Hosseini and R. K. L. Gay, An online laboratory framework for control engineering courses, *International Journal of Engineering Education*, **21**(6), 2005, pp. 1068–1075.
3. A. Jaimesa and N. Sebe, Multimodal human–computer interaction: A survey, *Computer Vision and Image Understanding*, **108**, 2007, pp. 116–134.
4. T. Dutta, Evaluation of the Kinect sensor for 3-D kinematic measurement in the workplace, *Applied Ergonomics*, **43**, 2012, pp. 645–649.
5. S. Kean, J. Hall and P. Perry, *Meet the Kinect: An Introduction to Programming Natural User Interfaces*, A Press, CA, 2011.
6. P. Mantzicopoulos and H. Patrick, The Seesaw is a machine that goes up and down: young children's narrative responses to science-related informational text, *Early Education and Development*, **21**(3), 2010, pp. 412–444.
7. N. S. Chen, D. C. E. Teng, C. H. Lee and Kinshuk, Augmenting paper-based reading activity with direct access to digital materials and scaffolded questioning, *Computers & Education*, **57**(2), 2011, pp. 1705–1715.
8. G. J. Hwang, Y. R. Shi and H. C. Chu, A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning, *British Journal of Educational Technology*, **42**(5), 2011, pp. 778–789.
9. C. C. Liu, P. H. Don and C. M. Tsai, Assessment based on linkage patterns in concept maps, *Journal of Information Science and Engineering*, **21**(5), 2005, pp. 873–890.
10. J. D. Novak and D. B. Gowin, *Learning how to Learn*, Cambridge University Press, Cambridge, UK, 1984.
11. Y. Erdogan, Paper-based and computer-based concept mappings: The effects on computer achievement, computer anxiety and computer attitude, *British Journal of Educational Technology*, **40**, 2009, pp. 821–836.
12. K. E. Chang, Y. T. Sung, R. B. Chang and S. C. Lin, A new assessment for computer-based concept mapping, *Educational Technology & Society*, **8**(3), 2005, pp. 138–148.
13. P. Panjaburee, G. J. Hwang, W. Triampo and B. Y. Shih, A multi-expert approach for developing testing and diagnostic systems based on the concept effect model, *Computers & Education*, **55**, 2010, pp. 527–540.
14. G. Y. M. Kao, S. S. J. Lin and C. T. Sun, Breaking concept boundaries to enhance creative potential: using integrated concept maps for conceptual self-awareness, *Computers & Education*, **51**, 2008, pp. 1718–1728.
15. S. Singh, S. Bhatt, S. Kapoor, A. Bhavsar and B. P. Kumar, A student-accessible graphical user interface-based FDTD algorithm for visualization of electromagnetic fields, *International Journal of Engineering Education*, **21**(4), 2005, pp. 625–635.
16. S. O. Cheung, K. W. Cheung and C. H. Suen, Web-based learning in engineering education: A portal for teaching of construction contracts, *International Journal of Engineering Education*, **20**(1), 2004, pp. 124–138.
17. L. F. Johnson, A. Levine, R. S. Smith and K Haywood, Key emerging technologies for postsecondary education, *The Education Digest*, **76**(2), 2010, pp. 34–38.
18. H. J. Hsu, The potential of Kinect in education, *International Journal of Information and Education Technology*, **1**(5), 2011, pp. 365–370.
19. A. M. Gordon and S. Y. Okita, Augmenting pediatric constraint-induced movement therapy and bimanual training with video gaming technology, *Technology and Disability*, **22**, 2010, pp. 179–191.
20. C. H. Lee, C. L. Liu, Y. A. Chen and Y. S. Chen, Painting in the air with Wii Remote, *Expert Systems with Applications*, **38**, 2011, pp. 14668–14678.
21. J. D. Grieser, Y. Gao, L. Ransdell and S. Simonson, Determining intensity levels of selected Wii fit activities in college aged individuals, *Measurement in Physical Education and Exercise Science*, **16**, 2012, pp. 135–150.
22. Y. J. Chang, S. F. Chen and J. D. Huang, A Kinect-based system for physical rehabilitation: A pilot study for young adults with motor disabilities, *Research in developmental disabilities*, **32**, 2011, pp. 2566–2570.
23. N. Vernadakis, A. Gioftsidou, P. Antoniou, D. Ioannidis and M. Giannousi, The impact of Nintendo Wii to physical education students' balance compared to the traditional approaches, *Computers & Education*, **59**, 2012, pp. 196–205.
24. R. Hall, D. Dansereau and L. Skaggs, Knowledge maps and the presentation of related information domains, *Journal of Experimental Education*, **61**(1), 1992, pp. 5–18.
25. G. J. Hwang, P. H. Wu and H. R. Ke, An interactive concept map approach to supporting mobile learning activities for natural science courses, *Computers & Education*, **57**(1), 2011, pp. 2272–2280.
26. C. Fisher, H. Gleitman and L. R. Gleitman, On the semantic content of subcategorization frames, *Cognitive Psychology*, **23**, 1991, pp. 331–392.
27. C. H. Chiu, C. C. Huang and W. T. Chang, The evaluation and influence of interaction in network supported collaborative concept mapping, *Computers and Education*, **34**(1), 2000, pp. 17–25.
28. J. D. Novak, Concept maps and diagrams: Two metacognitive tools for science and mathematics education, *Instructional Science*, **19**, 1990, pp. 29–52.
29. M. Lipson, The effect of semantic mapping instruction on prose comprehension of below-level college readers, *Reading Research and Instruction*, **34**, 1995, pp. 367–378.
30. E. F. Guastello, Concept mapping effects on science content comprehension of low-achieving inner-city seventh graders, *Remedial & Special Education*, **21**(6), 2000, pp. 356–364.
31. S. C. Chiang and S. Y. Guo, Various learning processes of cognitive mapping strategies on boosting to become experts and comprehension of knowledge experts, *Journal of National Taiwan Normal University*, **42**, 1997, pp. 1–16.
32. G. Y. M. Kao, S. S. J. Lin and C. T. Sun, Beyond sharing: Engaging students in cooperative and competitive active learning, *Educational Technology & Society*, **11**(3), 2008, pp. 82–96.
33. G. J. Hwang and H. F. Chang, A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students, *Computers & Education*, **56**(1), 2011, pp. 1023–1031.
34. P. Denton, J. Madden, M. Roberts and P. Rowe, Students' response to traditional and computer-assisted formative feedback: a comparative case study, *British Journal of Educational Technology*, **39**, 2008, pp. 486–500.

Sheng-Wen Hsieh is Secretary General of the Far East University in Taiwan. He earned his Ph.D. in Management Information Systems at the National Sun Yat-sen University. He has published over 120 papers in academic journals, international conferences and book chapters. Dr. Hsieh also made great effort in supporting and promoting the e-learning application of the Taiwan Academic Network (TANet). He received the Excellent Contribution Award of TANet from the Ministry of Education in 2011. Dr. Hsieh is very keen to promote information technology for education and business. He is also an associate editor of *the International Journal of Instruction* and an assistant editor of the *International Journal of Organizational Innovation*.

Tzong-Song Wang received a Ph.D. in information education Administration at the University of South Dakota, in 2003. His research interest areas are web-based learning, information education, RFID mobile device, electronic commerce, mobile commerce. Dr. Wang has been working in several projects for the companies and governmental agencies by more than 15 years. Dr. Wang has been written several conference and journal articles in the area of web-based engineering education. He received the Research and Academic Award of international conference of organizational innovation in 2012. He is currently an assistant professor of the Graduate Institute of Cultural and Creative Industries.

Ming-Chia Hsieh is the Assistant Professor in the Department of Digital Media Design and Management at Far East University in Taiwan. He earned a Ph.D. in Management Information Systems of National Kaohsiung First University of Science and Technology. He has published over 30 papers in academic journals and international conferences. His research interests include electronic commerce, internet marketing and e-learning.