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A co-creation blended KM model for cultivating critical-thinking skills

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ABSTRACT

Both critical thinking (CT) and knowledge management (KM) skills are necessary elements for a university student's success. Therefore, this study developed a co-creation blended KM model to cultivate university students' CT skills and to explore the underlying mechanisms for achieving success. Thirty-one university students participated in this study. Findings from the 17-week training program suggest that scaffolding university students through knowledge sharing, internalization, and co-creation processes in a blended KM environment can effectively enhance their CT skills. Moreover, the attribute–treatment interaction (ATI) analysis suggests that judicial thinking style which relates to a deep learning approach may facilitate KM and help improve CT skills. Notably, the complex underlying mechanisms and paths of influence found in this study attest to the highly dynamic nature of the proposed KM processes.

1. Introduction

Critical thinking is regarded as an effective learning strategy, a requirement for business leaders, and an essential ability for generating knowledge (Yeh, 2009). However, knowledge management (KM) has recently emerged as a new discipline that involves acquiring, capturing, sharing, using, and creating knowledge (Ungaretti & Tillberg-Webb, 2011). KM involves leveraging explicit knowledge and implicit knowledge to stimulate innovation, build a sense of community, preserve the institutional knowledge base, and promote internal and external organizational effectiveness (Liebowitz & Frank, 2011). Many researchers have suggested that KM and e-learning share some characteristics and that e-learning can be a good vehicle for knowledge acquisition, knowledge sharing, knowledge application, and knowledge creation (e.g., Adams & Lamont, 2003; Liebowitz & Frank, 2011; Wild, Griggs, & Downing, 2002). As a result, blended KM models that integrate KM and e-learning have been used in several human resource training programs (e.g., Alony, Whymark, & Jones, 2007; Ferguson, Mathur, & Shah, 2005; Wang, Huang, & Yang, 2009).

To date, many KM training models have been proposed, but most models are focused on knowledge sharing (e.g., Bartol & Abhishek, 2002; Choi & Lee, 2003; Earl, 2001; Gagné, 2009; Matzer, Renzl, Müller, Herting, & Mooradian, 2008) or knowledge creation (e.g., Baskerville & Dulipovici, 2006; Imani, 2007; Nonaka & Toyama, 2003). Few models have emphasized the importance of knowledge internalization (e.g., Nonaka & Takeuchi, 1995; Nonaka & Toyama, 2003). A KM process is, in essence, a loose and collaborative behavior because knowledge is always fuzzy and messy, and the knowledge creation process involves shared knowledge creation (Baskerville & Dulipovici, 2006). Therefore, effective knowledge creation should be achieved via a "co-creation" process rather than an "individual creation" process. Aptitude–treatment interactions (ATIs) refer to the idea that some training strategies are more effective for particular people depending on their traits and abilities (Snow, 1991). Previous scholars have found that ATIs influence the course and outcomes of training (e.g., Dane, Baer, Pratt, & Oldham, 2011; Yeh, 2007) and that thinking styles are related to the development of critical-thinking skills (Yang & Lin, 2004). Accordingly, thinking style may influence the development of critical-thinking skills during a blended KM training program.

Given the current emphasis on teaching critical-thinking skills in higher education as well as the rapidly evolving theories and practices of KM and e-learning in recent years, the goals in this study were fourfold: (1) develop a blended KM model for cultivating critical-thinking skills that emphasizes knowledge sharing, internalization, and co-creation; (2) conduct a training program based on the developed model to

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improve university students' critical-thinking skills; (3) investigate whether there were ATIs of thinking styles on the development of critical-thinking skills during the training process; and (4) explore and validate the underlying mechanisms that may ensure the success of the model and the program.

2. Literature review

2.1. What is critical thinking?

Moore and Parker (2009) defined critical thinking as "the careful application of reason in the determination of whether a claim is true" (p. 3). Halpern (1998) argued that critical thinking is purposeful and goal-directed; it is the thinking that is required to solve problems, formulate inferences, calculate probabilities, and make decisions. As for the thinking process, Hooks (2010) declared that critical thinking involves two stages. The first stage involves discovering the who, what, when, and how of things; the second stage involves utilizing previously discovered information such that an individual can sort and rank the information. Based on a thorough review of critical-thinking definitions, Yeh (2009) proposed that the construct of critical thinking is composed of three elements: critical-thinking skills, critical-thinking dispositions, and prerequisite knowledge. This study, however, focused mainly on critical-thinking skills.

Critical-thinking skills are demonstrated by strategically employing such cognitive skills as analysis, identification of assumptions, interpretation, inference, induction, deduction, and argument evaluation (Halpern, 2003; Hughes, Lavery, & Doran, 2010; McCarthy-Tucker, 2000; Moore & Parker, 2009; Norris & Ennis, 1989). Critical-thinking skills also require such metacognitive skills as self-discipline, self-evaluation, self-regulation, and self-correction. These skills are typically cultivated via effective communication and problem solving (Paul & Elder, 2001). From a more comprehensive perspective, Paul and Elder (2001) declared that critical thinking is a thinking mode in which the thinker improves the quality of his or her thinking by skillfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them. These intellectual standards are clarity, precision, accuracy, significance, relevance, completeness, logicalness, fairness, breadth, and depth. Moreover, critical thinkers routinely apply these intellectual standards to eight elements of reasoning to develop their intellectual traits. These elements are purpose, questions or issues, points of view, information, inferences, concepts, implications, and assumptions. These elements have been integrated into situation-based critical-thinking tests and have been confirmed to be important indicators of critical-thinking skills (Yeh, 2009).

2.2. Definitions and evolving models of KM

KM usually involves three elements: people, process, and technology. The people element emphasizes the construction of a knowledge-sharing culture; the process element deals with the incorporation of KM into learning or work processes; and the technology element refers to the creation of a knowledge network that integrates isolated knowledge (Liebowitz & Frank, 2011). Based on the process viewpoint, Ungaretti and Tillberg-Webb (2011) argued that KM involves the acquiring, capturing, sharing, using, and creating of knowledge. Along the same line, Darroch (2003) claimed that KM comprises three processes: knowledge acquisition, knowledge dissemination, and knowledge application. In addition, knowledge can be categorized into tacit knowledge and explicit knowledge (Matzer et al., 2008). Hult (2003) defined KM as the systematic process of using explicit and tacit knowledge to achieve a competitive advantage in the marketplace. Tacit knowledge is difficult to articulate and is usually developed from direct experiences, interactive conversations, and shared experiences, whereas explicit knowledge can be precisely articulated and is ready for sharing and transfer (Ungaretti & Tillberg-Webb, 2011). In sum, from the process-oriented viewpoint of KM, knowledge sharing and knowledge creation constitute the core processes; from the category-oriented viewpoint of KM, knowledge management consists of the management of tacit and explicit knowledge.

To date, considerable attention has been paid to the roles of knowledge sharing and knowledge creation during the KM application process. Knowledge sharing consists of the transfer of knowledge from one specific set of interactions to another. Knowledge sharing is important for sustaining competitive advantages because innovation occurs when people share and combine their personal knowledge (Matzer et al., 2008). Knowledge creation involves the analysis, application, and expansion of knowledge, and it encourages individual learning, confidence, lifelong learning, and learning within communities (Swirski, Wood, & Solomonides, 2008). Nonaka and Toyama (2003) defined knowledge creation as "a dialectical process, in which various contradictions are synthesized through dynamic interactions among individuals, the organization, and the environment" (p. 2). Based on these concepts, they proposed the SECI model (socialization, externalization, combination, internalization). The SECI model defines "socialization" as the process of creating new tacit knowledge through shared experiences in daily social interactions. Such tacit knowledge is then converted into explicit knowledge through the process of "externalization". Next, explicit knowledge is processed to form more complex and systematic explicit knowledge through the process of "combination". Finally, the combined explicit knowledge is converted into tacit knowledge through the process of "internalization".

Recently, "blended learning" has emerged as a popular format for learning. This learning system involves both traditional face-to-face instruction and online communication in an electronic classroom (Bender & Vredevoogd, 2006). The e-learning process reflects the needs of a dynamic knowledge society and implies a freedom to access knowledge unrestricted by cultural and social boundaries (Raza & Murad, 2008). Many researchers have advocated integrating KM and e-learning systems and have argued that this integration can upgrade existing learning effects. For example, Lee and Choi (2003) found that information technology facilitates the exchange of tacit knowledge. Wild et al. (2002) claimed that e-learning and basic KM processes share many attributes and that e-learning can be used as a tool for KM systems. Chen and Hsiang (2007) argued that e-learning contributes to the formation of a knowledge-sharing culture. Some researchers have also claimed that KM systems help personalize learning experiences because e-learning is creating a growing body of knowledge (e.g., Barker, 2005; Wild et al., 2002). Moreover, Ungaretti and Tillberg-Webb (2011) claimed that whereas KM relies on knowledge sharing and transfer, e-learning emphasizes the development of an individual's knowledge, competencies, and dispositions through a technologically designed learning process. Both epistemologies are essential for effective learning and should be viewed as reciprocal learning processes. In the same vein, Adams and Lamont (2003) proposed that integrating e-learning and KM processes helps build learning experiences and bring students closer to their goals. Accordingly, the necessity of integrating KM and e-learning processes has become apparent. As a result, the application of "blended KM" models has become popular among researchers.

2.3. Blended KM models and critical-thinking skills

Adamides and Karacapilidis (2005) argued that information systems supporting collaboration and argumentation allow for a holistic representation of the argumentation process. Such systems regard knowledge creation as a design requirement, support knowledge exploration, promote asynchronous exchanges of dialogs or views, and employ face-to-face argumentative dialog in a structured manner. Given that argumentation is a key process in critical thinking (Moore & Parker, 2009; Norris & Ennis, 1989), a blended KM environment should facilitate the ability to learn critical-thinking skills via knowledge sharing and knowledge co-creation that emphasize collaboration.

Some researchers have stressed the importance of co-creation in KM-based training, although this term is seldom used in the literature. For example, the concept of 'ba' in the SECI has recently been discussed by scholars (Baskerville & Dulipovici, 2006). 'Ba' represents a shared space for knowledge creation. Participation in a 'ba' creates another form of knowledge creation, shared knowledge creation, which is a fundamental property of collaborative activities, such as communities of practice and strategic communities (Baskerville & Dulipovici, 2006). Cecez-Kecmanovic (2004) claimed that knowledge becomes a group resource during the process of knowledge creation and that sense-making activities are critical for the success of knowledge creation. Sense making, with its high potential for collective learning, refers to the social interactions between people and their environments (Baskerville & Dulipovici, 2006).

Another critical but often ignored KM process is "knowledge internalization". According to Vygotsgy's socio-cultural theory, internalization is a key process in personal development and higher-order thinking skills, and this process is usually realized via social interactions. Through social interactions, individuals gradually develop their tools of thought and construct their knowledge base (Santrock, 2005). In the SECI model, Nonaka and Toyama (2003) argued that internalization is the process by which knowledge is applied to practical situations and becomes the base for new routines. They claimed that explicit knowledge has to be actualized through action, practice, and reflection such that a person can convert this knowledge into his or her own. Notably, a reflective mind is the hallmark of critical thinking (Schroyens, 2005). Study findings have suggested that enhancing self-awareness and mindfulness nurtures reflective practices (e.g., Collier, 1999; Tillema, 2000; Yeh, Huang, & Yeh, 2011) and that providing feedback enhances self-awareness and mindful learning (Titone, Sherman, & Palmer, 1998). Moreover, researchers have suggested that interacting with others enhances self-reflection and increases the exchange of ideas, which further facilitates mindful learning (Steele, 2001).

Scardamalia and Bereiter (2006) declared that knowledge sharing consists of the acquisition, re-organization, transfer, and distribution of experience-based knowledge. Choi and Lee (2003) suggested that KM methods include four styles: dynamic, system, human-oriented, and passive. The dynamic style is characterized by knowledge sharing that is achieved through informal discussions. The authors found that the dynamic style results in the highest level of performance. In addition, the development of a knowledge community has been found to be critical to the knowledge-sharing process. For example, scholars have found that the community of practice plays an important role in the distribution and creation of knowledge (Choi & Lee, 2003) and that a knowledge community in an e-learning system is influenced by the following factors: practice of a knowledge strategy, establishment of a knowledge-sharing loop, involvement in a knowledge community, learner-centered technology, and sufficient learning time and space (Chen & Hsiang, 2007). Moreover, researchers have found that observational learning (i.e., learning by observing and imitating others (Woolfolk, 2007)) also facilitates knowledge sharing (Yeh et al., 2011).

Accordingly, a well-designed blended KM model can be a good vehicle for improving critical-thinking skills. Such a model should emphasize the dynamic interactions of knowledge sharing, internalization, and co-creation. During the KM process, community building, collaborative learning, observational learning, and interactive discussions are important to knowledge sharing; self-reflection, self-awareness, mindful learning, feedback, practices, and interactive discussions are critical to knowledge internalization; and community building, co-creation activities, and interactive discussions are important to knowledge co-creation.

2.4. Thinking styles and their ATI effects on learning critical-thinking skills

Thinking style is the preferred method used to employ one's intellectual abilities. Thinking style influences an individual's decisions regarding the use of knowledge in his or her daily interactions with the environment (Zhang & Sternberg, 2000). Based on the perspective of functions, Sternberg (1997) proposed three thinking styles: legislative, executive, and judicial. Individuals with legislative styles prefer activities that are based on creative and constructive planning. Individuals with judicial styles prefer activities that require analysis and evaluation of existing rules. Individuals with an executive style prefer to engage in pre-structured tasks.

Previous ATI studies have attempted to understand how an outcome depends on the relationship between an individual's specific aptitude(s) and the treatment he or she receives (Caspi & Bell, 2004). Aptitude refers to a measurable personal characteristic that impacts the learning outcomes of the designated treatment; an interaction of aptitude and treatment may occur if a treatment has different levels of influence on individuals with different types of aptitude (Yeh, 2011). If a treatment and an individual's aptitude(s) are well matched, then the treatment's effect will be optimal (Astleitner & Koller, 2006).

To date, few studies have investigated the ATI effects of thinking styles on university students' capacities to learn critical-thinking skills. Yeh (2007) conducted a study that utilizes a computer simulation to analyze behavioral changes in preservice teachers during an educational session teaching critical-thinking skills. This study found that participants with a judicial thinking style benefit the most from the computer-simulated training program, and those with executive thinking styles benefit the least. This finding suggests that thinking styles exert an ATI effect on the ability to improve one's critical-thinking skills. The ATI effects of thinking styles have also been found in studies on problem solving. For example, O'Hara and Sternberg (2001) found that a person's thinking style determines his or her creative problem-solving skills under a different set of instructions. Dane et al. (2011) also found that thinking styles interact with a person's problem-solving approach and influenced his or her ability to generate creative ideas. Critical thinking is a necessary skill in problem solving. Thus, the ATI effects found in the studies on problem solving lend support to the notion that thinking styles exert ATI effects on critical-thinking skills.

Researchers have argued that the integration of KM and e-learning systems should be learner-centered such that various teaching paradigms are adapted to meet the needs of students with different learning styles (Liebowitz & Frank, 2011). Accordingly, investigating the ATI effects of thinking styles on the ability to develop critical-thinking skills may provide implications for future studies in this area.

2.5. Hypotheses of this study

The four objectives proposed in this study are as follows: (1) develop a blended KM training program to cultivate university students' critical-thinking skills, (2) conduct a training program based on the blended KM model to improve university students' critical-thinking skills, (3) investigate the ATI effects that occur during the training process, and (4) explore the underlying mechanisms of this program. In accordance with the second and the third objectives, this study proposed the following hypotheses: (1) A blended KM training program that incorporated knowledge sharing, knowledge internalization, and knowledge co-creation would significantly improve university students' critical-thinking skills. (2) Thinking styles would exert ATI effects on university students' ability to improve their critical-thinking skills during the training process. That is, the participants with different level of thinking styles would have different levels of improvement in their critical-thinking skills after undergoing the training program.

3. Method

3.1. Participants

The participants in this study were 31 university students enrolled in the course "Critical-thinking Instruction". They were preparing to be secondary school teachers. With a mean age of 21.93 years (SD = 3.16), the participants included 7 males (22.6%) and 24 females (77.4%).

3.2. Instruments

The main instruments employed in this study were the e-learning interface developed by National Chengchi University in Taiwan (http://wm3.nccu.edu.tw/learn/index.php), the Situation-Based Critical Thinking Test (SB-CTT), the Inventory of Thinking Styles (ITS), and a reflection questionnaire. The NCCU e-learning platform consisted of an Information Center, Assessment Center, Communication Center, Personal Area, and Public Zone.

This study employed the SB-CTT to measure the participants' critical-thinking skills. The higher score one gets, the better critical-thinking skills he/she has. The SB-CTT is based on Paul and Elder's (2001) advocation on intellectual standards and reasoning elements. Empirical studies have validated the SB-CTT's measures of critical-thinking skills (Yeh, 2005, 2009). The Cronbach's coefficient for the SB-CTT was .80. In accordance with the main theme of "happiness", the SB-CTT described Albert's beliefs and thoughts about life in one paragraph. The paragraph consisted of several assumptions and issues, such as happiness, pessimism, selfishness, irresponsibility, and believing in fate. Following the paragraph, seven open-ended questions investigated seven critical-thinking abilities: (1) identifying purposes and information, (2) defining issues, (3) recognizing assumptions, (4) identifying points of view, (5) making inferences, (6) identifying implications, and (7) evaluating arguments (Yeh, 2005). Two trained doctoral students scored the test in this study. The answers of each question were scored on a scale ranging from 1 to 5 points based on specific scoring rubrics. In addition, this study employed an item of self-evaluated critical-thinking skills to provide supplementary supports to the participants' improvements in critical-thinking skills. This item asked, "How do you describe your critical-thinking skills?" The item was scored on a scale ranging from 1 to 6 points, which represented "extremely poor" to "extremely excellent", respectively.

The ITS was employed to measure the participants' thinking styles. It was a 5-point Likert scale and was adapted from the Sternberg–Wagner Thinking Styles Inventory (Li, 1999). The response options for each item ranged from "never" to "always", which corresponded to 1 point and 5 points, respectively. The original ITS included 7 types of thinking styles and each type of the style included 5 items. Among the thinking styles, the judicial, the legislative, and the executive style have been the most commonly used; moreover, these thinking styles may help to distinguish the concerned ATI in this study. These three thinking styles were therefore selected in this study and the mean score of each style was calculated to represent an individual's tendency in thinking styles. The Cronbach's coefficients for the three styles were .69, .62, and .61, respectively.

Finally, a reflection questionnaire consisting of 7 open-ended questions was developed by the researcher to obtain a deep understanding of each participant's feelings toward the training program and the underlying mechanisms that contributed to the effectiveness of the training program. The reflection questions are listed in the Results section.

3.3. Procedures and instructional design

To determine whether a blended KM model that emphasizes knowledge sharing, knowledge internalization, and knowledge co-creation would improve university students' critical-thinking skills and whether there were any ATI effects during the training process, this study employed a before-and-after design. The experimental instruction, a 34-h course designed for Taiwanese university students who were unfamiliar with critical thinking, had lasted for 17 weeks (2 h per week). The instruction was conducted by the researcher with the help of two doctoral students; the staff/student ratio was 3/31. The pretests were given in the first week, and the posttests were completed in the 17th week. The pretests included the SB-CTT, the self-evaluations of critical-thinking skills, and the ITS, whereas the posttests included the two instruments used to measure critical-thinking skills and the reflection questionnaire. In the second week, the participants were divided into six self-determined groups to facilitate the development of learning communities via conducting group assignments and discussions. Except for one group which was composed of 6 people, the other groups were composed of 5 people. Moreover, while 3 groups were consisted of participants from the same department, the other groups had the majority of members from 2 different departments. A series of group assignments were distributed from the fourth week onwards to facilitate the formation of the learning communities and the development of critical-thinking skills.

The instructional goals of this training program were to enhance the participants' critical-thinking skills, as measured by the SB-CTT. Based on the aforementioned literature review on critical-thinking skills, the KM theories, and the factors that influence the KM training process, the researcher proposed a co-creation blended KM model for improving critical-thinking skills (see Fig. 1). The central idea of this model was to enhance the participants' critical-thinking skills by continually scaffolding them in knowledge sharing, internalization, and

co-creation via in-class and online-learning activities. Scaffolding refers to an instructional support system that allows students to perform a skill and thereby help them progress into their zone of proximal development (ZPD): the phase at which a student can master a task if appropriate help or support is provided (Woolfolk, 2007). Notably, this model emphasized the dynamics of the three KM processes. More specifically, to facilitate knowledge sharing, this study encouraged the formation of learning communities and observational learning. To enhance the knowledge internalization process, this study emphasized the enhancement of self-awareness and self-reflection, participation in discussions, and practices on critical-thinking skills. In this part, constructive peer feedback which encouraged giving rational suggestions for improvement during discussions of others' viewpoints or assignments was especially emphasized. Finally, several group assignments were used to achieve knowledge co-creation. Meanwhile, thinking styles may have ATI effects on learning critical-thinking skills during training (Yeh, 2007). More details concerning the mechanisms of achieving KM processes and critical-thinking skills are shown in Fig. 1.

Past study findings have suggested that a blended learning approach that combines classroom instruction and e-learning is more effective than a pure e-learning approach (Osguthorpe & Graham, 2003) and students are less satisfying with the pure online discussion approach (LaPointe & Reisetter, 2008). On the other hand, while the asynchronous online discussion allows learners to go beyond the space and time constraints and provides support for community building and productive discourse (Gao, 2011; McCrory, Putnam, & Jansen, 2008), the face-to-face discussion is more prompt in responses, easier to make conclusions, more natural in communication, and more multidirectional in interaction (Wang & Woo, 2007). Online discussion and in-class discussion are therefore complimentary. Accordingly, online discussions were followed by in-class discussions to enhance discussion effects in this study. To facilitate online discussions, the researcher designed the following discussion topics: (1) five critical-thinking skills (i.e., assumptions identification, deduction, induction, explanation, and argument evaluation), (2) situation-based problems that require comprehensive applications of critical-thinking skills, (3) strategic thinking designed to avoid egocentric thinking, and (4) argument evaluations based on concept mapping. Concept maps emphasize the visualization of concepts, knowledge, and relationships (Shaw, 2010). In this study, the participants were requested to develop arguments based on the self-selected topic, and then to illustrate the arguments via concept maps. All of the online topic discussions, scored by discussion frequencies to facilitate discussions, were based on the test items or dialogs developed by the participants. An example of the discussed critical-thinking skill of assumption identification was as follows:

"To effectively reduce our stress, we'd better learn how to manage our emotions."
Assumption 1: The ability to manage our emotions can be learned.
Assumption 2: As long as we can manage our emotions, we can effectively reduce our stress.
(a) Assumption 1 is valid.
(b) Assumption 2 is valid.
(c) Both Assumption 1 and Assumption 2 are valid.
(d) Neither Assumption 1 nor Assumption 2 is valid.

The main content of the class instructions consisted of the following: (1) the nature of critical thinking, (2) the factors that influence critical thinking, (3) critical-thinking skills, (4) the evaluation of critical thinking, (5) the processes and stages of critical thinking, (6) the application of critical-thinking skills, (7) the analysis and development of situation-based problems, (8) strategic thinking, and (9) effective thinking strategies, such as discussion, collaborative learning, concept mapping, role play, and problem-based learning. All activities and instruments employed in this study were in Chinese.

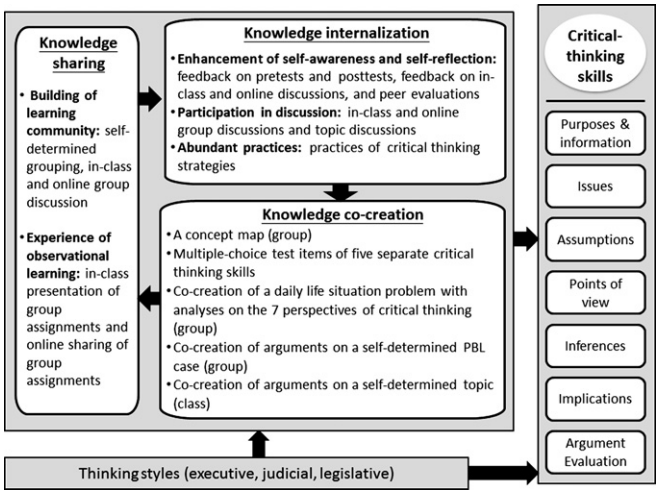

Fig. 1. A blended KM model for improving critical-thinking skills.

3.4. Analysis

A repeated measure analysis of variance (Repeated Measure ANOVA) was employed to investigate the improvements (pretest vs. posttest) in the participants' critical-thinking skills, and a univariate analysis of covariance (ANCOVA) was employed to examine the ATI effects of thinking styles on these improvements. In addition, the study employed content analysis to examine the participants' responses in the reflection questionnaires. Two trained doctoral students conducted the content analysis. First, they independently reviewed the participants' responses and generated an initial checklist of categories and concepts. Then, they compared notes and revised the initial checklist. Finally, the researcher revised and confirmed the checklist and created a final checklist for coding. When inconsistencies in coding occurred, discussions were conducted to reach a consensus.

4. Results

4.1. Improvements in critical-thinking skills

This study used two instruments to evaluate the improvements in the participants' critical-thinking skills: the SB-CTT and one self-reported item measuring critical-thinking skills. Although the participants included 7 males and 24 females, there were no significant test (pretest vs. posttest) × gender (male vs. female) interactions on the improvement of critical thinking as measured by the SB-CTT or the self-reported item, $F(1, 29) = .072$, $p = 0.790$, $\eta_p^2 = .002$, and $F(1, 29) = .3.567$, $p = 0.069$, $\eta_p^2 = .113$. Moreover, although some groups in this study were composed of members from different departments and the others were consisted of members from the same department, there were no significant differences between groups with regard to the performance of critical-thinking dispositions or critical-thinking skills in the pretest and in the posttest, $Fs(5, 25) = .567–2.062$, $ps = .118–.724$. The following analyses therefore included all the participants. The repeated measure ANOVA yielded a significant test (pretest vs. posttest) effect on the score of the SB-CTT, $F(1, 30) = 185.537$, $p = .000$, $\eta_p^2 = .861$ (see Table 1). The comparisons of the means revealed that the participants had better performances in the posttest than in the pretest for the overall SB-CTT.

To verify the training effects in this study, the researcher analyzed the subjects' self-evaluations of their improvements in their critical-thinking skills. Again, the repeated measure ANOVA yielded a significant test (pretest vs. posttest) effect on the self-evaluations of critical-thinking skills, $F(1, 29) = 7.373$, $p = .011$, $\eta_p^2 = .203$. The comparison of the means revealed that the participants evaluated their critical-thinking skills more highly in the posttest than in the pretest (see Table 1). Accordingly, the participants significantly improved their critical-thinking skills after the training.

4.2. Analysis of ATI effects

Only 26 participants were included in this part of analysis because 5 participants did not take the ITS. Using the median score as a cut-off point of each thinking style, this study respectively divided the participants into two groups (lower vs. higher) while analyzing the ATI effects of the thinking styles on the improvements in the participants' critical-thinking skills. Table 2 displays the means and standard deviations of the groups with executive, legislative, and judicial thinking styles. With the pretest score of the SB-CTT acting as covariance, the results of the ANCOVA indicated that only the judicial thinking style had a significant group (lower vs. higher) effect on the SB-CTT, $F(1, 23) = 5.610$, $p = .027$, $\eta_p^2 = .196$ (see Table 3). The comparisons of the means revealed that the participants with higher levels of judicial thinking experienced more improvement in their critical-thinking skills than did their counterparts.

4.3. Mechanisms that contributed to training effects

At the end of the training program, the participants were asked to answer seven reflection questions to further clarify their opinions about the training program.

1. Do the topic discussions on critical-thinking skills contribute to improvements in your critical-thinking skills? How?

A great majority (91.2%) of participants agreed that the topic discussions contributed to improvements in their critical-thinking skills and knowledge. These improvements were mainly achieved via the discussions (42.2%), the designs of the critical-thinking test items (26.7%), and the reviews of the examples developed by the other groups (11.1%). The main reason for not supporting such discussions was the respondent's personal habit of thinking and learning (8.9%).

Table 1
Tests of within-subjects effects on the SB-CTT and self-reported critical-thinking ability.

Source	*N*	*M*	SD	Type III SS	df	MS	*F*	Sig.	η_p^2
SB-CTT									
Pretest	31	18.484	3.539	1610.581	1	1610.581	185.537***	.000	.861
Posttest	31	28.677	3.637						
Self-report									
Pretest	31	3.830	.834	3.750	1	3.750	7.373*	.011	.203
Posttest	31	4.330	.922						

*$p < .05$. ***$p < .001$.

Table 2
Means and standard deviations of thinking styles.

	Executive			Legislative			Judicial		
	N	*M*	SD	*N*	*M*	SD	*N*	*M*	SD
Pretest									
Lower	13	18.308	3.146	13	17.308	3.225	14	17.571	3.390
Higher	13	18.846	3.955	13	19.846	3.044	12	19.750	3.415
Posttest									
Lower	13	27.769	4.106	13	27.154	3.625	14	27.071	3.269
Higher	13	29.923	3.201	13	30.539	3.205	12	30.917	3.315

2. Have you read other groups' assignments online? If yes, approximately how many times? What are the major benefits?

Over half of the participants had read other groups' assignments more than 6 times (55.9%). The reported benefits included increased understanding of individual differences and unique perspectives (47.1), acquisitions of references (22.6%), and verification of the subject's personal understanding of the concepts (17.0). The major benefits also included improved ability to stimulate creative thoughts (11.3%).

3. Does the integrated design of e-learning and classroom instruction (blended design) enhance your critical-thinking skills? How?

A great majority (93.3%) of the participants responded positively toward the blended design. E-learning increased opportunities for communication and discussion (37.5%) and provided plentiful resources and space for discussion, practice, and assignment sharing (27.1%). In-class instructions provided feedback (12.5%) as well as systematic lectures and dialectical discussion (12.5%). Only a few participants complained about the limitations of the e-learning platform (6.3%).

4. Does the blended design facilitate your self-reflection of your critical-thinking skills? How?

Most of the participants (94.1%) confirmed that the design enhanced their capacity for self-reflection, which was mainly achieved via online and in-class discussions and interactions (75.6%) as well as assignment sharing and online observational learning (19.5%).

5. Does presenting arguments via concept maps enhance your critical-thinking skills? Why?

All of the participants confirmed the effectiveness of concept mapping, which helped them clarify the logical relationships between the concepts (60%) and facilitated effective communication (20%).

6. Does the blended design facilitate knowledge sharing and knowledge creation? Why?

All of the participants confirmed the effectiveness of the blended design in facilitating knowledge sharing and knowledge creation. Such KM processes were achieved via the sharing of information and opinions online (65.5%), individual and group assignments (24.2%), and peer feedback (10.3).

7. How do you feel about the co-creation of a term project that requires each group to develop a small project under a common topic?

A significant majority (94.1%) responded positively toward the idea of a co-creation assignment. It improved not only their capacity for self-reflection (15.6%), multi-perspective thinking (12.5%), and collaborative learning (9.4%) but also their knowledge of the common topic (37.5%) and their motivation toward achievement (18.8%).

Table 3
ANCOVA of thinking styles on the SB-CTT.

Source	Type III SS	df	MS	*F*	Sig.	η_p^2
Executive						
Pretest	69.336	1	69.336	6.232*	.020	.213
Group	23.266	1	23.266	2.091	.162	.083
Error	255.895	23	11.126			
Legislative						
Pretest	35.648	1	35.648	3.343	.081	.127
Group	33.886	1	33.886	3.178	.088	.121
Error	245.275	23	10.664			
Judicial						
Pretest	35.424	1	35.424	3.630	.069	.136
Group	54.739	1	54.739	5.610*	.027	.196
Error	224.422	23	9.757			

*$p < .05$.

Integrating the participants' responses on the reflection questionnaire, this study depicts the process of improving critical thinking via knowledge sharing, internalization, and co-creation in Fig. 2. The numbers in parentheses refer to question numbers in the reflection questionnaire. In Fig. 2, knowledge internalization mainly represents "self-reflection" across the questions, and co-creation includes the term project indicated in question 7 as well as the other group assignments mentioned in the other questions. Fig. 2 illustrates that both e-learning and in-class instruction influenced the KM processes and the ability to learn critical-thinking skills. Moreover, knowledge sharing influenced knowledge internalization and knowledge co-creation. In addition, knowledge internalization and knowledge co-creation reinforced each other through their interactions. Although two mechanisms were critical to all of the KM processes, four mechanisms influenced knowledge internalization and co-creation. Finally, all three KM processes contributed to the improvements in the participants' critical-thinking skills and knowledge, whereas only knowledge co-creation contributed to their improvements in critical-thinking dispositions.

5. Discussion

5.1. Effectiveness of the blended KM model

To improve critical-thinking skills, this study proposed a blended KM model in which knowledge sharing, knowledge internalization, and knowledge creation were included and in which both e-learning and in-class instruction were emphasized. To further validate the effectiveness of the proposed model, the researchers conducted a before-and-after design based on a 17-week training program and examined a hypothesis concerning the effectiveness of this program. To compensate for the potential shortcomings generated by the before-and-after design, the researcher employed two complementary instruments: a self-evaluation item measuring critical-thinking skills and a 7-item reflection questionnaire.

The results of the Repeated Measure ANOVA and the content analysis of the participants' responses in the reflection questionnaire supported both the training program's effectiveness and the hypothesis proposed in this study. Specifically, the results showed that after receiving the training program, the participants significantly improved their critical-thinking skills, as evaluated by the SB-CTT ($\eta_p^2 = .861$) and the self-evaluation question ($\eta_p^2 = .203$). Moreover, 93.3% of the participants confirmed that the blended design had improved their critical-thinking skills (question 3); 94.1% of the participants agreed that the blended design had enhanced their capacity for self-reflection, which is critical for knowledge internalization (question 4); and all of the participants reported that the blended design had contributed to knowledge sharing and knowledge creation (question 6).

The findings of the content analysis also revealed that the blended design had effectively improved the participants' skills, knowledge, and dispositions pertaining to critical thinking. Specifically, the improved personal traits included the following: the skills identified in the SB-CTT as well as the skills to undertake self-reflection, adopt multi-perspective thinking, communicate and question, and produce creative thoughts; the understanding of individual strengths and weaknesses, various unique perspectives, and the applicability of critical-thinking skills; and the motivation toward achievement.

Moreover, the results of the content analysis (see Fig. 2) suggest that knowledge sharing facilitates knowledge internalization and co-creation and that knowledge internalization and co-creation are interactive. These findings support this study's assumption that the three KM processes share dynamic relationships. However, although all three KM processes contributed to the improvements in critical-thinking skills and knowledge, only knowledge co-creation enhanced the critical-thinking disposition (Fig. 2), which suggests that knowledge co-creation is especially critical to the improvement of critical-thinking dispositions. In addition, the participants' responses suggested that online learning and in-class instruction play complementary roles in teaching critical-thinking skills. On the one hand, e-learning increases opportunities for communication and discussion and provides plentiful resources and space for discussion, practice, and assignment sharing. On the other hand, in-class instruction provides feedback, systematic lectures, and dialectical discussions (question 3).

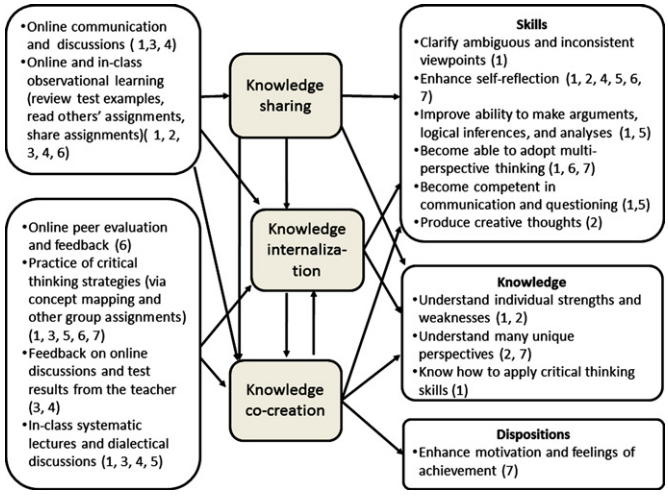

Fig. 2. Integrated results of the reflection questionnaires.

Accordingly, the findings in this study support the claim that integrating KM and e-learning may create a robust and dynamic learning system that will facilitate the ability to learn critical-thinking skills (Gagné, 2009). Moreover, the dynamic relationships among the three KM processes support the mediator-role of internalization during KM training, as proposed in the SECI model (Nonaka & Toyama, 2003). The close relationship between knowledge sharing and knowledge creation also lends support to the argument that knowledge sharing promotes the mutual exchange of knowledge and the joint creation of new knowledge, which implies a synergistic collaboration between individuals working toward a common goal (Gagné, 2009). In addition, the dynamic process of knowledge creation supports the claim that the KM process is essentially collaborative and that dynamic interactions occur during knowledge creation process (Baskerville & Dulipovici, 2006). Notably, the importance of co-creation illuminates the concepts of "shared knowledge creation" (Baskerville & Dulipovici, 2006) and "knowledge as collaborating activities and knowledge as group assets" (Cecez-Kecmanovic, 2004).

Moreover, the training program was designed to "scaffold" the participants through the dynamic processes of knowledge sharing, internalization, and co-creation. Zydney (2005) claimed that scaffolding tools positively affect a student's ability to ask critical questions. The effectiveness of the scaffold employed in this study was validated by the significant improvements in the participants' critical-thinking skills and the participants' responses, which confirmed that the training program had facilitated interactive discussions and thereby enhanced their critical-thinking skills.

5.2. Mechanisms that contribute to the success of the blended KM model

To validate the effectiveness and the underlying mechanisms of the model, this study employed a reflection questionnaire at the end of the training program. The findings in this study revealed the following: the formation of a learning community, online communication and discussion, and observational learning both directly and indirectly contributed to all three KM processes; enhancement of self-awareness and self-reflection, participation in discussions, training in critical-thinking strategies, online peer evaluation and feedback, feedback in online discussions from the teacher, in-class systematic lectures, and in-class dialectical discussions both directly and indirectly contributed to knowledge internalization and co-creation; and knowledge co-creation was mainly achieved via group and class assignments. These findings support the rationale behind the construction of the training model in this study. Basically, the mechanisms for improving critical-thinking skills in the KM processes in this study are consistent with those assumed in the model, though some direct influence paths were not assumed in the initial model.

The importance of community building supports the claim that the integration of KM and e-learning processes should be knowledge-enabled, learner-centered, and accessible to the community (Liebowitz & Frank, 2011) and that online-learning communities are a collaborative means of achieving shared creation and shared understanding (Ludwig-Hardman & Woolley, 2000). The findings in this study suggest that the formation of online-learning communities is not only important to knowledge sharing and creation (e.g., Chen & Hsiang, 2007; Choi & Lee, 2003) but also to knowledge internalization. Research findings have suggested that meaning-making participation in online discussions and group assignments requires substantial interaction and discussion and that participation in these activities exerts influence over community development (Yeh, 2010). Therefore, this study requested that the participants engage in online topic discussions and complete several group assignments that demanded a great deal of interaction and discussion. The findings in this study clearly support such designs. Moreover, the results of this study lend support to the notions that observational learning facilitates knowledge sharing (Yeh et al., 2011) and that internalization is achieved via action, practice, and reflection (Nonaka & Toyama, 2003).

In addition, this study found that peer feedback of evaluations and discussions as well as instructor feedback in online discussions and critical-thinking-related tests were critical to knowledge internalization. For example, it was reported that "expressing opinions and reading others' great viewpoints on the e-learning platform has enhanced my self-reflection on how to be a better critical thinker." and "both online discussion and classroom teaching contributed to my self-correction and self-reflection on my imperfect thinking." Accordingly, such feedback successfully enhanced the participants' self-awareness and self-reflection with regard to their personal weaknesses and strengths in critical thinking. Furthermore, the feedback enhanced their mindful learning capacity in the following activities. A reflective mind that takes a rational thinking process seriously is the hallmark of critical thinking (Schroyens, 2005). Thus, the findings here are in line with the self-awareness and mindfulness that help nurture reflective practices (Collier, 1999; Tillema, 2000; Yeh et al., 2011).

Finally, Shaw (2010) claimed that knowledge maps can improve learning performance. Knowledge maps are similar to concept maps in that they emphasize the visualization of concepts, knowledge, and relationships. This study found that all of the participants supported the use of concept maps, which helped the participants clarify the logical relationships between the concepts and facilitated effective communication (question 5). Accordingly, concept mapping constitutes an effective tool for knowledge sharing and knowledge creation.

5.3. ATI effects on improvement of critical-thinking skills

The results of the ANCOVA indicated that, of the three thinking styles, only the judicial thinking style had ATI effects on the improvement of critical-thinking skills in the blended KM training program. In other words, those with higher levels of judicial thinking made greater improvements in their critical-thinking skills than their counterparts. Zhang and Sternberg (2000) found that the type I thinking style, which denotes higher levels of cognitive complexity (e.g., judicial and legislative thinking style), relates to a deep learning approach (learning with understanding). However, the type II thinking style, which denotes lower levels of cognitive complexity (e.g., executive thinking style), relates to a surface learning approach (e.g., rote learning). Sternberg (1997) suggested that those who prefer a judicial thinking style tend to analyze and evaluate rules. Therefore, the participants with judicial thinking styles might have employed more analysis and evaluations of strategies to obtain, apply, share, internalize, and create knowledge during the training process. As a result, they made significant improvements in their critical-thinking skills after receiving the training. The ATI effects found in this study are in line with the finding that critical thinking has a positive correlation with judicial thinking styles (Yang & Lin, 2004). Thinking styles interact with problem-solving approaches (Dane et al., 2011), and people with judicial thinking styles benefit the most in a computer-simulated training program for critical-thinking instruction (Yeh, 2007).

6. Conclusions and suggestions

Both critical thinking and KM ability have been regarded as necessary elements for university students to succeed in the era of knowledge economics and information technology. Although KM has emerged as an important field of practice, KM models suitable to educational settings, especially those that instruct critical-thinking skills, are still in development. This study successfully develops an innovative blended KM training model for improving university students' critical-thinking skills; moreover, important underlying mechanisms and ATIs of thinking styles during the training are uncovered, which provides insightful principles for designing a related training program.

This study developed a blended KM model, in which three key processes of KM (knowledge sharing, knowledge internalization, and knowledge co-creation) and the dynamic relationships among these processes were emphasized, several underlying mechanisms for achieving each KM process were assumed, and corresponding teaching strategies were employed. The findings from the quantitative and qualitative data obtained in this study suggest that if certain mechanisms are incorporated, scaffolding university students through knowledge sharing, internalization, and co-creation processes in a blended KM environment can effectively enhance their critical-thinking skills knowledge and dispositions. Halpern (1998) proposed that a model for teaching critical thinking should also include a dispositional component that prepares learners for cognitive work. Thus, future studies can design a blended KM model that focuses on improving university students' critical-thinking dispositions. In such a design, knowledge co-creation should be considered because it was found to be critical for the improvement of critical-thinking dispositions in this study. This study also found that observational learning of reading other's assignments may contribute to the improvement of critical-thinking skills. Accordingly, future studies can further investigate how frequent and what proportion of learning time of such observational learning may significantly contribute to the improvement of critical-thinking skills.

Moreover, the findings in this study suggest that thinking styles exert ATI effects on the improvements of university students' critical-thinking skills in a blended KM training program. Thinking styles can be changed as people interact within different environments, and thinking styles can be modified as a result of social experiences. Cultivating a judicial thinking style during a blended KM training program may enhance the participants' ability to learn critical-thinking skills. According to Sternberg (1997), individuals with judicial style prefer activities that require analysis and evaluation of existing rules. Activities emphasize analysis and evaluation, therefore, can be designed into a blended KM training program to enhance training effects.

Notably, the findings of this study suggest that online community building is critical to the success of the blended KM training program. An online-learning community may be built in four stages: motivation and acquaintance; socialization and belongingness; information exchange and consensus; and tacit understanding and development (Yeh, 2010). Therefore, future studies may facilitate the formation of online communities during the training process to maximize the training effects in a blended KM-based environment. Due to the difficulty of getting a control group (a pure online-learning group or a pure face-to-face learning group) to finish all the pretests and posttests, this study employed a before-and-after design. To compensate for this disadvantage, both quantitative and qualitative methods were employed. The consistent results of these two approaches suggest that the findings in this study are reliable and valid. Future studies, however, may validate the findings of this study by adding a control group.

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