Aptitude-Treatment Interactions during Creativity Training in E-Learning: How Meaning-Making, Self-Regulation, and Knowledge Management Influence Creativity

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ABSTRACT

The goal of aptitude-treatment interactions (ATIs) is to find the interactions between treatments and learners' aptitudes and therefore to achieve optimal learning. This study aimed at understanding whether the aptitudes of meaning-making, self-regulation, and knowledge management (KM) would interact with the treatment of 17-week KM-based training and then influence creativity in e-learning. The participants were 31 university students, and all variables were measured using online systems. ATIs and mediation effects during the training were found. Specifically, while meaning-making indirectly influenced creativity via KM, self-regulation influenced creativity both directly and indirectly via KM; moreover, university students with higher level of KM and self-regulation ability benefited more from the training than their counterparts. This study not only sheds lights on understanding how ATIs influence creativity learning, but also provides a new approach—KM-based training—to improve university students' creativity in environments of e-learning.

Introduction

Creativity is the foundation of human civilization (Dietrich & Kanso, 2010). Given the central importance of creativity and the dominance of e-learning in higher education, it is important to identify the underlying mechanisms that contribute to university students' learning of creativity in e-learning environments and, accordingly, to design effective training programs to enhance their creativity. According to aptitude-treatment interactions (ATIs), individuals differ in their readiness to profit from a particular treatment and individuals may adapt their situations to fit their own characteristics; therefore, finding the interactions between treatments and learners' aptitudes helps to create an environment in which the treatments match the aptitude of the learner and, further, to achieve optimal learning (Yeh, 2012b). It has also been suggested that the effects of any learning environment on behavioral engagement in learning are mediated by learner characteristics (Sha, Looi, Chen, Seow, & Wong, 2012). Accordingly, designing an e-learning program to improve university students' creativity is related not only to technological issues but also to learners' aptitudes.

This study is concerned with the ATIs effects of three aptitudes on the learning of creativity: meaning-making ability, self-regulation ability, and knowledge management (KM) ability. People with high level of meaning-making ability can actively reappraise events or series of events (Davis & Nolen-Hoeksema, 2009). People with great self-regulation ability tend to actively participate in the learning process in terms of behaviors, motivation, and metacognition (Lee, Lim, & Grabowskig, 2009). Finally, people with great knowledge management ability are competent in knowledge acquisition, knowledge sharing, knowledge application, and knowledge creation (Gagné, 2009; Yeh, 2012a). These aptitudes may contribute to the development of creative ideas and the coping of frustration during creative processes. Therefore, this study aimed to investigate whether the aptitudes of meaning-making, self-regulation, and KM would interact with the treatment of creativity training and then influence creativity in e-learning.

Definitions of creativity

A recent consensus of creativity is that creativity refers to the ability of producing responses that are novel and appropriate (Shamay-Tsoory, Adler, Aharon-Peretz, Perry, & Mayseless, 2011). However, whether creativity is a domain-specific or a domain-general ability remains a debate. While some researchers (e.g. Baer & Kaufman, 2005) argued that creativity is a domain-general trait, some researchers claimed that creativity is domain-specific (e.g. Simonton, 2012; Reiter-Palmon, Illies, Cross, Buboltz & Nimps, 2009), and the others (e.g. Silvia, Kaufman, & Pretz, 2009) supported hybrid models in which general factors are required for the development of creativity and domain-specific factors are critical to certain creative activities. This study supports the hybrid model and suggests that creativity is a process in which one generates a culturally "original" and "valuable" response or product within a certain domain. Moreover, during the creation process, both general factors and domain-specific factors are required and a creative outcome is the result of the interactions of personal characteristics and the environment. Accordingly, three personal characteristics that may influence creation process were included in the experimental instruction in this study. However, since the experimental instruction were integrated into a liberal education course, participants were from different disciplines, only the general factors of creativity were investigated in this study.

Over the past six decades, divergent thinking tests have been the most popular evaluation instrument for understanding the general factors of creativity. Such tests measure the ability to generate new ideas, allowing the development of multiple solutions to a given problem. Two central indices of divergent thinking test are *fluency* and *originality*. While fluency describes the productivity of ideas, originality refers to the uniqueness of responses (Shamay-Tsoory et al., 2011). These two indices of creativity were measured in this study.

KM and creativity

Most existing theories of KM emphasize the competencies of knowledge acquisition and storage, knowledge application, knowledge sharing, and knowledge creation (Yeh, 2012a). Recently, many information technology industries have integrated blended KM models into their human resources training programs; most models emphasize either knowledge sharing (e.g., Alony, Whymark, & Jones, 2007; Gagné, 2009) or knowledge creation (e.g., Imani, 2007; Yeh, Yeh, & Chen, 2012).

Yeh, Huang, & Yeh (2011) found that KM processes were effectively facilitated in a blended learning environment using the strategies of socialization (e.g., building a learning community, engaging in observational learning, and participating in online group discussions), externalization (e.g., sharing opinions in online discussions and group assignments), combination (e.g., creating stories and design products), and internalization (e.g., giving feedback on performance and providing opportunities for practice). Moreover, many researchers have claimed that knowledge sharing is a key component of KM systems; the influential factors of these KM processes include individual factors, organizational factors, and technological factors (Park, Ribiere, & Schulte, 2004; Riege, 2005). Another key component of KM is knowledge creation, which can be enhanced through shared experiences in social interactions (Nonaka & Toyama, 2003), community building (Swirski, Wood, & Solomonides, 2008), practice, reinforcement, and imitation (Leroy & Ramanantsoa, 1997). Obviously, collaborative knowledge construction as well as the interplay between individual and collective knowledge building are greatly emphasized in KM. Recently, the building of learning community has been regarded as an important mechanism for achieving collaborative knowledge construction. In a well-developed learning community, learners collaboratively communicate during their educational experience to construct knowledge, and such process are often built upon social presence (participants seem like actual people), teaching presence (the design and development of learning experiences), and cognitive presence (the ability of learners to use online communication to construct meaning) (Kucuk & Sahin, 2013).

Studies from e-learning also support the interplay between individual and collective knowledge construction. For example, Moskaliuk, Kimmerle, & Cress (2009) suggested that the cognitive systems of the individuals involved and the social system wiki mutually influence each other, and new knowledge is generated through the processes of discussion, internalization, and externalization. Cress, Held, and Kimmerle (2013) also claimed that tag clouds generated in social tagging systems can capture the collective knowledge of communities, and both collective and individual knowledge have a significant influence on link selection, incidental learning, and information processing.

A sound knowledge base is essential for the development of creativity. Du Plessis (2007) claimed that KM allows collaboration, knowledge sharing, and continual learning, explaining that it plays the following roles in creativity: (1) enabling the sharing of tacit knowledge; (2) making explicit knowledge available for producing creative ideas; (3) enabling the transfer of tacit knowledge via collaborative processes; and (4) conducing knowledge sharing and creation, as well as collaboration, through the creation of a culture. Accordingly, KM is critical to creativity. This study attempted to emphasize collaborative knowledge construction as well as the interaction between individual and collective knowledge building in a training program to facilitate university students' KM and, thereby, to improve their creativity. Our first hypothesis was proposed as follows:

H1: KM would have positive effects on improvements of creativity in KM-based training. Those students with better KM capacities would show more improvement in creativity than their counterparts.

Meaning-making, KM, and creativity

Meaning-making refers to the active process through which individuals reappraise an event or a series of events. Such processes usually involve two aspects: benefit-finding and sense-making (Baumeister, 2005; Davis & Nolen-Hoeksema, 2009). Benefit-finding involves the process of transforming adversity into prosperity. A benefit-finding individual tries to find the positive aspects of a negative event. On the other hand, sense-making involves looking for ways to understand the event (Davis & Nolen-Hoeksema, 2009). Klein, Moon, and Hoffman (2006) defined this process as "how people make sense out of their experience in the world" (Davis & Nolen-Hoeksema, 2009).

Regarding the relationship between meaning-making and KM, the data-information-knowledge-wisdom (DIKW) hierarchy provides supporting arguments. The DIKW hierarchy includes four components: data (raw facts), information (relevant contexts), knowledge (meaningful interrelations), and wisdom (perceiving outcomes and determining their values) (Müller & Faltin, 2011). In reflective learning, knowledge results from meaningful interrelations between the information about a reflected situation and information about its environment as well as the feelings and behaviors of the reflecting person (Müller & Faltin, 2011). Moreover, according to the generative learning model (Wittrock, 1992), to comprehend a complex topic, learners must generate meaning for events by constructing relationships between new information and previously acquired information, conceptions, and background knowledge. Therefore, generative learning that emphasizes the actual creation of relationships and meanings is, in essence, knowledge generation (Lee et al., 2009). In other words, meaning-making and KM are closely related during knowledge generation.

As for the relationship between meaning-making and creativity, benefit-finding is a construct that captures lifestyle and behavioral changes in perception (Lenchner, Tennen, & Affleck, 2009). Although benefit-finding is idiosyncratic, most benefits that are reported following adversity can be categorized within the areas of relating to others, new life possibilities, personal strength, appreciation of life, and spiritual or religious change (Lenchner et al., 2009). Sense-making, based on its characteristics of enactment and plausibility, can be viewed as the reciprocal interaction, including seeking cues, assigning meaning, and moving towards plausible action. The extracted cues from one's environment (e.g., availability of resources for creativity) may act as triggers or may signify that certain meaning is required (Madjar, Nora, Greenberg, & Chen, 2011). Moreover, sense-making may represent curiosity; it has been referred to as the trigger for "scientific imagination" (Klein et al., 2006). Thus, the positive dispositions of benefit-finding and sense-making may contribute to the development of creative ideas and coping with frustration during creative processes.

Integrating the relationship between meaning-making, KM, and creativity, we proposed the following two hypotheses:

H2: Meaning-making would have positive effects on the improvement of creativity. Those students with better meaning-making abilities would show more improvement in creativity than their counterparts in creativity training.

H3: Meaning-making would have positive effects on KM. Those students with better meaning-making capacities would show better performance in KM than their counterparts in creativity training.

Self-regulation, KM, and creativity

Self-regulated learners are active participants in their own learning processes in terms of behaviors, motivation, and metacognition (Lee et al., 2009). The various self-regulation learning (SRL) theories share three basic assumptions, stating that self-regulated learners are able to (1) personally improve their abilities to learn through the selective use of metacognitive and motivational strategies; (2) proactively select, organize, and even create advantageous learning environments; and (3) play significant roles in choosing the forms and amounts of instruction they need (Sha et al., 2011). Recently, Fruhmann, Nussbaumer, and Albert (2010) proposed the Responsive Open Learning Environments (ROLE) model, in which self-regulated learning is defined by four learner-centered phases: (1) learner profile information is defined or revised; (2) the learner finds and selects learning resources; (3) the learner works on selected learning resources; and (4) the learner reflects on and reacts to strategies, achievements, and usefulness. These phases are summarized in the "plan-learn-reflect-plan" loop.

As for the relationship between self-regulation and KM, Lee et al. (2009) proposed that SRL guides generative activities that enhance learners' knowledge generation by creating relationships between new information and prior knowledge. In addition, KM and technology-enhanced learning are confronting many new challenges due to the rapid pace of technological progress (Müller & Faltin, 2011). Müller and Faltin (2011) argued that in work-intensive environments, a formal method of knowledge acquisition and learning is often insufficient. Therefore, a new generation of tools supporting self-regulated learning is needed.

Regarding the relationship between self-regulation and creativity, research findings have suggested that self-perceived creativity is positively related to daily planning, confidence in long-range planning, overall time management, perceived time management, and tenacity and negatively related to preference for disorganization. Zampetakisa, Bourantab, and Moustakis (2010) claimed that time management skills, which characterize self-regulated learners, are related to creativity. In related studies, Hon (2011) found that self-concordance mediated social-contextual variables and creativity. Self-concordant goals are intrinsically motivating because they are derived from self-choice. People with high levels of self-concordance are, therefore, competent in identifying and pursuing goals (Hon, 2011), which is critical for self-regulated learners. Along the same lines, King and Gurland (2007) found that autonomous orientation is related to the detail and complexity aspect of creativity. Creative individuals tend to overcome barriers by deploying time management skills that maximize effectiveness as a function of time; such a tendency can also be seen in self-regulated learners, who develop plans and strategies and monitor their behaviors to attain their anticipated goals (Zampetakisa et al., 2010). Accordingly, self-regulation should contribute to the learning of creativity.

Integrating the relationship between self-regulation, KM, and creativity, we proposed the following two hypotheses:

H4: Self-regulation would have positive effects on the improvement of creativity. Those students with better self-regulation abilities would show more improvement in creativity than their counterparts in creativity training.

H5: Self-regulation would have positive effects on KM. Those students with better self-regulation capacities would show better performance in KM than their counterparts in creativity training.

Method

Participants

The participants were 31 undergraduates (9 males and 22 females) with a mean age of 19.93 years (*SD* = 1.44 years). All of the participants were enrolled in a liberal education course "Creativity," which emphasized KM and e-learning.

Instruments

The instruments employed in this study included an e-learning website (http://moodle.nccu.edu.tw/) and an online experimental system developed by PHP and JavaScript. The experimental system included the Inventory of

Knowledge Management in E-learning (IKME), the Inventory of Meaning-making in E-learning (IMME), and the Inventory of Self-regulation in E-learning (ISRE).

The Digital Imagery Test, a divergent thinking test, was employed to test creativity in this study. The Digital Imagery Test, which includes 12 pictures, was developed via the PHP programming language based on a picture book (Shaw, 1993) using Adobe Flash Professional CS4 (Yeh, 2011) (see Figure 1). The pictures were displayed in a fixed order on the website for 2 minutes each. The participants were encouraged to imagine what they had seen and then type in as many answers as possible. The Digital Imagery Test scores included two commonly measured indices of creativity: fluency and originality (Mayer, 1999). When an answer was appropriate, the fluency is scored as "1" point; the total fluency score was the sum of appropriate answers of all picture. On the other hand, given that X is the percentage of an answer, the scoring of originality was determined as follows: when $X \geq 16\%$, originality was scored "0" points; when $5\% \leq X < 16\%$, originality was scored "1" point; when $2\% \leq X < 5\%$, originality was scored "2" points; and when $X < 2\%$, originality was scored "3" points. The test-retest reliability coefficients based on a 3 month interval were .779 and .785 (ps $< .001$) for fluency and originality. The total originality score was the sum of appropriate answers of all pictures. The Digital Imagery Test has good criterion-related validity, the ability of fluency and originality are positively related self-evaluation of creativity, rs(33) = .413, and .433, ps $< .05$, respectively.
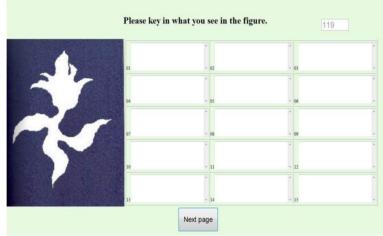

Figure 1. A sample screenshot from the Digital Imagery Test

All three e-learning inventories were validated by reliability analyses ($N = 1017$), exploratory factor analyses ($N = 1017$), and confirmatory factor analyses (CFA) ($N = 1647$) (Yeh, Yeh, & Lin, 2013). Moreover, all e-learning inventories used 6-point Likert scales, with response options ranging from "totally disagree" to "totally agree." The tests were administered online with no time limit imposed.

The IKME, with a total of 22 items, included four factors: knowledge acquisition (7 items), knowledge application (6 items), knowledge sharing (5 items), and knowledge creation (4 items). Example items include "I participate in or organize e-learning communities (e.g., BBS, Facebook, etc.) to increase interactions with others" and "I try to integrate the knowledge I have learned to produce creative ideas during e-learning." The Cronbach's alphas for the four factors and the IKME were 0.887, 0.897, 0.827, 0.910, and 0.942, respectively.
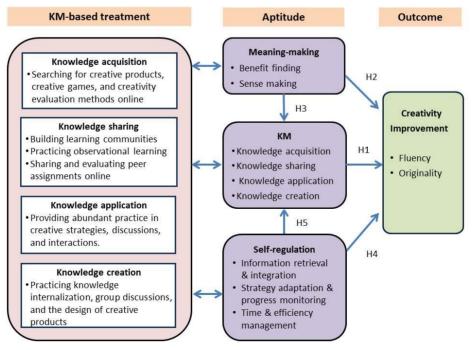
The IMME, with a total of 25 items, included two factors: benefit-finding (14 items) and sense-making (11 items). Sample items include "although conducting discussions in e-learning platforms is time consuming, it stimulates my multi-perspective views and creative ideas" and "I can't effectively interact with others in an e-learning interface because I am not used to the interface". The Cronbach's alphas for the two factors and the IKME were 0.922, 0.869, and 0.884, respectively.

The ISRE, with a total of 16 items, included three factors: information retrieval and integration (6 items), strategy adaptation and progress monitoring (7 items), and time and efficiency management (3 items). Example items include "when conducting e-learning, I can adjust my methods of searching resources to find useful information" and "when conducting e-learning, I plan my learning time". The Cronbach's alphas for the three factors and the ISRE were 0.882, 0.872, 0.793, and 0.924, respectively.

Experimental design and procedures

This study employed a before-and-after design. A 17-week creativity training program, which emphasized the integration of KM processes and e-learning, was designed to investigate the relationships between meaning-making, self-regulation, KM, and improvements in creativity in e-learning environments. The pretest was administered during the second week, while the posttest was administered at week 17. The pretests included the Digital Imagery Test, the IKME, the ISRE, and the IMME, whereas the posttests included the Digital Imagery Test and the IKME.

Systematic lectures were given in combination with in-class and online discussion activities throughout the training program. The goal of the program was to enhance participants' creativity (including fluency and originality) by facilitating KM processes. Based on past findings (Cress, Held, & Kimmerle, 2013; Kucuk & Sahin, 2013; Nonaka & Toyama, 2003; Park et al., 2004; Riege, 2005; Swirski et al., 2008; Yeh et al., 2011, Yeh 2012a), several strategies were incorporated into the training program. To enhance knowledge acquisition, online information was requested (e.g., searching for creative products, creative games, and creativity evaluation methods). To facilitate knowledge sharing, the following activities were emphasized: (1) building learning communities through self-determinate grouping and group discussions; (2) practicing observational learning via in-class presentations of group assignments; and (3) online sharing and evaluations of other groups' assignments. To facilitate knowledge application, abundant practice in creative strategies, discussions, and interactions were provided. Finally, knowledge internalization, group discussions, and the design of creative products were used to achieve knowledge creation. Specifically, the following seven assignments were given and scored in this study: participation in in-class discussion and instructional activities (including lectures, discussions, presentations of assignments), online and in-class sharing of creative products, online and in-class sharing of creative games, and four assignments for producing creative products (creative self-introduction, mind maps, stories of positive thinking, and digital creative story-telling). Throughout the training program, e-learning emphasizing the integration of online learning and in-class activities was employed. Specifically, all assignments were completed and shared online for discussion after in-class lectures and practices. Then, in-class discussions followed the online discussion that had lasted for one week. The online discussion allows learners to go beyond the time and space constraints and provides support for community building (Gao, 2011) which is important to knowledge management (Kucuk & Sahin, 2013; Yeh, 2012a). Comparatively, the face-to-face discussion is more prompt in responses and more multidirectional in interaction (Wang & Woo, 2007), which contributes to knowledge integration, knowledge creation, and knowledge internalization (Yeh et al., 2012).

Figure 2. The hypothesized model and instructional design of this study
(H1 to H5 represent hypothesis 1 to hypothesis 5)

Based on the aforementioned literature review, meaning-making and self-regulation may directly influence the learning of creativity as well as indirectly influence the learning of creativity via KM in an e-learning environment. Thus, this study attempted to improve university students' creativity through facilitating KM in an e-learning program. The hypothesized model and the instructional design are illustrated in Figure 2.

Data analysis

A two (within-group variables: pretest vs. posttest) by two (between-groups variable: high vs. low) mixed design of repeated measures Analysis of Variance (repeated measures ANOVA) was used to examine whether the three positive personal traits (KM, meaning-making, and self-regulation) influenced improvements in creativity. Moreover, univariate ANOVAs were employed to investigate the effects of meaning-making and self-regulation on KM. The between-groups variables of the three positive personal traits were divided into high and low groups based on the median score. Because more than one participant obtained the median score, the group sizes differed.

Results

Preliminary analyses

Preliminary analyses of the correlations between important interventions and creativity performance in this study found that (1) the frequency of online discussion and the performance of mind mapping were related to the performance of creative digital story-telling—the most important group assignment in this study, $r = 0.395$, $p < 0.05$ and $r = 0.612$, $p < 0.001$; (2) the frequency of online discussion was related to the posttest scores of fluency and originality measured by the Digital Imagery Test, rs = 0.445 and 0.446, ps < 0.01; (3) self-perceived knowledge-creation measured by the IKME was related to the performance of creative digital story-telling, $r = 0.360$, $p < 0.05$; (4) participation in in-class discussion and instructional activities was related to the performance of creative digital story-telling and mind mapping, rs = 0.460 and 0.486, ps < 0.01; (5) The composite score of the seven major assignments was related to the posttest score of fluency and originality, rs = 0.526 and 0.521, ps < 0.01.
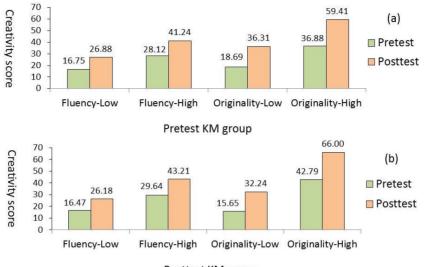
These findings revealed that the creativity measured by the divergent thinking test of Digital Imagery Test was closely related to the participants' product-oriented creativity, suggesting that the score of Digital Imagery Test is predictive to actual creativity performances; moreover, the close relationships between interventions, knowledge creation, and creativity performances suggest that the interventions are effective in improving the participants' creativity.

The effects of KM on improvements in creativity

To investigate whether the training program would enhance the influence of KM on improving creativity, we separately analyzed the influences of pretest KM scores and of posttest KM scores on creativity improvement. Figure 3 (a) and Figure 3 (b) display the mean creativity scores in the different KM groups. Using the pretest KM group as the independent variable, the 2 (pretest KM group: high vs. low) $\times$ 2 (test: pretest vs. posttest) repeated measures ANOVA revealed that the interaction effect was not significant for fluency or originality. However, the main effect of the test (pretest vs. posttest) was significant for both fluency and originality, $F(1, 29) = 28.464$, $p < 0.001$, $\eta^2_p = 0.479$ and $F(1, 29) = 24.670$, $p < 0.001$, $\eta^2_p = 0.443$, respectively. The main effect of the group was also significant for fluency and originality, $F(1, 29) = 5.698$, $p = 0.023$, $\eta^2_p = 0.155$ and $F(1, 29) = 3.996$, $p = 0.054$, $\eta^2_p = 0.114$, respectively.

Using the posttest KM group as the independent variable, the 2 (posttest KM group: high vs. low) $\times$ 2 (test: posttest vs. pretest) repeated measures ANOVA analysis revealed that the interaction effect was not significant for fluency or originality. However, the main effect of the test was significant for both fluency and originality, $F(1, 29) = 28.675$, $p < 0.001$, $\eta^2_p = 0.497$ and $F(1, 29) = 23.972$, $p < 0.001$, $\eta^2_p = 0.453$, respectively. The main effect of the group was also significant for fluency and originality, $F(1, 29) = 9.185$, $p = 0.005$, $\eta^2_p = 0.241$ and $F(1, 29) = 10.590$, $p = 0.003$, $\eta^2_p = 0.267$, respectively.

In both analyses, comparisons of the means revealed that the participants had higher fluency and originality scores on the posttest than on the pretest and that those participants with higher levels of KM ability showed greater improvements in fluency and originality than those with lower levels. Moreover, the relationship between posttest KM and improvements in creativity was much stronger than that between pretest KM and improvements in creativity.

Figure 3. Mean creativity scores in different KM groups

The effects of meaning-making on improvements in creativity

Figure 4 (a) displays the mean scores for creativity in the different meaning-making groups. The 2 (group: high vs. low) $\times$ 2 (test: pretest vs. posttest) repeated measures ANOVA analysis revealed that the interaction effect was not significant for fluency or originality. Moreover, the main effect of the group was not significant for fluency or originality. However, the main effect of the test was significant for both fluency and originality, $F(1, 29) = 27.588$, $p < 0.001$, $\eta^2_p = 0.488$ and $F(1, 29) = 22.950$, $p < 0.001$, $\eta^2_p = 0.442$, respectively. Comparisons of the means revealed that the participants obtained higher scores for fluency and originality on the posttest than on the pretest, but those participants with higher levels of meaning-making ability did not show greater improvements in fluency or originality after the training compared with those participants who had lower levels of meaning-making ability.
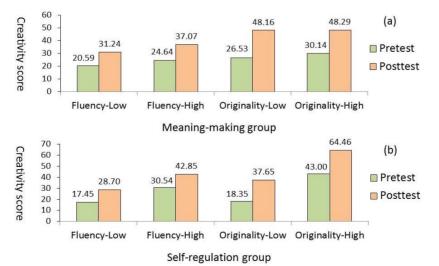

Figure 4. Mean creativity scores in the different meaning-making and self-regulation groups

The effects of self-regulation on improvements in creativity

Figure 4 (b) displays the mean creativity scores in the different self-regulation groups. The 2 (group: high vs. low) × 2 (test: pretest vs. posttest) repeated measures ANOVA analysis revealed that the interaction effect was not significant for fluency or originality. However, the main effect of the test was significant for fluency and originality, $F(1, 29) = 27.581$, $p < 0.001$, $\eta^2_p = 0.471$ and $F(1, 29) = 24.067$, $p < 0.001$, $\eta^2_p = 0.437$, respectively. The main effect of the group was also significant for fluency, $F(1, 29) = 6.184$, $p = 0.018$, $\eta^2_p = 0.166$ and originality, $F(1, 29) = 6.327$, $p = 0.005$, $\eta^2_p = 0.170$. Comparisons of the means revealed that the participants had higher scores for fluency and originality on the posttest than on the pretest, and those with higher levels of self-regulation showed greater improvements in fluency and originality than those with lower levels of self-regulation.

The effects of meaning-making and self-regulation on KM

With the total meaning-making score as the independent variable and the total KM score as the dependent variable, the Univariate ANOVA analysis revealed that meaning-making had a significant effect on KM, $F(1, 29) = 7.167$, $p = 0.012$, $\eta^2_p = 0.198$, suggesting that those participants with greater meaning-making ability were more competent in KM than their counterparts.

Using the total self-regulation score as the independent variable and the total KM score as the dependent variable, the Univariate ANOVA analysis revealed that self-regulation had a significant effect on KM, $F(1, 29) = 22.445$, $p < 0.001$, $\eta^2_p = 0.420$, suggesting that those participants with greater self-regulation were more competent in KM than their counterparts.

Discussion

Effectiveness of the training program

This study proposed five hypotheses when investigating whether the KM-based training program designed in this study would strengthen the relationship between KM and creativity and whether KM would mediate meaning-making, self-regulation, and the learning of creativity in such a program. Except for the hypothesis concerning the direct influence of meaning-making on the learning of creativity, all of the proposed hypotheses were supported.

The findings in this study revealed that, after the training, all participants significantly improved in creativity, as evidenced by the significant improvement in scores of fluency and originality after the training as well as (see the repeated measures ANOVA) the close relationships between the major interventions, knowledge creation and creativity performances (see the preliminary analyses). Moreover, the KM-based training successfully strengthened the influence of KM on creativity and, therefore, enhanced the improvements in creativity. Since the main purpose of this study was to investigate the relationship between KM, mediate meaning-making, and self-regulation during the learning of creativity in a 17-week training program, the control group was not employed. Nevertheless, the findings based on a deliberately designed program can provide valuable information for the teaching of creativity.

The training program is, in essence, conducted in an e-learning environment that emphasizes four KM processes: knowledge acquisition, knowledge sharing, knowledge application, and knowledge creation. Therefore, the findings suggest that university students' creativity can be enhanced through the facilitation of KM processes in a 17-week e-learning training program. The training program in this study emphasizes the learning community, group discussions, observational learning, online sharing and evaluation, abundant practice and interactions, and group assignments. The effectiveness of this training program suggests that these mechanisms contribute to the facilitation of KM processes and creativity. The findings in this study also support the arguments that creativity is the process of knowledge building (e.g., Craft, 2005; Paavola, Lipponen, & Hakkarainen, 2004) and that KM plays a critical role in the development of creativity (Du Plessis, 2007). Moreover, the findings suggest that KM processes can be effectively facilitated in e-learning environments through the KM strategies of socialization, externalization, combination, and internalization (Cress et al., 2013; Kimmerle, Cress, & Held, 2010; Yeh et al., 2011)

Aptitude-treatment interactions during the training

This study found aptitude-treatment interactions during the training. Specifically, the participants with higher levels of KM ability showed greater improvements in fluency and originality following the training than those with lower levels of KM. Similarly, the participants with greater self-regulation showed greater improvements in fluency and originality after the training than those with less self-regulation.

According to the DIKW model, knowledge is defined as information connected through relationships (Müller & Faltin, 2011). Participants with better KM are, therefore, more capable of connecting information with creativity during training. As a result, they benefit more from training than their counterparts do. Existent theories and previous empirical findings on self-regulation can also be used to describe aptitude-treatment interactions and their effects on training. For example, past studies have suggested that self-regulated learners are more capable of making plans, managing time, identifying and pursuing goals, and conducting autonomous learning (Hon, 2011; King & Gurland, 2007; Zampetakisa et al., 2010). Accordingly, people with greater self-regulation are more competent in managing their learning processes during the learning of creativity, therefore benefitting more than their counterparts.

Mediating effects during the training

Notably, this study also found mediating effects during the training; specifically, meaning-making and self-regulation influenced the improvement of creativity through KM. In addition, self-regulation had stronger indirect effects than meaning-making did (η_p^2 = 0.012 vs. 0.420). These findings support the aforementioned DIKW theory, in that knowledge in reflective learning is derived from meaningful interrelations between information about a reflected situation and its environment (Müller & Faltin, 2011). These results also support the argument that the creation of relationships and meaning is, in essence, knowledge generation (Lee et al., 2009). The findings in this study are in line with the claims that different social value orientations lead to different perceptions of the costs and benefits of knowledge sharing decisions, thereby influencing the inclination to share knowledge (Cyr & Choo, 2010). Moreover, the decision to engage in creative work entails, in addition to personal and contextual factors, sophisticated cognitive processes and sense-making activities (Madjar et al., 2011). Accordingly, university students with good meaning-making abilities are able to employ KM processes effectively, further enhancing their creativity.

As for the mediating effects of KM on self-regulation and creativity, the findings in this study support the argument that self-regulated learners are able to generate activities that enhance knowledge generation by creating relationships between new information and prior knowledge (Lee et al., 2009); in addition, the results are consistent with suggestions that self-regulated learners are characterized by self-concordance, autonomous orientations, and goal setting (Hon, 2011; King & Gurland, 2007; Zampetakisa et al., 2010). Accordingly, university students who are competent self-regulators should be able to flexibly employ KM strategies to achieve their goals and, further, to improve their creativity.

Conclusions and suggestions

In this epoch of information technology and knowledge economics, KM and creativity have become required competences for university students. This study designed a KM-based training program to facilitate university students' KM processes and, further, to enhance their learning of creativity. Most importantly, this study mainly aimed at understanding whether university students with different aptitudes would benefit differently from the training program. The findings in this study suggest that KM is a mediator between meaning-making, self-regulation and the learning of creativity in an e-learning environment, and ATIs exist during the training.

Due to the long period of experimental instruction and creativity training that emphasizes discussions and interactions can be better achieved via a small sample, only a small sample was included. However, since the training program in this study is deliberately designed based on a sound base of theories and empirical findings and the training session lasts for 17 weeks, the findings have important implications to the curriculum and instructional design aimed at improving creativity in an e-learning environment. Accordingly, this study not only sheds lights on understanding how ATIs influence creativity learning, but also provides a new approach—KM-based training— to improve university students' creativity in environments of e-learning.

Due to the great variety of participants' disciplines, the designed instructional activities in this study were based on a domain-general perspective; further studies can replicate the KM-based framework of instructional design employed in this study to facilitate domain-specific creativity. Moreover, this study found that self-regulation is predictive to the learning of creativity. Further studies can develop self-regulation focused training to facilitate the learning of creativity. Nussbaumer, Steiner, and Albert (2008) proposed that the following six self-regulatory processes are important for web-based learning: (1) goal setting supported by communication tools; (2) the use of task strategies supported by content delivery tools (e.g., concept mapping software; (3) self-monitoring supported by the use of discussion forums; (4) self-evaluation supported by the use of rubrics, evaluation criteria, and peer feedback; (5) time planning and management supported by communication tools meant for time budgeting; and (6) help-seeking supported by hypermedia tools. These mechanisms can be taken into consideration while designing a training program for the learning of creativity.

Acknowledgments

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