科技部補助專題研究計畫報告

數位科技導向的正念學習介入對提升創造力之效果：神經可塑性之探究(第2年)

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報 告 附 件 ： 出席國際學術會議心得報告

本研究具有政策應用參考價值：■否 □是，建議提供機關
（勾選「是」者，請列舉建議可提供施政參考之業務主管機關）
本研究具影響公共利益之重大發現：□否 □是

中 華 民 國 109 年 11 月 01 日

中 文 摘 要 ： 本計畫為兩年期計畫，共進行四個行為研究和兩個fMRI研究。研究一在發展本計畫所需量表，包括行動裝置促進創造力態度量表(Inventory of Attitude toward Mobile Devices for Creativity Learning)、智慧型手機熱情量表(Inventory of Passion towards Smart Phones)、創造力心向量表(Creativity Mindset Inventory)、智慧型手機正念學習量表(Mindful Learning towards Smart Phones)、智慧型手機可能性思考量表(Inventory of Possibility Thinking towards Smart Phones)。研究發現，所發展量表均具有良好信度與效度。研究二探討科技導向正念介入對提升創造力之效果，149位大學生參與前後測控制組設計之實驗教學。實驗教學的參與者為一組控制組和三組實驗組；所有組別均進行相隔一週的創造力前測和後測。研究發現顯示科技導向的正念學習介入可應於日常生活中並能促進大學生的創造力學習。研究三發展曖昧相片想像力測驗(Ambiguous-photo Imagination Test)，參與者為133位大學生。本研究發展一份20題的長題本和一份10題的短題本，兩份測驗均具有良好信度與效度。研究四探討正念學習介入的效果和手機使用熱情、成長心向、固定心向和自我效能之群集型態，參與者為84位大學生。研究發現，實驗介入能促進大學生之成長-內在心向、和諧-內在熱情、和諧-外在熱情和創造力自我效能。此外，集群分析得到三組主要群集型態。研究五進行黑白曖昧圖片和彩色生活照片想像力神經網路之比較，20位大學生參與此實驗並於fMRI掃描器中進行創造力測驗。研究發現，不管是黑白圖片或是彩色圖片測驗，在產生創意點子的過程中，有許多共同活化的腦區，但黑白圖片有較廣的活化腦區。研究六檢驗正念學習的介入對於創造力學習的神經可塑性之效果，25位大學生參與前後測設計之fMRI實驗。所有參與者接受為期10天的實驗介入，針對生活周遭有興趣的主題自由拍照並上傳至指定網站分享。研究發現，在正念介入後，參與者能夠利用較少的神經資源，以較佳的神經效率，達到更好的創意表現。此兩年期計畫的研究發現闡明創造力研究統整大腦、心智與學習的可能性與價值性。

中 文 關 鍵 詞 ： 正念學習、創造力、科技、fMRI、個人特質

英 文 摘 要 ： In this two-year project, four behavioral studies and two fMRI studies were conducted. Study 1 focused on developing related instruments, including the Inventory of Attitude towards Mobile Devices for Creativity Learning, the Inventory of Passion towards Smartphones, the Inventory of Passion towards Smartphones, Creativity Mindset Inventory, Mindful Learning towards Smartphones, and the Inventory of Possibility Thinking towards Smartphones. All instruments had good validity and reliability. Followed the instrument development, study 2 explored the effectiveness of technology-oriented mindfulness learning intervention on enhancing creativity. With a pretest and post-test control group design, 149 college students participated in an experimental instruction. The findings of this study suggest that applying technology-oriented mindfulness

learning intervention in daily life has the potential for promoting creative learning among college students. Study 3 developed an Ambiguous-photo Imagination Test that included a longer version of twenty test items and a shorter version of ten test items. Participants were 113 college students. Both versions of Ambiguous-photo Imagination Test had good validity and reliability. Study 4 explored the learning effect and the cluster profiles of passion in smartphone use, growth creative mindset, fixed mindset, and self-efficacy among 84 college students. The findings revealed that the college students significantly improved their growth-internal and external creativity mindset, harmonious-intrapersonal passion, harmonious-interpersonal passion, and creativity self-efficacy. In addition, three distinctive patterns emerged in the cluster analysis that included the concerned personal traits. Study 5 compared the participants' imagination neural network of ambiguous black-and-white versus color daily life photos. Twenty college students participated in this experiment and took the creativity tasks inside a fMRI scanner. The findings suggest that the black-and-white photos, which are more abstract than the color photos, requires more cognitive resources to recognize the shapes and characteristics in the photos and use more neural resources to generate creative ideas. Study 6 examined the effectiveness of mindful learning intervention on the neuroplasticity of creative learning. Twenty-five college students participated in an fMRI experiment with pretest-posttest design. All participants received a 10-day mindful intervention, in which they were requested to freely taking photos of daily life and upload them to a designated website for sharing. The findings suggest that the brain uses fewer neural resources for efficient neural actions to achieve better creativity performance after the intervention. The findings of this two-year study demonstrate the possibility and valuableness of integrating mind, brain, and learning in creativity.

英文關鍵詞：mindful learning, creativity, technology, fMRI, personal traits

行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

數位科技導向的正念學習介入對提升創造力之效果：神經可塑性之探究

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數位科技導向的正念學習介入對提升創造力之效果：神經可塑性之探究

執行期限：107 年 8 月 1 日至 109 年 10 月 31 日
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摘要

本計畫為兩年期計畫，共進行四個行為研究和兩個 fMRI 研究。研究一在發展本計畫所需量表，包括行動裝置促進創造力態度量表(Inventory of Attitude toward Mobile Devices for Creativity Learning)、智慧型手機熱情量表(Inventory of Passion towards Smartphones)、創造力心向量表(Creativity Mindset Inventory)、智慧型手機正念學習量表(Mindful Learning towards Smartphones)、智慧型手機可能性思考量表(Inventory of Possibility Thinking towards Smartphones)。研究發現，所發展量表均具有良好信度與效度。研究二探討科技導向正念介入對提升創造力之效果，149 位大學生參與前後測控制組設計之實驗教學。實驗教學的參與者為一組控制組和三組實驗組；所有組別均進行相隔一週的創造力前測和後測。研究發現顯示科技導向的正念學習介入可應於日常生活中並能促進大學生的創造力學習。研究三發展曖昧相片想像力測驗(Ambiguous-photo Imagination Test)，參與者為 133 位大學生。本研究發展一份 20 題的長題本和一份 10 題的短題本，兩份測驗均具有良好信度與效度。研究四探討正念學習介入的效果和手機使用熱情、成長心向、固定心向和自我效能之群集型態，參與者為 84 位大學生。研究發現，實驗介入能促進大學生之成長-內在心向、和諧-內在熱情、和諧-外在熱情和創造力自我效能。此外，集群分析得到三組主要群集型態。研究五進行黑白曖昧圖片和彩色生活照片想像力神經網路之比較，20 位大學生參與此實驗並於 fMRI 掃描器中進行創造力測驗。研究發現，不管是黑白圖片或是彩色圖片測驗，在產生創意點子的過程中，有許多共同活化的腦區，但黑白圖片有較廣的活化腦區。研究六檢驗正念學習的介入對於創造力學習的神經可塑性之效果，25 位大學生參與前後測設計之 fMRI 實驗。所有參與者接受為期 10 天的實驗介入，針對生活周遭有興趣的主題自由拍照並上傳至指定網站分享。研究發現，在正念介入後，參與者能夠利用較少的神經資源，以較佳的神經效率，達到更好的創意表現。此兩年期計畫的研究發現闡明創造力研究統整大腦、心智與學習的可能性與價值性。

關鍵字：正念學習、創造力、科技、fMRI、個人特質

Implementing mindful learning intervention through digital technology to enhance creativity: An exploration of neural plasticity

Abstract

In this two-year project, four behavioral studies and two fMRI studies were conducted. Study 1 focused on developing related instruments, including the *Inventory of Attitude towards Mobile Devices for Creativity Learning*, *the Inventory of Passion towards Smartphones*, *the Inventory of Passion towards Smartphones, Creativity Mindset Inventory, Mindful Learning towards Smartphones, and the Inventory of Possibility Thinking towards Smartphones*. All instruments had good validity and reliability. Followed the instrument development, study 2 explored the effectiveness of technology-oriented mindfulness learning intervention on enhancing creativity. With a pretest and post-test control group design, 149 college students participated in an experimental instruction. The findings of this study suggest that applying technology-oriented mindfulness learning intervention in daily life has the potential for promoting creative learning among college students. Study 3 developed an Ambiguous-photo Imagination Test that included a longer version of twenty test items and a shorter version of ten test items. Participants were 113 college students. Both versions of Ambiguous-photo Imagination Test had good validity and reliability. Study 4 explored the learning effect and the cluster profiles of passion in smartphone use, growth creative mindset, fixed mindset, and self-efficacy among 84 college students. The findings revealed that the college students significantly improved their growth-internal and external creativity mindset, harmonious-intrapersonal passion, harmonious-interpersonal passion, and creativity self-efficacy. In addition, three distinctive patterns emerged in the cluster analysis that included the concerned personal traits. Study 5 compared the participants' imagination neural network of ambiguous black-and-white versus color daily life photos. Twenty college students participated in this experiment and took the creativity tasks inside a fMRI scanner. The findings suggest that the black-and-white photos, which are more abstract than the color photos, require more cognitive resources to recognize the shapes and characteristics in the photos and use more neural resources to generate creative ideas. Study 6 examined the effectiveness of mindful learning intervention on the neuroplasticity of creative learning. Twenty-five college students participated in an fMRI experiment with pretest-posttest design. All participants received a 10-day mindful intervention, in which they were requested to freely taking photos of daily life and upload them to a designated website for sharing. The findings suggest that the brain uses fewer neural resources for efficient neural actions to achieve better creativity performance after the intervention. The findings of this two-year study demonstrate the possibility and valuableness of integrating mind, brain, and learning in creativity.

Keywords: mindful learning, creativity, technology, fMRI, personal traits

Introduction

The field of education has recently applied mindful pedagogies because of the known benefits of improved attention, cognitive flexibility (Levy, Jennings, & Langer, 2001), problem solving (Ostafin & Kassman 2012), emotion, working memory, and creativity (Langer, 2000). A more recent definition of mindfulness proposed by Langer (2016) has added that mindfulness is characterized by the continuous creation of new categories, openness to new information, and an implicit awareness of multiple perspectives. Such characteristics are also important to creative thinking across subject domains. Researchers (Hennessey & Amabile, 2010; Yeh, 2017) have argued that understanding the cognitive processes of creativity is crucial for effective creativity instruction. An effective way of improving mindful learning and creativity is to practice such cognitive processes through life experiences. To date, few studies have employed technology-based interventions in daily life to investigate the relationship between mindful learning and creativity, and no study has been conducted to explore the neural substrates underlying creative thinking after a Langerian mindful learning intervention is employed. This study sought to explore how technology-based mindful learning interventions carry effects on creativity in daily life as well as examine the neural plasticity of such practice. The aims of this study were as follows:

Developing Inventory of Attitude toward Mobile Devices for Creativity Learning, Inventory of Passion towards Smart Phones, Creativity Mindset Inventory, Mindful Learning towards Smart Phones, Inventory of Possibility Thinking towards Smart Phones, and Ambiguous Imagination Test.

- Developing different types of technology-oriented mindful learning interventions that can be practiced in daily life.
- Investigating the effects of different types of technological mindful learning interventions through smartphone-based interventions.
- Exploring the learning effects and cluster profiles of passion in smartphone use, growth creative mindset, fixed mindset, and self-efficacy in a mindful learning intervention.
- Comparing imagination neural networks of ambiguous black-and-white versus color daily life photos.
- Examining brain plasticity with regard to mindful learning intervention in creativity learning.

Literature review

Mindfulness, creativity, and creativity self-efficacy

According to Langer (2012), mindfulness can be increased by paying attention to novelty, trying to be flexible in evaluations and perceptions, and questioning previous points of view that have been taken for granted. Education is one of the areas to which mindfulness has been commonly applied in recent years. When people engage in mindful learning, they avoid forming mindsets that unnecessarily confine them (Langer, 2000). In this study, we define mindfulness as a mindful learning process in which individuals actively and consciously pay attention to the things they are curious about or interested in, and further, try to bring about new meanings or original thinking from these ordinary or special things.

Self-efficacy refers to beliefs in one's abilities to organize and execute the actions essential for producing given outcomes; individuals with self-efficacy act with forethought, self-reactiveness, and self-reflectiveness (Bandura, 2001). More recently, some researchers have employed the concept of self-efficacy in creativity studies and suggest that creativity self-efficacy is critical to creative performance (Tierney & Farmer, 2002; Wang, Liu & Shalley, 2018) and that it involves one's intrinsic motivation to perform creative behaviors (Gong,

Huang & Farh, 2009). Integrating the concept of self-efficacy and the learning of creativity, this study defines creativity self-efficacy as the belief in one's ability to produce creative ideas or solutions and the confidence in achieving creative performance.

It has been shown that creativity is related to individual differences in executive functions. Working memory is the executive and attentional aspect of short-term memory, which is involved in integration, processing, and retrieval of information, as well as the maintenance and manipulation of task-relevant information, to guide subsequent behavior (Autin & Croizet, 2014). It's been found that working memory influenced creativity via attention to task-related information (Yeh, Lai, Lin, Lin, & Sun, 2015). On the other hand, mindfulness involves the self-regulation of attention with curiosity, open-mindedness, and self-regulation, which are important to creativity performance (Bishop et al., 2004; Pang & Ruch, 2019; Yeh, Chang, & Chen, 2019). Accordingly, enhancing mindfulness may improve creativity.

Mindful learning interventions

Mindfulness is a natural human ability as well as a set of skills that can be fostered and developed via a regular meditation practice or specifically customized interventions (Iani, Lauriola, Cafaro, & Didonna, 2017). Many different mindfulness programs or interventions have been found to be effective in varied areas (Creswell, 2017). To date, most empirical studies on Langerian mindfulness used selected components from Langer's theory; these designs were successful in inducing a state of Langerian mindfulness which has shown positive effects on learning (e.g., Lawrie, Tuckey & Dollard, 2018; Miralles-Armenteros, Chiva-Gómez, Rodríguez-Sánchez & Barghouti, 2019; Stewart & Bower, 2019) and creativity (e.g., Grant, Langer, Falk & Capodilupo, 2004; Langer, 2000; Wang & Liu, 2016). Accordingly, interventions of mindfulness may facilitate attention and cognitive flexibility and then enhance creativity and creativity self-efficacy. To maximize the intervention effect, this study adds two components to the smartphone-based intervention: knowledge sharing and self-determination. Study findings have suggested that knowledge/idea-sharing enhanced the improvement of creativity and creativity self-efficacy. This study requested the participants to share their tasks on a designated website to enhance knowledge sharing. On the other hand, self-determination involves the concepts of choice, self-control, and self-management (Peterson, Aljadeff-Abergel, Eldridge, VanderWeele, & Acker, 2020). Three basic psychological needs required to reach this optimal functioning are autonomy, competence, and relatedness (Ryan & Deci, 2000; Vansteenkiste & Ryan, 2013). This study incorporated the concept of autonomy to enhance creativity.

According to aptitude-treatment interactions (ATIs), individuals with different aptitudes may benefit at varying degrees from treatment or training. Understanding the interaction between learners' aptitude and treatment helps create a learning environment in which the treatment matches the aptitude of the learner and, further, in which the optimal learning effect can be achieved (Yeh and Lin, 2015). The aptitude of concern in this study was the attitude toward mobile devices for creativity learning. When people hold positive attitudes toward using mobile devices to enhance creativity, they may have more enjoyment and positive emotions, which contribute to creative performance (Boyle, Connolly & Hainey, 2011; Yeh, Lai, Lin, Lin, & Sun, 2015) and self-efficacy of creativity. We, therefore, assume that attitude toward mobile devices for creativity learning would moderate the effects of mindful learning intervention on the improvement of self-efficacy.

Mindfulness, creativity mindset, passion for mobile learning, and self-efficacy of creativity

Passion, proposed by Vallerand (Vallerand, 2012), typically includes two types of passions, namely, harmonious passion and obsessive passion. Individuals who are passionate usually tend to engage in a

particular activity for a lengthy period of time (Kaiser, Müller-Seitz, Lopes, & Pina e Cunha, 2007). More recently, Yeh and Chu (2018) proposed a two-dimensional model of passion in e-learning that includes the dimension of the locus of control (internal versus external) and internalization drives (HP versus OP). Based on their theory, they proposed four types of passion in the use of mobile devices: (1) Harmonious-intrapersonal passion refers to the harmonious and controllable passion that is derived from self-determined enjoyment and satisfaction while undertaking individual learning; (2) Harmonious-interpersonal passion refers to the harmonious and controllable passion that is derived from self-determined enjoyment and satisfaction while interacting with others; (3) Obsessive-intrapersonal passion refers to the excessive and uncontrollable passion that is derived from internally compelled forces; and (4) Obsessive-interpersonal passion refers to excessive and uncontrollable passion which is derived from externally compelled forces while interacting with others.

Creativity mindset (CM) refers to how people perceive their own creative ability. People with a growth CM believe that their creative ability can be developed through training or practice. On the other hand, people who hold a fixed CM consider creativity to be innate and unchangeable (Hass, Katz-Buonincontro, & Reiter-Palmon, 2016; Karwowski, 2014). We propose that people who hold Growth-Internal control (GI) believe that creativity can be improved through self-learning, those who hold Growth-External control (GE) believe that creativity can be improved under good learning environments or through others' help, those who hold Fixed-Internal control (FI) believe that creativity is an inborn ability and that there is no way to improve it through self-learning, and those who hold Fixed-External control (FE) believe that creativity cannot be improved even under good learning environments or through others' help. It has been suggested that people with a growth mindset are consistently on the go and fearless when facing obstacles (McClendon et al., 2017).

Researchers have found the use of mobile technology such as smartphones is engaging, especially under proper guidelines. For example, Hegarty and Thompson (2019) found that with a well-designed learning environment and with a proper guideline by the instructor, students showed great passion for the learning process. Accordingly, this study tried to develop a smartphone-based intervention to facilitate college student's growth creativity mindset and harmonious passion in smartphone use. To date, little research has been performed with the goal of identifying the pattern of different types of creativity mindset, passion for mobile learning, and self-efficacy of creativity. In related research, Raphiphatthana, Jose, & Salmon (2018) found positive associations between mindfulness and grit which refers to perseverance and passion for long-term goals; the act-awareness is particularly predictive to the consistency of interest and perseverance of effort of mindfulness. On the other hand, Schellenberg, Bailis, and Mosewich's (2016) suggest that people with a predominant obsessive passion are more likely to avoid treating themselves with kindness and compassion when faced with failure, which may lead to maladaptive outcomes. Raphiphatthana et al. (2018) found that the influences of harmonious and obsessive passion on players' addiction to online computer games differ significantly. Obsessive passion may lead to addiction, while harmonious passion normally does not. These findings suggest different types of passion may lead to varied subsequent self-regulated behavior. In addition, the mobile technology tool suits well with growth mindset learning traits and passion (Hegarty &Thompson, 2019).

Mindfulness and neural plasticity of creativity

Related findings have indicated that divergent thinking is related to widespread brain regions including the supramarginal gyrus (SMG), angular gyrus (AG), middle temporal gyrus (MTG), posterior parietal cortex (PPC), precuneus, anterior cingulate cortex (ACC) and prefrontal cortex (PFC) (Shi et al., 2018). It has been also found that the generation of new ideas during a divergent thinking task was related to increased engagement of the left inferior parietal lobule (IPL), which provides support for a role of the DMN in creative

cognition (Benedek et al., 2014). Moreover, regions of the FPN have been implicated in divergent thinking (Gonen-Yaacovi et al., 2013), which is associated with cognitive processes, such as working memory, suppression of unrelated thoughts and task-set switching (Niendam et al., 2012). In addition, many researchers emphasize the interactions between frontoparietal cognitive control and dorsal and ventral attention brain networks as well as brain regions involved semantic cognition in divergent thinking tasks (Fink et al. 2015; Sun et al. 2016; Davey et al., 2016; Noonan et al. 2013; Madore, Thakral, Beaty, Addis, & Schacter, 2019). A meta-analysis of functional neuroimaging studies indicates that activity in lateral prefrontal, anterior cingulate, and posterior parietal and temporal cortices underlies component processes of divergent thinking, which are typically thought to include semantic retrieval and expansion, inhibition and cognitive control, top-down and bottom-up attention (Wu et al. 2015).

On the other hand, researchers considered that mindful is consists of five facets (non-reactivity to inner experience, non-judging of inner experience, acting with awareness, describing, and observing. It is believed that "each facet of mindfulness might be related to the development of the gray matter volume in different brain regions" (Baer, Smith, Hopkins, Krietemeyer, &Toney, 2006; Murakami et al., 2012). Murakami et al. (2012) scanned neurological or psychiatric disorder free participants alone with assessing their self-report five facets of mindset to deeper investigate their brain and mindfulness activities. The results indicated that the participants' self-report of mindfulness is positively associated with the right anterior insular cortex and right parahippocampal gyrus/ amygdala. None of the mindfulness subscales is correlated with gray matter volume in the right anterior insula and right amygdala.

Few studies have investigated the neural plasticity of Langerian mindful learning on creativity. However, meditation, one key strategy of mindfulness, has been found help strengthen both the default mode network (DMN) and executive control networks (ECN), as well as the salience network (SN) which maintains balance of the first two networks by deciding which is activated, and when (Goh, 2017). Past behavioral studies have found that mindfulness training enhances positive affect, emotion regulation (e.g. Langer, 2000; Peffer et al., 2012), and executive functioning and attention regulation abilities (Moore & Malinowski, 2009; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Therefore, improving mindfulness may change brain functions related to positive emotion, attention, working memory, and further improve creativity.

研究一、量表發展
Study 1: Development of Inventories

研究 1-1、行動裝置促進創造力態度量表之發展
Study 1-1: Development of the Inventory of Attitude toward Mobile Devices for Creativity Learning

1. The present study

This study aimed at developing an inventory to measure college students' attitudes toward using mobile devices for creativity learning.

2. Method

2.1. Participants

All participants, aged from 20 to 30 years old, were recruited through an online ad posted on a campus

website. Participants in the inventory development stage were 183 college students (61 males and 122 females; M_{age} = 20.97; SD_{age} = 1.469); they were rewarded with approximately USD 3.

2.2. Instruments

The instrument AMD-CL, with 13 items, was developed to measure college students' attitudes toward mobile devices for creative learning. AMD-CL is a 6-point Likert-type scale from 1 point to 6 points, representing strongly disagree to strongly agree.

2.3. Procedures

Data were collected through a website designed by the researchers with no time limit. This study was approved by the Institutional Review Board of National Chengchi University, Taiwan, and written informed consent was obtained from all participants.

3. Results

3.1. Exploratory factor analysis and reliability analysis

Exploratory factor analysis, internal consistency reliability, and confirmatory factor analysis were employed to examine the reliability and validity of AMD-CL. Finally, 13 items were kept in AMD-CL. Principal Component Analysis and direct oblimin were employed in factor extraction and rotation when conducting exploratory factor analysis. The results yielded three factors: strategy enhancement (5 items), motivation and knowledge sharing (4 items), and thinking efficiency (4 items). With factor loadings ranging from .480 to .902, 69.55% of the total variance was explained by the three factors (see Table 1). The correlations between each of the factors and the total score were .919, .783, and .865 (ps < .001), respectively.

The Cronbach's α of AMD-CL and the three factors were .917, .861 (strategy enhancement), .846 (Motivation and Knowledge sharing), and .870 (efficiency). Moreover, the item-total correlation coefficients ranged from .528 to .802.

3.2. Confirmatory factor analysis

The three-factor structure with 13 items extracted from the exploratory factor analysis was validated by confirmatory factor analysis with maximum likelihood estimation. Confirmatory factor analysis results indicated that AMD-CL has good construct validity and reliability, $\chi^2(N = 183, df = 58) = 103.395$ ($p < .05$), the goodness-of-fit index (GFI) = .921, the adjusted goodness-of-fit index (AGFI) = .876, the root mean square residual (RMR) = .046, root mean square error of approximation (RMSEA)= .066, the incremental fit index (IFI) = .967, the comparative fit index (CFI) = .967. Moreover, the composite reliability values (ρ_c) were .861, .851, .852, and the average variance extracted values (ρ_v) were .557, .591, and .589 (see Figure 1).

Table 1. The factor loadings of the AMD-CL (N = 183)

No	Factors and items	Factor loading 1	2	3
	Factor 1:能力增進 Strategy enhancement (α = .861)			
9	使用行動裝置，有助於提升我多元思考的能力。 Using mobile devices helps enhance my multi-perspective thinking.	.817		
8	行動裝置有助於強化我的創造思考技能，如腦力激盪及說故事等能力。 Mobile devices help enhance my creative skills, such as brainstorming, storytelling,	.805		

	etc.			
13	使用行動裝置，有助於提升我對事物的觀察力及敏感度。 Using mobile devices helps enhance my abilities of observation and sensitivity.	.735		
10	使用行動裝置，有助於我產出獨特的點子 Using mobile devices helps me produce unique ideas.	.745		
12	使用行動裝置，有助於我將創意點子更精緻化。 Using mobile devices helps me elaborate my ideas.	.573		
	Factor 2: 動機與知識分享 Motivation and knowledge sharing (α = .846)			
6	行動裝置是共創知識的好工具。 Mobile devices are great tools for knowledge co-creation.		.862	
3	使用行動裝置有助於即時表達與分享創意點子。 Using mobile devices helps me express and share creative ideas quickly.		.861	
5	行動裝置是蒐集創意點子的好工具。 Mobile devices are great tools for collecting creative ideas.		.804	
7	行動裝置提供我學習很多新知識的機會。 Mobile devices provide me many learning opportunities.		.569	
	Factor 3: 思考效能Thinking efficiency (Cronbach's α = .870)			
2	使用行動裝置來學習創造力是有效率的學習方法。 Using mobile devices to learn creativity is an efficient way of learning.			.902
1	使用行動裝置可以有效改善我的創造力。 Using mobile devices can effectively improve my creativity.			.843
4	使用行動裝置很容易進行創意發想。 It is easy to bring about creative ideas through mobile devices.			.677
11	使用行動裝置，有助於我即時產出很多創意點子。 Using mobile devices helps me produce many creative ideas quickly.			.480

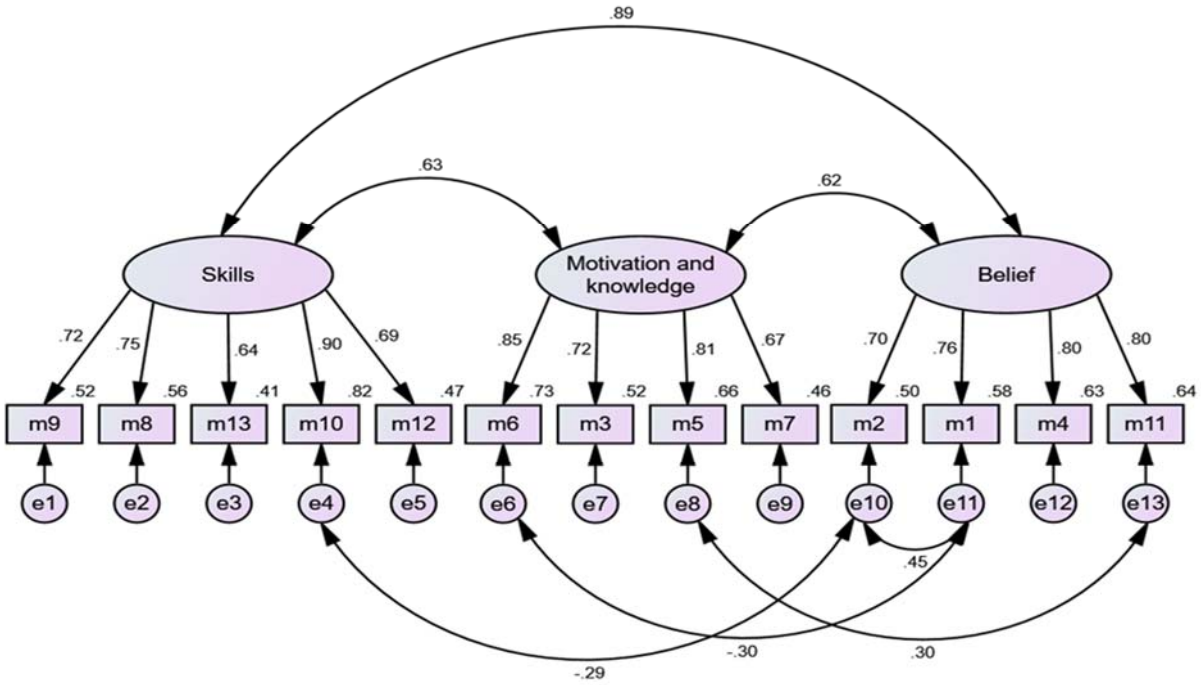


Figure 1. CFA model of the AMD-CL

研究 1-2、智慧型手機熱情量表之發展

Study 1-2: Development of the Inventory of Passion towards Smart Phones

1. The present study

This study aimed at developing an inventory to measure college students' passion towards using mobile phones.

2. Method

2.1. Participants

All participants, aged from 20 to 30 years old, were recruited through an online ad posted on a campus website. Participants in the inventory development stage were 183 college students (61 males and 122 females; M_{age} = 20.97; SD_{age} = 1.469); they were rewarded with approximately USD 3

2.2. Instrument

The Inventory of Passion towards Smart Phones (IPSP) was developed to measure college students' passion towards using mobile phones. The IPSP is a 2-dimension (Harmonious-Obsessive and Intrapersonal-Interpersonal), 6-point Likert type scale with 1 point to 6 points, representing strongly disagree to strongly agree. The original version has 20 items; after two stages of the construction process, 5 items were eliminated. The final version of IPSP has 15 items and includes four types of passion: Harmonious-Intrapersonal (H-Intra, 4 items), Harmonious-Interpersonal (H-Inter, 4 items), Obsessive-Intrapersonal (O-Intra, 4 items), and Obsessive-Interpersonal (O-Inter, 3 items) (see Table 7 and Figure 4). The inventory was administered online without time constraints. Moreover, H-Intra and H-Inter can be added together as a score of Harmonious-Passion, while O-Intra and O-Inter can be added together as a score of Obsessive-Passion. Higher scores on a certain subscale represent stronger passion in that dimension.

2.3. Procedures

Data were collected through a website designed by the researchers with no time limit. This study was approved by the Institutional Review Board of National Chengchi University, Taiwan, and written informed consent was obtained from all participants.

3. Results

3.1. Confirmatory factor analysis

A confirmatory factor analysis (CFA) using maximum likelihood estimation was conducted to examine the reliability and validity of the four-factor model(see Figure 2). The CFA results indicated that the IPSP has good construct validity and reliability: χ^2 (N = 183, df = 79) = 120.636 (p = .002), the goodness-of-fit index (GFI) = .922, the adjusted goodness-of-fit index (AGFI) = .882, the root mean square residual (RMR) = .072, and the root mean square error of approximation (RMSEA) = .054. In terms of relative fit measures, the normed fit index (NFI) = .905, the relative fit index (RFI) = .873, the incremental fit index (IFI) = .965, and the comparative fit index (CFI) = .964. Moreover, values of the composite reliability (ρ_c) of H-Intra, O-Intra, O-Inter, and H-Inter were .846, .844, .627, and .810, respectively. The average variance extracted (ρ_v) values of the four factors were .581, .580, .380, and .517, respectively (see Table 2). The correlations between each of the factors and the total score were .890, .803, .803, and .861 (ps < .001), respectively.

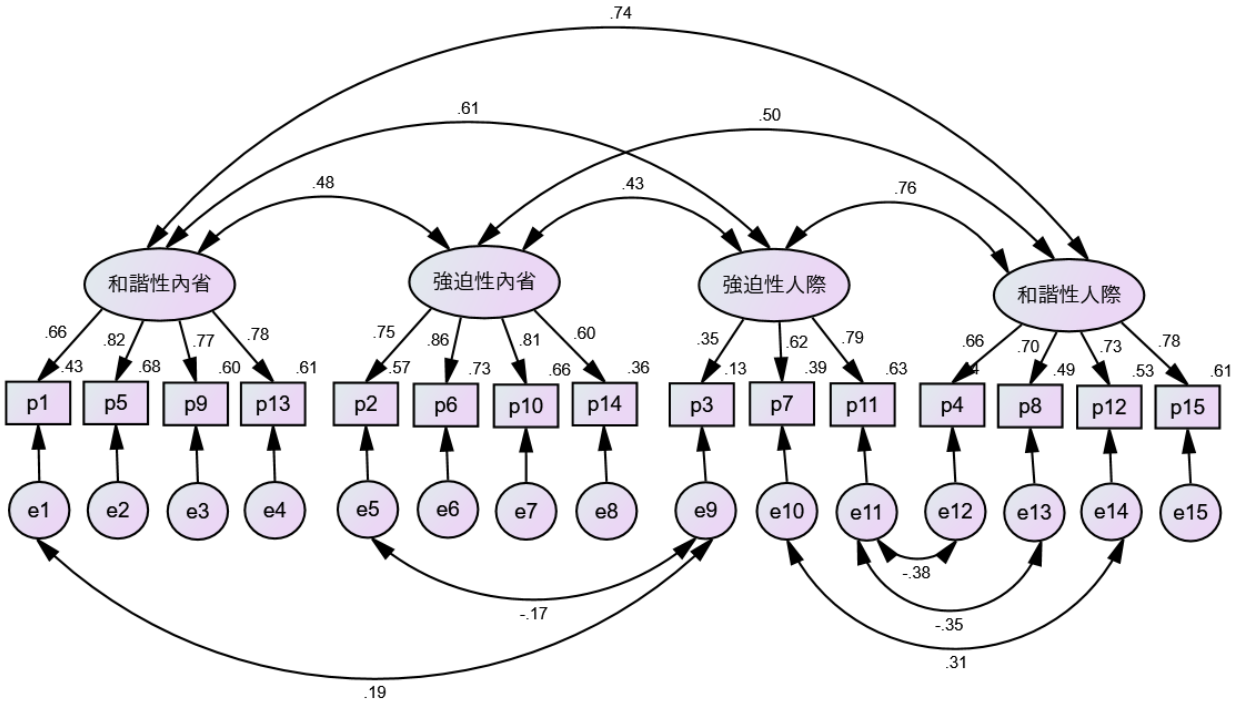


Figure 2. CFA model of the IPSP

Table 2. IPSP驗證性因素分析模式之參數估計、完全標準化參數估計、及顯著性考驗摘要表

題號	因素負荷量（λ）	SE	t	R^2	組合信度(ρ_c)	平均變異解釋量(ρ_v)
H-Intra					.846	.581
1	.66			.434		
5	.83	.126	9.203	.681		
9	.78	.135	8.800	.601		
13	.78	.138	8.842	.607		
O-Intra					.844	.580
2	.75	.083	10.608	.567		
6	.86	.086	11.935	.733		
10	.81			.656		
14	.60	.085	8.127	.362		
O-Inter					.627	.380
3	.35	.116	4.218	.125		
7	.79	.122	6.704	.386		
11	.62			.630		
H-Inter					.810	.517
4	.66			.441		
8	.70	.144	7.894	.490		
12	.73	.148	8.218	.527		
15	.78	.139	8.647	.608		

Table 3. The test items, Cronbach's α, and CFA factor loadings of the IPSP

No	Test item	CFA factor loading			
		1	2	3	4
	Harmonious (α = .930)				
Factor 1: 和諧-內省 Harmonious-Intrapersonal (α = .910)					
1	我常使用智慧型手機進行學習，因為它能讓我掌握最新的資訊。 I often use my smartphone for learning because it helps me stay up-to-date on the latest news.	.66			
5	我常使用智慧型手機進行學習，因為它能提供符合我個人能力和需求的學習。 I often use my smartphone for learning because it provides learning resources that meet my needs and ability.	.83			
9	我常使用智慧型手機進行學習，因為它很有趣。 I often use my smartphone for learning because learning is interesting.	.78			
13	我常使用智慧型手機進行學習，因為它讓我能自由選擇與決定學習的內容。 I often use my smartphone for learning because it allows me to make free choices and decisions about what I want to learn.	.78			
Factor 2: 和諧-人際 Harmonious-Interpersonal (α = .876)					
4	我常透過智慧型手機與他人互動，以激發不同的想法。 I often interact with others using my smartphone for inspiration.		.66		
8	我常在智慧型手機的介面協助他人解決問題，因為它使我有成就感。 I often help others solve problems through the interfaces of my smartphone because it gives me feelings of achievement.		.70		
12	我常透過智慧型手機，主動與他人分享自己的知識或觀點。 I often actively share my knowledge or viewpoints using my smartphone.		.73		
15	我常透過智慧型手機介面與他人進行互動與討論，以使學習更有效率。 In order to enhance my learning efficiency, I often use my smartphone to interact and discuss with others.		.78		
	Obsessive (α = .859)				
Factor 3: 強迫-內省 Obsessive-Intrapersonal (α = .903)					
2	我每天早上起床後一定要使用智慧型手機，否則我會覺得全身不對勁。 I will feel uncomfortable if I don't use my smartphone after I get up in the morning.			.75	
6	如果一天沒有使用智慧型手機，我就會覺得生命變得無趣。 I will feel bored if I don't use my smartphone for just one day.			.86	
10	不管我有多忙多累，我每天一定要使用智慧型手機，否則我會覺得虛度當日。 I have to use my smartphone every day, no matter how busy and tired I am, or I will feel that I have wasted my day.			.81	
14	我通常不能控制自己使用智慧型手機的衝動。 I often cannot control the impulse to use my smartphone.			.60	
Factor 4: 強迫-人際 Obsessive-Interpersonal (α = .701)					
3	我會在智慧型手機與他人進行互動與討論，通常是為了要繳交作業。 When I use my smartphone to have discussions and interact with others, it's often because I have to complete assignments.				.35
7	為了避免學習表現比別人差，我常使用智慧型手機與他人互動與討論。				.79

	In order not to have worse performance than others, I often interact and have discussions with others using my smartphone.	
11	周遭朋友經常使用智慧型手機進行學習，迫使我也必須常使用這樣的學習方式。 My friends often use smartphones for learning, which inspires me to learn in the same way.	.62

3.2. Reliability analysis

The Cronbach's α values of the IPSP and the four factors were .935, .910 (H-Intra), .876 (H-Inter), .903 (O-Intra), and .701 (O-Inter) (Table 3). Moreover, the item-total correlation coefficients ranged from .490 to .824 (Table 4).

Table 4. The reliability analysis of the IPSP

		Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
1	我常使用智慧型手機進行學習，因為它能讓我掌握最新的資訊。 I often use my smartphone for learning because it helps me stay up-to-date on the latest news.	.665	.635	.928
5	我常使用智慧型手機進行學習，因為它能提供符合我個人能力和需求的學習。 I often use my smartphone for learning because it provides learning resources that meet my needs and ability.	.824	.780	.924
9	我常使用智慧型手機進行學習，因為它很有趣。 I often use my smartphone for learning because learning is interesting.	.744	.653	.926
13	我常使用智慧型手機進行學習，因為它讓我能自由選擇與決定學習的內容。 I often use my smartphone for learning because it allows me to make free choices and decisions about what I want to learn.	.780	.764	.925
2	我每天早上起床後一定要使用智慧型手機，否則我會覺得全身不對勁。 I will feel uncomfortable if I don't use my smartphone after I get up in the morning.	.666	.718	.928
6	如果一天沒有使用智慧型手機，我就會覺得生命變得無趣。 I will feel bored if I don't use my smartphone for just one day.	.652	.779	.929
10	不管我有多忙多累，我每天一定要使用智慧型手機，否則我會覺得虛度當日。 I have to use my smartphone every day, no matter how busy and tired I am, or I will feel that I have wasted my day.	.638	.783	.929
14	我通常不能控制自己使用智慧型手機的衝動。 I often cannot control the impulse to use my smartphone.	.636	.611	.929
3	我會在智慧型手機與他人進行互動與討論，通常是為了要繳交作業。 When I use my smartphone to have discussions and interact with	.490	.335	.932

	others, it's often because I have to complete assignments.			
11	周遭朋友經常使用智慧型手機進行學習，迫使我也必須常使用這樣的學習方式。 My friends often use smartphones for learning, which inspires me to learn in the same way.	.528	.465	.932
7	為了避免學習表現比別人差，我常使用智慧型手機與他人互動與討論。 In order not to have worse performance than others, I often interact and have discussions with others using my smartphone.	.729	.636	.927
4	我常透過智慧型手機與他人互動，以激發不同的想法。 I often interact with others using my smartphone for inspiration.	.735	.734	.926
8	我常在智慧型手機的介面協助他人解決問題，因為它使我有成就感。 I often help others solve problems through the interfaces of my smartphone because it gives me feelings of achievement.	.738	.641	.926
12	我常透過智慧型手機，主動與他人分享自己的知識或觀點。 I often actively share my knowledge or viewpoints using my smartphone.	.628	.620	.929
15	我常透過智慧型手機介面與他人進行互動與討論，以使學習更有效率。 In order to enhance my learning efficiency, I often use my smartphone to interact and discuss with others.	.662	.643	.928

研究 1-3、創造力心向量表之發展

Study 1-3: Development of the Creativity Mindset Inventory (CMI)

1. The present study

This study aimed at developing an inventory to measure how college students perceive their own creative mindset.

2. Method

2.1. Participants

All participants, aged from 20 to 30 years old, were recruited through an online ad posted on a campus website. Participants in the inventory development stage were 137 college students (32 males and 105 females; M_{age} = 21.19; SD_{age} = 1.593); they were rewarded with approximately USD 3.

2.2. Instrument

Through a lot of discussions with our research team, we developed the CMI, which was further used in the path model analysis. The CMI originally included 16 test items with 4 items in each of the following dimensions: Growth-Internal control (GI), Growth-External control (GE), Fixed-Internal control (FI), and Fixed-External control (FE). After reliability and validity analysis, one test item in each of the categories was deleted. Finally, with 12 test items, the CMI has good reliability and validity. More details are shown in the results session.

2.3. Procedures

Data were collected through a website designed by the researchers with no time limit. This study was approved by the Institutional Review Board of National Chengchi University, Taiwan and written informed consent was obtained from all participants.

3. Results

3.1. CFA results

In this study, we developed the two-dimensional CMI. Because we had a theoretical structure of the types of CM, we used CFA instead of EFA to verify the validity of CMI. After repetitive examination of CFA and internal-consistency reliability, the CMI includes four types of CM: GI (3 items), GE (3 items), FI (3 items), and FE (3 items) (see Table 5 for test items). Using maximum likelihood estimation, the reliability and validity of the four-factor model were examined. CFA results indicated that the model had good construct validity and reliability: χ^2 (N = 137, df = 44) = 96.646, p < .001; the goodness-of-fit index (GFI) = .899, the adjusted goodness-of-fit index (AGFI) = .821, the root mean square residual (RMR) = .055, and the root mean square error of approximation (RMSEA) = .094. In terms of relative fit measures, the normed fit index (NFI) = .907, the incremental fit index (IFI) = .947, and the comparative fit index (CFI) = .946.

The composite reliability (ρ_c) for GI, GE, FI, and FE were .773, .655, .834, and .827, respectively. The average variance extracted (ρ_v) values four of the four factors were .534, .397, .630, and .619, respectively. These results suggested that CMI has good reliability and validity. CFA results also revealed that GI and GE were moderately and positively correlated. Moreover, while GI was highly and negatively related to FI and FE, GE was moderately and negatively related to FI and FE. On the other hand, FI and FE were very strongly correlated (see Fig. 3).

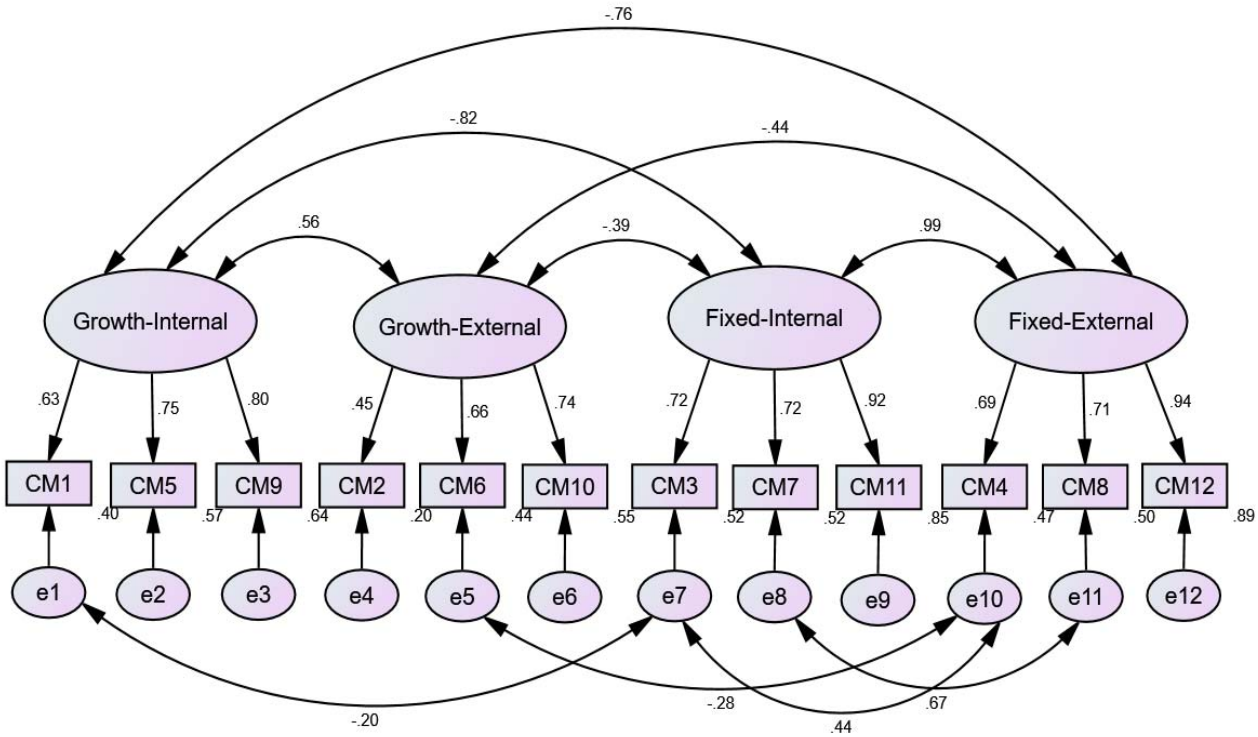


Figure 3. CFA model of college students' mindset

Table 5. The test items, Cronbach's α, and CFA Factor Loadings of CMI

No	Test item	CFA factor Loading			
		1	2	3	4
	Growth Mindset (α = .747)				
Factor 1: Growth-Internal locus of control (GI) (α = .783)					
1	It's never too late to learn creativity, and creativity can be enhanced through self-learning. 我的創造力是可以透過自學而改變的，而且什麼時候開始學習都不會太晚。	.63			
5	I can improve my creative ability through self-learning. 我的創造力是可以靠自己平常自學就會進步的。	.75			
9	I can be more creative as long as I am willing to learn. 只要我有意願學習，就可以讓自己變得更有創造力。	.80			
Factor 2: Growth-External locus of control (GE) (α = .638)					
2	My creativity can be improved, but it needs the help of good teachers.我的創造力是會進步的，但是需要有好老師協助。		.45		
6	I am willing to learn creativity and I can become more creative, but a good learning environment is required. 我有意願學習創造力，而且我可以變得更有創造力，但是要有好的學習環境才能達成。		.66		
10	My creativity can be substantially improved, but it can only be achieved when I have sufficient learning opportunities。我的創造力可以有很大進步，但是要有足夠的學習機會才能達成。		.74		
	Fixed mindset (α = .918)				
Factor 3: Fixed-Internal locus of control (FI) (α = .831)					
3	It is hard to improve my creativity even if I work hard to improve it through self-learning. 我的創造力是很難進步的，自己平常自學也沒有用。			.72	
7	Even if I am willing to learn creativity, it is hard for me to become more creative. 就算我自己有意願學習，也很難讓自己變得更有創造力。			.73	
11	Even if I work hard by myself, my creativity won't be substantially improved. 就算我非常努力的自學，我的創造力也不會有很大的進步。			.92	
Factor 4: Fixed-External locus of control (FE) (α = .829)					
4	It is hard to improve my creativity even if I have good luck and meet good teachers. 我的創造力是很難進步的，就算運氣好，遇到好老師也沒有用。				.69
8	Even if there is someone to tutor me, it's hard for me to become more creative. 就算有人教導我，也很難讓我變得更有創造力。				.71
12	Even if I have sufficient learning opportunities, my creativity won't be substantially improved. 就算我有很好的學習機會，我的創造力也不會有很大的進步。				.94

3.2. Reliability analysis

Regarding the reliability of Growth CM (GI and GE). The Cronbach's α for the Growth CM, GI, and GE were .747, .783, and .638, respectively. Regarding the reliability of Fixed CM (FI and FE), the item-total correlation ranged from .707 to .812. The Cronbach's α for the Fixed CM (FI and FE) were .914, .830, and.854, respectively. The correlations among Growth CM, Fixed CM, and the four types of CM were -.714 to .975 (*p*s < .01). The results were very similar to the CFA results. In other words, the GI and GE were slightly correlated,

but GI was negatively related to FI or FE; GE was slightly negatively related to FI and FE, and FI and FE were strongly correlated. Moreover, the GM was negatively related to the FM, r = -.620, p < .001 (see Table 6).

Table 6. The correlations among the GM, FM, and the four types of CM

Variable	GM	GI	GE	FM	FI	FE
GM	1.00					
GI	.870***	1.00				
GE	.790***	.384***	1.00			
FM	-.620***	-.698***	-.291**	1.00		
FI	-.604***	-.714***	-.243**	.973***	1.00	
FE	-.604***	-.648***	-.323***	.975***	.899***	1.00

Note. ** p < .01 ***p < .001

研究 1-4、智慧型手機正念學習量表之發展

Study 1-4: Development of Mindful Learning towards Smart Phones

1. The present study

This study aimed at developing the Inventory of Mindful Learning towards Smart Phones (MLSP) to measure college students' mindful learning towards using mobile phones.

2. Method

2.1. Participants

Participants were recruited through an online ad posted on a campus website. One hundred and ninety-nine college students (64 males, 131 females and 4 Others; M_{age} = 22.77; SD_{age} = 2.388) from Australia were included in the stage of reliability analysis and confirmatory factor analysis. Written informed consent was obtained from all participants they were rewarded with approximately $10 AUD.

2.2. Instrument

The Inventory of Mindful Learning towards Smart Phones (MLSP) was developed to measure college students' mindful learning towards using mobile phones. The MLSP used a 6-point Likert-type scale with 1 point to 6 points, representing strongly disagree to strongly agree. The original version has 20 items; after two stages of the construction process, 6 items were eliminated. The final version of MLSP has 14 items and includes 3 dimensions: Attention (ATT, 5 items), Open-Minded (OPM, 5 items), and Emotion (EM, 4 items) (see Table7). The inventory was administered online without time constraints.

2.3. Procedures

Data were collected through Goggle Sites designed by the researchers. All participants completed the PTSP online. Then, we conducted internal-consistency reliability, exploratory factor analysis (EFA) through SPSS 21, and confirmatory factor analysis (CFA) through AMOS 21 to examine the reliability and validity of the MLSP.

3. Results

3.1. Exploratory factor analysis and reliability analysis

Principal Component Analysis and direct oblimin were employed in factor extraction and rotation when conducting exploratory factor analysis. The results yielded three factors: Attention and awareness (ATT, 5 items), Open-Mindedness and rational thinking (OPM, 5 items), and Emotion regulation (EM, 4 items). With factor loadings ranging from .617 to .790, 60.036% of the total variance was explained by the three factors (see Table 7). The correlations between each of the factors and the total score were .826, .864, and .833 (*p*s < .001), respectively. Moreover, the item-total correlation coefficients ranged from .478 to .673 (see Table 8).

Table 7. The test items, Cronbach's α, and EFA factor loadings of the MLSP

No.	Test Items	EFA factor loading		
		1	2	3
	Factor 1: 注意和自覺 Attention and awareness (Cronbach's α = .796)			
2	使用手機時，我清楚了解使用目的，不會無意識的滑手機。 When I use my smartphone, I am aware of my purpose for using it instead of using it unconsciously.	.761		
1	使用手機時，我可以專注於當下應處理事項。 When I use my smartphone, I can focus on problems that I have to take care of in the moment.	.694		
9	使用手機時，我可以長時間專注在一件事情上而不分心。 When I use my smartphone, I can concentrate on one thing for a long time without becoming distracted.	.693		
10	使用手機時，我能掌控可使用時間，不會因此耽誤其他事情。 I can control the amount of time I spend using my smartphone so that I won't put off important things.	.682		
8	使用手機讓我有活在當下的真實感。 When I use my smartphone, I feel the reality of living in the moment.	.617		
	Factor 2: 心胸開放與理性思考 Open-mindedness and rational thinking(Cronbach's α = .833)			
18	對於手機流傳的訊息，我能保持理性思考，不會人云亦云。 When I receive information that is being passed around, I can stay rational and maintain independent thinking.		.732	
6	使用手機時，我可以掌握自己的想法和感受的脈絡。 When I use my smartphone, I can control my thoughts and feelings.		.728	
16	我常使用手機的不同功能來體驗新事物。 I often use my smartphone to experience new things through its varied functions.		.676	
4	使用手機讓我心胸開放，接納當下的體驗。 When I use my smartphone, I can stay open-minded to accept the experience of the moment.		.657	
12	我常使用手機探索新奇事物。 I often use my smartphone to explore new things.		.645	
	Factor 3: 情緒調節 Emotion regulation (Cronbach's α = .767)			
7	使用手機可以降低我的孤獨感。 When I use my smartphone, I feel less lonely.			.790
19	使用手機讓我擁有更多正向的情緒感受。 Using my smartphone brings me more positive emotions.			.702

13	使用手機時，我更容易將自己的信念與想法化為文字。 It is easier for me to transcribe my beliefs and ideas using my smartphone.	.626
15	當我感到心情沮喪時，使用手機可以讓我心情變好。 When I feel depressed, using my smartphone can help me become happier.	.617
	解釋總變異量	60.036 %

Table 8. The reliability analysis of the MLSP

No.	Test Items	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
2	使用手機時，我清楚了解使用目的，不會無意識的滑手機。 When I use my smartphone, I am aware of my purpose for using it instead of using it unconsciously.	.493	.362	.885
1	使用手機時，我可以專注於當下應處理事項。 When I use my smartphone, I can focus on problems that I have to take care of in the moment.	.482	.410	.885
9	使用手機時，我可以長時間專注在一件事情上而不分心。 When I use my smartphone, I can concentrate on one thing for a long time without becoming distracted.	.655	.528	.877
10	使用手機時，我能掌控可使用時間，不會因此耽誤其他事情。 I can control the amount of time I spend using my smartphone so that I won't put off important things.	.601	.382	.879
8	使用手機讓我有活在當下的真實感。 When I use my smartphone, I feel the reality of living in the moment.	.548	.470	.882
18	對於手機流傳的訊息，我能保持理性思考，不會人云亦云。 When I receive information that is being passed around, I can stay rational and maintain independent thinking.	.586	.559	.880
6	使用手機時，我可以掌握自己的想法和感受的脈絡。 When I use my smartphone, I can control my thoughts and feelings.	.586	.434	.880
16	我常使用手機的不同功能來體驗新事物。 I often use my smartphone to experience new things through its varied functions.	.505	.641	.884
4	使用手機讓我心胸開放，接納當下的體驗。 When I use my smartphone, I can stay open-minded to accept the experience of the moment.	.478	.509	.885
12	我常使用手機探索新奇事物。 I often use my smartphone to explore new things.	.557	.388	.881
7	使用手機可以降低我的孤獨感。 When I use my smartphone, I feel less lonely.	.585	.468	.880
19	使用手機讓我擁有更多正向的情緒感受。 Using my smartphone brings me more positive emotions.	.673	.479	.876
13	使用手機時，我更容易將自己的信念與想法化為文字。 It is easier for me to transcribe my beliefs and ideas using my smartphone.	.615	.415	.879

15	當我感到心情沮喪時，使用手機可以讓我心情變好。 When I feel depressed, using my smartphone can help me become happier.	.589	.480	.880

3.2. Confirmatory factor analysis

A confirmatory factor analysis (CFA) using maximum likelihood estimation was conducted to examine the reliability and validity of the three-factor model (see Figure 4). The CFA results indicated that the MLSP has good construct validity and reliability: χ^2 (N = 199, df = 72) = 132.036 (p = .000), the goodness-of-fit index (GFI) = .916, the adjusted goodness-of-fit index (AGFI) = .877, the root mean square residual (RMR) = .080, and the root mean square error of approximation (RMSEA) = .065. In terms of relative fit measures, the normed fit index (NFI) = .884, the relative fit index (RFI) = .853, the incremental fit index (IFI) = .944, and the comparative fit index (CFI) = .943. Moreover, values of the composite reliability (ρ_c) of ATT, OPM, and EM were .790, .836, and .773, respectively. The average variance extracted (ρ_v) values of the three factors were .431 .507, and .460, respectively (see Table 9).

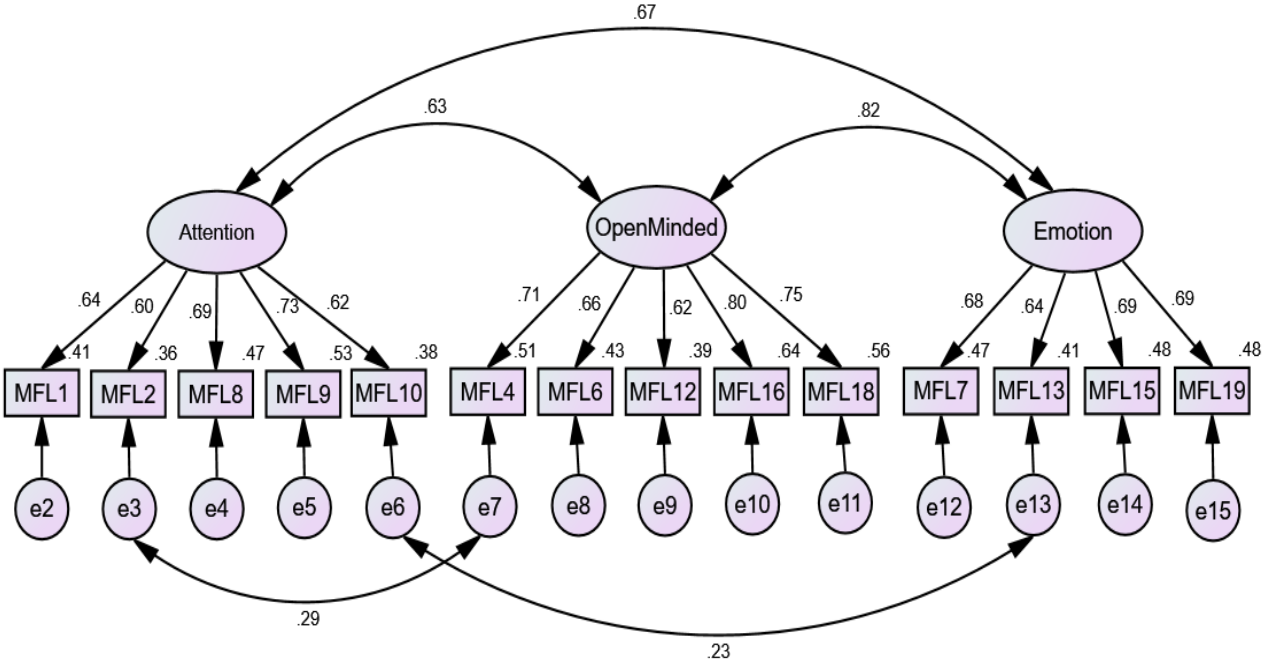


Figure 4. CFA model of the MLSP

Table 9. MLSP驗證性因素分析模式之參數估計、完全標準化參數估計、及顯著性考驗摘要表

Item	因素負荷量（λ）	*SE*	*t*	R^2	組合信度(ρ_c)	平均變異解釋量(ρ_v)
Attention						
1	.640			.410		
2	.602	.124	6.945	.362	.790	.431
8	.686	.138	7.603	.470		
9	.727	.150	7.905	.528		
10	.618	.132	7.068	.382		
Open-minded					.836	.507

4	.714			.509		
6	.659	.117	8.589	.434		
12	.623	.115	8.132	.388		
16	.801	.113	10.304	.641		
18	.748	.117	9.692	.559		
Emotion						
7	.684	.124	7.803	.468		
13	.644	.121	8.254	.415	.773	.460
15	.692	.112	8.252	.480		
19	.692	.124	7.803	.479		

研究 1-5、智慧型手機可能性思考量表之發展

Study 1-5: Development of Inventory of Possibility Thinking towards Smart Phones

1. The present study

This study aimed at developing the Inventory of Possibility Thinking towards Smart Phones (PTSP) to measure college students' possibility thinking (PT) towards using mobile phones.

2. Method

2.1. Participants

Participants were recruited through an online ad posted on a campus website. One hundred and ninety-nine college students (64 males, 131 females and 4 Others; M_{age} = 22.77; SD_{age} = 2.388) from Australia were included in the stage of reliability analysis and confirmatory factor analysis. Written informed consent was obtained from all participants they were rewarded with approximately AUD 10.

2.2. Instrument

The Inventory of Possibility Thinking towards Smart Phones (PTSP) was developed to measure college students' possibility of thinking towards using mobile phones. The PTSP used a 6-point Likert-type scale with 1 point to 6 points, representing never to always. The original version has 21 items; after two stages of the construction process, 6 items were eliminated. The final version of PTSP has 15 items and includes 3 dimensions: Creative Problem-Solving 創意問題解決 (CPS, 7 items), Flow Experience and Challenge 福樂經驗與挑戰 (FEC, 5 items), and Interpersonal relationship 他人互動交流) (ITP, 3 items) (see Table 10 and Figure 5). The inventory was administered online without time constraints.

2.3. Procedures

Data were collected through Goggle Sites designed by the researchers. All participants completed the PTSP online. Then, we conducted internal-consistency reliability, exploratory factor analysis (EFA) through SPSS 21, and confirmatory factor analysis (CFA) through AMOS 21 to examine the reliability and validity of the MLSP.

3. Results

3.1. Exploratory factor analysis and reliability analysis

Principal Component Analysis and direct oblimin were employed in factor extraction and rotation when

conducting exploratory factor analysis. The results yielded three factors: 創意啟發與分享(Creativity inspiring and sharing) (7 items)、生活與心靈支持(Life and spiritual support) (5 items)、互動與問題解決(Interaction and problem solving) (3 items),. With factor loadings ranging from .541 to .825, 60.40% of the total variance was explained by the three factors. The correlations between each of the factors and the total score were .924, .800, and .743 (*p*s < .001), respectively. The Cronbach's α values of the PTSP and the three factors were .900, .875, .822, .692 (see Table 10). Moreover, the item-total correlation coefficients ranged from .419 to .663 (see Table 11).

Table 10. The test items, Cronbach's α, and CFA factor loadings of the PTSP

No	Test Items	CFA factor loading		
		1	2	3
	Factor 1: 創意啟發與分享 Creativity inspiring and sharing (Cronbach's α = .875)			
15	使用智慧手機增進了我的想像力。 Using a smartphone can enhance my imagination.	.796		
13	使用智慧手機有助於我建構自己的想法。 I develop my ideas by using my smartphone.	.769		
8	使用智慧手機時，我的創意靈感較易被激發。 My creative ideas are more possible to be inspired when I use my smartphone.	.751		
21	使用智慧手機讓我更勇於嘗試生活中的新經驗（例如：去陌生地方自助旅行）。 Using smartphones encourages me to try new life experiences (e.g.travel alone in an unfamiliar place).	.610		
14	我使用智慧手機表達自己對一些議題的看法。 I express my ideas toward some issues by using my smartphone.	.600		
3	我使用智慧手機表達我的創新想法。 I express my creative ideas through my smartphone.	.582		
4	我使用智慧手機來幫助我做決定。 I use the smartphone to help me make decisions in my daily life.	.541		
	Factor 2: 生活與心靈支持 Life and spiritual support (Cronbach's α = .822)			
19	我勇於嘗試智慧手機中的新事物(例如:新的 App 或新的功能)。 I am brave to try new things on the smarphone (e.g., try new Apps or new functions).		.797	
10	智慧手機的多元功能給我生活上很大的支持。 The multi-function of the smartphone provides me a lot of supports in my daily life.		.782	
17	我使用智慧手機與他人進行合作或交流。 I do collaboration or communication with other people by using my smartphone.		.733	
12	當我使用智慧手機時，我易於沉浸其中並覺得時光飛逝。 I am prone to feel emerged and feel that time flies when I use my smartphone.		.705	
2	當我使用智慧手機時，我覺得有趣且愉快。 I have fun and feel pleasant when I use my smartphone.		.570	
	Factor 3: 互動與問題解決 Interaction and problem-solving (Cronbach's α = .692)			
1	當我碰到問題時，常使用智慧手機向他人請教。 I ask for help through my smartphone when I suffer problems.			.825
6	我使用智慧手機主動拋出議題供他人討論。 I actively post issues for the discussions by using my smartphone.			.651
11	我使用智慧手機去回答他人拋出的問題。 I answer the questions posted by others through my smartphone.			.614

Table 11. The reliability analysis of the PTSP

No.	Test Items	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
15	使用智慧手機增進了我的想像力。 Using a smartphone can enhance my imagination.	.658	.584	.891
13	使用智慧手機有助於我建構自己的想法。 I develop my ideas by using my smartphone.	.633	.529	.892
8	使用智慧手機時，我的創意靈感較易被激發。 My creative ideas are more possible to be inspired when I use my smartphone.	.652	.554	.891
21	使用智慧手機讓我更勇於嘗試生活中的新經驗(例如:去陌生地方自助旅行)。 Using smartphones encourage me to try new life experiences (e.g.travel alone in an unfamiliar place).	.646	.491	.891
14	我使用智慧手機表達自己對一些議題的看法。 I express my ideas toward some issues by using my smartphone.	.663	.457	.891
3	我使用智慧手機表達我的創新想法。 I express my creative ideas through my smartphone.	.608	.454	.893
4	我使用智慧手機來幫助我做決定。 I use the smartphone to help me make decisions in my daily life.	.616	.436	.892
19	我勇於嘗試智慧手機中的新事物(例如:新的 App 或新的功能)。 I am brave to try new things on smartphones (e.g., try new Apps or new functions).	.523	.523	.896
10	智慧手機的多元功能給我生活上很大的支持。 The multi-function of the smartphone provides me a lot of supports in my daily life.	.564	.597	.894
17	我使用智慧手機與他人進行合作或交流。 I do collaboration or communication with other people by using my smartphone.	.525	.472	.896
12	當我使用智慧手機時，我易於沉浸其中並覺得時光飛逝。 I am prone to feel emerged and feel that time flies when I use my smartphone.	.566	.486	.894
2	當我使用智慧手機時，我覺得有趣且愉快。 I have fun and feel pleasant when I use my smartphone.	.539	.354	.895
1	當我碰到問題時，常使用智慧手機向他人請教。 I ask for help through my smartphone when I suffer problems.	.419	.235	.900
6	我使用智慧手機主動拋出議題供他人討論。 I actively post issues for the discussions by using my smartphone.	.523	.549	.896
11	我使用智慧手機去回答他人拋出的問題。 I answer the questions posted by others through my smartphone.	.573	.521	.894

3.2. Confirmatory factor analysis

A confirmatory factor analysis (CFA) using maximum likelihood estimation was conducted to examine the reliability and validity of the three-factor model (see Figure 5). The CFA results indicated that the PTSP has good construct validity and reliability: χ^2 (N = 199, df = 84) = 125.078 (p = .000), the goodness-of-fit index (GFI) = .923, the adjusted goodness-of-fit index (AGFI) = .890, the root mean square residual (RMR) = .068, and the root mean square error of approximation (RMSEA) = .050. In terms of relative fit measures, the normed fit index (NFI) = .904, the relative fit index (RFI) = .881, the incremental fit index (IFI) = .966, and the comparative fit index (CFI) = .966. Moreover, values of the composite reliability (ρ_c) of CPS, FEC, and ITP were .875, .822, and .691, respectively. The average variance extracted (ρ_v) values of the three factors were .501 .486, and .435, respectively (see Table 12).

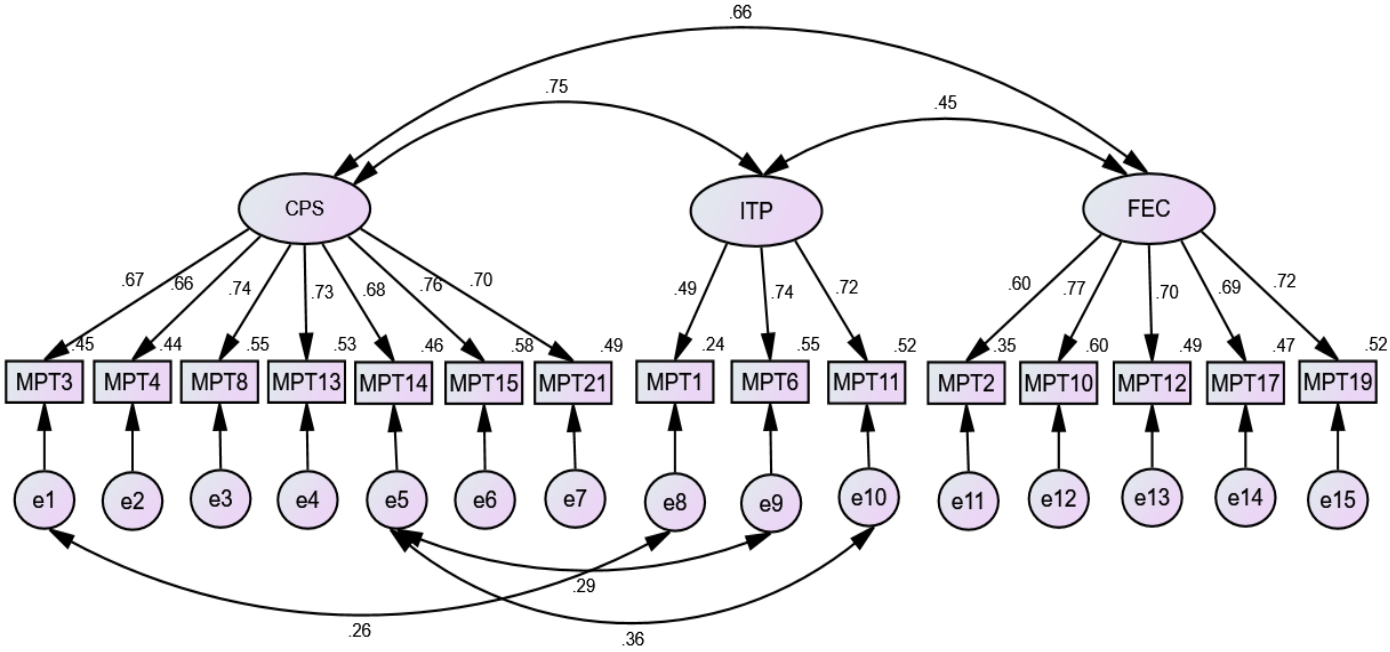


Figure 5. CFA model of the PTSP

Table 12. PTSP驗證性因素分析模式之參數估計、完全標準化參數估計、及顯著性考驗摘要表

Item	因素負荷量（λ）	SE	t	R^2	組合信度(ρ_c)	平均變異解釋量(ρ_v)
Creativity inspiring and sharing					.875	.501
3	.674			.454		
4	.660	.117	8.323	.436		
8	.744	.117	9.245	.554		
13	.728	.124	9.066	.529		
14	.676	.123	8.578	.457		
15	.764	.127	9.454	.584		
21	.701	.121	8.775	.491		
Life and spiritual support					.825	.486
2	.595			.354		
10	.773	.181	7.931	.597		
12	.697	.175	7.450	.486		
17	.687	.177	7.380	.472		
19	.723	.172	7.627	.523		

Interaction and problem solving					.691	.435
1	.485			.235		
6	.741	.281	5.860	.549		
11	.722	.263	5.822	.521		

Conclusion of Study 1

This study pioneers at developing AMD-CL, IPSP, and CMI. The results suggest that AMD-CL, IPSP, and CMI have good reliability and validity. AMD-CL measures college students' attitudes toward using mobile devices for creativity learning. The Cronbach's α coefficient for the AMD-CL was .917, and the confirmatory factor analysis showed that the three-factor structure was a good-fit model (Goodness-fit-index = .921). IPSP measures college students' passion towards using mobile phones. The Cronbach's α coefficient for the IPSP was .922, and the confirmatory factor analysis showed that the four-factor structure was a good-fit model (Goodness-fit-index = .935). CMI measures how college students perceive their own creative mindset. The Cronbach's α coefficient for GM and FM were .747 and .914, and the confirmatory factor analysis showed that the four-factor structure was a good-fit model (Goodness-fit-index = .899).

In addition, this study pioneers at developing PTSP and MLSP. MLSP measures college students' mindful learning (MFL) towards using mobile phones. The Cronbach's α coefficient for the MLSP was .889, and the confirmatory factor analysis showed that the three-factor structure was a good-fit model (Goodness-fit-index = .916). IPSP measures college students' possibility thinking (PT) towards using mobile phones. The Cronbach's α coefficient for the IPSP was .900, and the confirmatory factor analysis showed that the four-factor structure was a good-fit model (Goodness-fit-index = .923). The results suggest that both PTSP and MLSP have good reliability and validity.

研究二、科技導向正念介入之效果

Study 2: The effects of technological-based mindful learning interventions on creativity

1. The present study

This study aimed at developing different types of technology-oriented mindful learning interventions that can be practiced in daily life.

2. Hypotheses of this study

The following hypotheses were proposed.

- Hypothesis 1: Smartphone-based mindfulness interventions in everyday life would enhance college students' creativity.
- Hypothesis 2: Varied types of smartphone-based mindfulness interventions would have different effects on the improvement of college students' creativity.
- Hypothesis 3: Smartphone-based mindfulness interventions would have positive effects on college students' improvement in creativity self-efficacy, and such effects would be moderated by AMD-CL.

3. Method

3.1. Participants

The participants were 149 college students. They were randomly distributed into four groups with gender consideration. The control group (G1), who only took the pretest and the posttest, were rewarded with approximately USD 7, whereas the experimental groups (G2, G3, and G4), who took the pretest, intervention, and the posttest, were rewarded with approximately USD 35.

3.2. Instruments

3.2.1. Attitude toward Mobile Devices for Creativity Learning

The instrument AMD-CL, with 13 items, was developed to measure college students' attitudes toward mobile devices for creativity learning. AMD-CL is a 6-point Likert-type scale from 1 point to 6 points, representing strongly disagree to strongly agree.

3.2.2. Inventory of Self-Efficacy in Creativity

The Inventory of Creativity Self-Efficacy (ICSE)was employed to measure the participants' level of creativity self-efficacy. The ICSE is a 6-point Likert-type scale from 1 point to 6 points, representing strongly disagree to strongly agree. With a total of 9 items, the ICSE includes two factors: Ability to generate creative ideas (6 items) and Achievement of creative performance (3 items). Exploratory factor analysis revealed that the total variance explained by the two factors was 73.27%. The Cronbach's α coefficients of the ICSE and the two factors were .927, .908, and .844, With factor loadings of .606 to .879, 73.27% of the total variance was explained by the two factors.

3.2.3. Creativity

In this study, we requested the participants in the experimental groups to upload the photos they took to a designated website. For each photo, we requested the participant to write an imaginative narrative. Examples were shown as Figure 6. The imagination score, ranging from 0 points to 5 points, was rated by two trained coauthors based on their consensus.

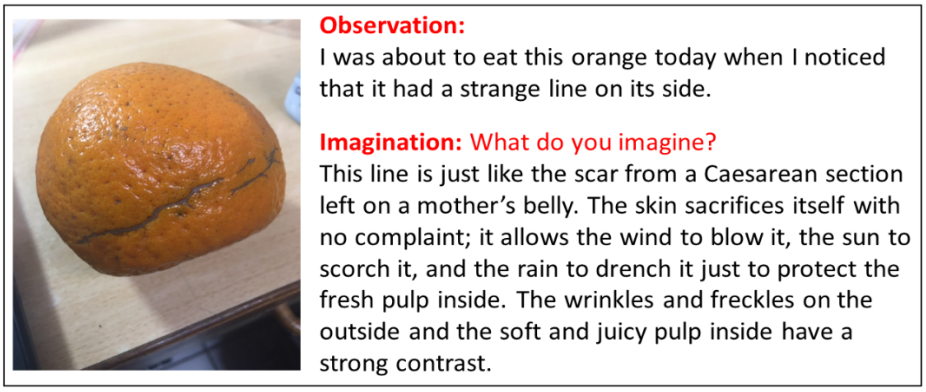


Figure 6. An example of uploading photo

3.3. Procedures and interventions for the experiment

Our central idea was that, for the smartphone-based mindfulness intervention, which emphasized mindfulness, self-determination, and knowledge sharing online would enhance mindfulness and imagination toward surrounding things in everyday life, which would further foster creativity and creativity self-efficacy. Meanwhile, AMD-CL would interact with the interventions and influence the learning process.

To further understand the influence of the intervention components, this study employed a pretest-posttest control group design that included four groups. During the one-week experimental period, the control group,

Group 1, did not receive any intervention, whereas the experimental groups, Groups 2, 3, and 4, were requested to use their smartphones to take photos with different emphases for four days and to share the photos with imaginative narratives on a designated website. Group 2 had emphases on complete free choices of photo-taking only, Group 3 had emphases on complete free choices of photo-taking and idea-sharing, and Group 4 had emphases on free choices of photo-taking in varied categories and idea-sharing.

4. Results

4.1. Group differences on the enhancement of creativity To understand the learning progress of the three experimental groups, we scored each participant's creativity based on the imaginative narratives they had uploaded. Each participant had uploaded 8 photos with imaginative narratives. A Repeated Measures Analysis of Variance, with Group (G1, G2, G3, and G4) as the between variable and Day (Day 1 [D1] vs. Day 2 [D2] vs. Day 3 [D3] vs. Day 4 [D4] creativity score) as the within variable, was employed to examine group differences in creativity improvement. The results revealed a significant main effect of Day, $F(3, 103) = 26.306$, $p < .001$, $\eta^2_p = .202$; participants' creative performance on D3 and D4 was better than that on D1 and D2, and the performance on D2 was better than that on D1. In addition, there was a significant Day × Group interaction on creativity, $F(3, 103) = 5.425$, $p < .001$, $\eta^2_p = .094$. Results of the simple main effect were as follows: No group differences were found on D1; on D2, G4 outperformed G2 and G3; on D3 and D4, G3 outperformed the other groups. Within each group, G2 and G3 performed better on D3 and D4 than on D1 and D2, and G4 performed better on D2–4 than on D1 (see Table 13 and Figure 7).

Table 13. Group differences on the enhancement of creativity

	ANOVA				
Source	*MS*	*F* (3, 103)	*p*	η^2_p	Post hoc test
Day	11.807	26.306***	.000	.202	D3 & D4 >D1 & D2; D2 > D1
Day × Group	2.435	5.425***	.000	.094	D2: G4 > G2, G4 > G3
					D3: G3 > G4; D4: G3 > G4
					G2: D3 & D4 > D1 & D2
					G3: D3 & D4 > D1 & D2
					G4: D2, D3 & D4 > D1
Group	2.237	2.244	.111	.041	*ns.*

Note. D1 = Day 1; D2 = Day 2; D3 = Day 3; D4 = Day 4. G1 = Group 1; G2 = Group 2; G3 = Group 3; G4 = Group 4.

*** $p < .001$.

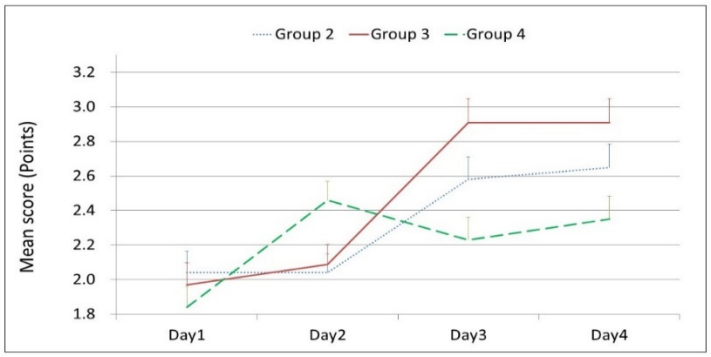


*Figure 7. M*s and *SD*s of the creativity score for the three experimental groups

4.2. Effects of BMD-CL and intervention groups on creative self-efficacy

With Group A (intervention groups: G1, G2, G3, and G4) and Group B (Low and High BMD-CL) as the between variable, the pretest score of creative self-efficacy as the covariance, and the posttest score of creative self-efficacy as the dependent variable, we conducted a two-way Analysis of Covariance to examine whether beliefs toward mobile devices would influence the improvement in creative self-efficacy. The cut-points of the BMD-CL groups were the median. The results revealed a significant Group A main effect, $F(3, 129) = 2.671$, $p = .050$, $\eta^2_p = .058$, as well as a significant Group B main effect, $F(3, 129) = 6.108$, $p = .015$, $\eta^2_p = .045$. However, the Group A × Group B interaction effect was not significant. Post hoc test revealed that the experimental groups (G2, G3, and G4) had better improvement in creative self-efficacy than the control group (G1). Moreover, those who had a higher level of BMD-CL improved more in creative self-efficacy than their counterparts (see Table 14 and Figure 8).

Table 14. Effects of Intervention × BMD-CL intervention on the enhancement of creative self-efficacy

	Analysis of Covariance				
Source	*MS*	*F*(3, 129)	*p*	η^2_p	Post hoc test
Corrected Model	10.284	33.946***	.000	.678	
Intercept	4.360	14.393***	.000	.100	
Pretest of ICSE	66.145	218.339***	.000	.629	
Group A	.809	2.671*	.050	.058	G2, G3, G4 > G1
Group B	1.850	6.108*	.015	.045	High > Low
Group A × Group B	.144	.476	.700	.011	

Note. Group A: Intervention group; Group B: BMD-CL group.
*$p < .05$. ***$p < .001$.

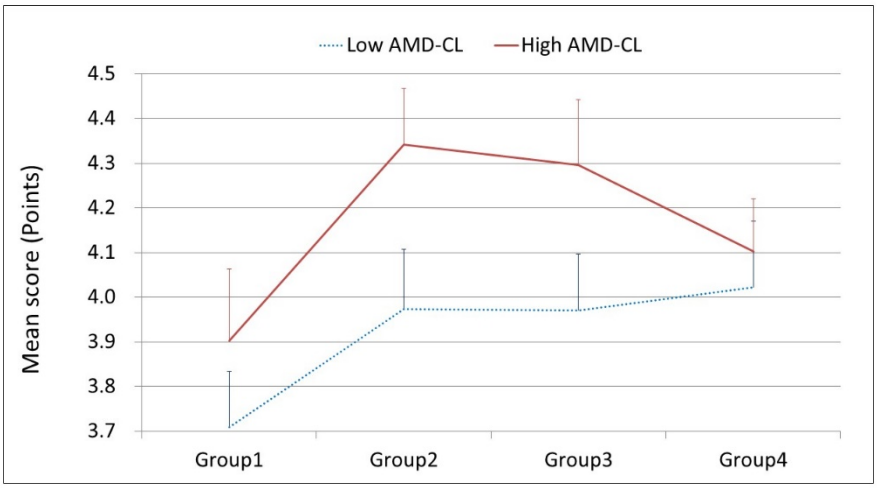


*Figure 8. M*s and *SE*s of the ICSE score for BMD-CL groups in the intervention groups

5. Discussion and conclusions

Smartphones have become the most popular device for learning as well as for capturing moments in life among college students. While most college students frequently take photos with smartphones, few students mindfully learn from the photos they take. This study pioneers the integration of smartphone use, mindfulness, knowledge sharing, self-determination, and everyday creativity to design varied types of interventions to enhance college students' ability and self-efficacy of creativity. Meanwhile, college students' attitude toward using mobile devices to improve creativity was also considered.

The major contributions of this study are as follows. First, a creativity learning and instructional approach

with ecological validity—smartphone-based mindfulness learning in everyday life—is proposed and confirmed. The findings of this study suggest that, even if only practiced for a short time, mindful learning using a smartphone lens in everyday life can effectively enhance attention, sensitivity, and imagination in regard to one's surroundings, which further leads to improvement of the ability of creativity. Moreover, practicing mindfulness in everyday life by taking photos and writing imaginative narratives, especially when both self-determination and knowledge sharing are emphasized, can enhance college students' creativity. These findings provide concrete answers to the proposed research Question 1 and 2. Finally, the findings suggest that attitude toward using mobile devices to enhance creativity self-efficacy played an important role as a moderator, which provides the answer to research Question 3 and reminds researchers of the importance of a positive attitude toward mobile devices' potential for creativity learning.

Notably, if smartphones can be used more mindfully and smartly in everyday life, they can be a very convenient and effective tool for enhancing personal creativity. In addition, since this study was conducted in an everyday life situation, it has better ecological validity than those conducted in laboratories. This study contributes to providing a very convenient and feasible approach for enhancing personal creativity through smartphones and computers, which provides insights for the instructional design of creativity learning.

研究三、曖昧相片想像力測驗發展

Study 3: The Development of Ambiguous-photo Imagination Test

1. The present study

The aim of this study was to develop the Ambiguous-photo Imagination Test (AIT).

2. Method

2.1. Participants

One hundred and thirty-three (32 males and 101 females; M_{age} = 21.26; SD_{age} = 1.27), aged from 20 to 29 years old, were recruited through an online ad posted on a campus website. Participants were rewarded with approximately USD 5. Written informed consent was obtained from all participants.

2.2. Instruments

The Ambiguous-photo Imagination Test and its short version (AIT and AIT-short) were developed and employed in this study to measure participants' creativity. The original AIT included 25 ambiguous black-and-white photos made from color photos. After the test of reliability and validity, the AIT included 20 photos and the short version included 10 photos. Their indices were measured: Originality, Fluency, and Flexibility. Past divergent thinking test scores originality and elaboration as different indices. However, the elaborated idea should be part of originality for it is a critical element that makes the idea unique. Accordingly, we scored originality for each photo as the sum of "novelty of the prototype" and "elaboration of the prototype." Novelty (X) is the frequency of a mentioned response divided by the total number of participants (0 point: X >= 16%; 1 point: X >= 5% and < 16%; 2 points: X >= 2% and < 5%; 3 points: X < 2%). Elaboration was based on the complexity of the description of each photo (1 point = description with simple adjectives; 2 points = description with compound adjectives or elaborated situations). Fluency refers to the ability to generate as many ideas as possible in a limited time, which was scored by the number of effective responses. Flexibility refers to the ability to think from different perspectives, which was measured by the number of categories

regarding all the effective responses. The information on reliability and validity are shown in the results section.

2.3. Procedure

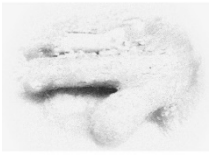
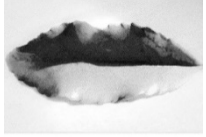
To begin with, the researchers searched photos in diverse categories on the Internet and collected 25 of them. Secondly, the photos were turned into black and white and somewhat blurred through Photoshop to make them ambiguous so that the participants could employ their imagination and creativity through the photos. After acquiring data, the researchers performed correlation analyses to eliminate photos with lower correlations. The Mean and Standard Deviation were also employed to eliminate pictures with extreme values. Next, reliability analyses and T-tests were utilized to examine internal consistency and discrimination. Then, we selected photos with consideration to maintaining the diversity in categories and arranged them in a S-shape in accordance with the means. Finally, 20 photos were kept as AIT. The same procedure was also applied to the selection of AIT-short (10 photos).

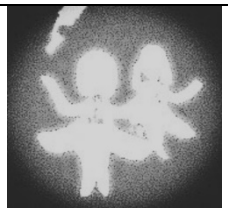
3. Results

3.1. Descriptive analysis

The means and SDs of originality, fluency, and flexibility for each photo in AIT and AIT-short are shown in Table 15 and Table 16.

Table 15. The means and SDs of originality, fluency, and flexibility for each phot in AIT

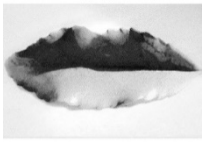
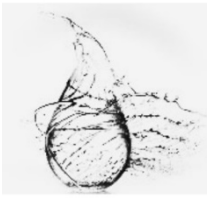
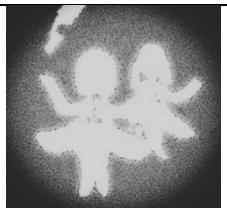
AIT					AIT-short				
No.	Photo	Index	*M*	*SD*	No.	Photo	Index	*M*	*SD*
1. (30)		C1	4.83	4.45	11. (20)		C1	4.70	3.68
		C2	3.31	2.07			C2	3.56	1.92
		C3	2.68	1.34			C3	2.82	1.42
2. (19)		C1	4.50	4.39	12. (21)		C1	4.58	4.62
		C2	3.21	1.94			C2	3.28	1.91
		C3	2.58	1.43			C3	2.84	1.38
3. (22)		C1	4.48	4.07	13. (14)		C1	4.31	4.29
		C2	3.20	2.02			C2	3.44	1.90
		C3	2.68	1.51			C3	3.08	1.43
4. (29)		C1	4.26	4.10	14. (12)		C1	4.27	4.11
		C2	3.76	1.76			C2	3.88	1.85
		C3	3.03	1.13			C3	2.42	1.37

5. (8)		C1	4.23	3.86	15. (25)		C1	4.25	3.83
		C2	3.30	1.76			C2	3.54	1.98
		C3	2.63	1.37			C3	3.23	1.58
6. (15)		C1	3.78	4.31	16. (7)		C1	4.19	3.84
		C2	3.23	1.79			C2	3.63	1.89
		C3	2.30	1.38			C3	2.48	1.26
7. (17)		C1	3.74	3.89	17. (13)		C1	3.41	3.83
		C2	3.09	1.92			C2	2.95	1.61
		C3	2.59	1.44			C3	3.23	1.58
8. (10)		C1	3.65	3.34	18. (23)		C1	3.48	4.31
		C2	3.44	1.84			C2	2.73	1.78
		C3	2.32	1.31			C3	2.46	1.45
9. (18)		C1	3.34	3.65	19. (11)		C1	3.14	4.06
		C2	2.92	1.67			C2	3.22	1.86
		C3	2.79	1.32			C3	2.69	1.40
10. (26)		C1	3.02	3.58	20. (27)		C1	3.08	3.35
		C2	3.42	1.88			C2	4.41	2.06
		C3	2.97	1.43			C3	3.32	1.40

Note. C1=Originality, C2=Fluency, C3=Flexibility. The number in ( ) is the original item number.

Table 16. The means and SDs of originality, fluency, and flexibility for each photo of the AIT-short

AIT					AIT-short				
No.	Photo	Index	*M*	*SD*	No.	Photo	Index	*M*	*SD*
1. (19)		C1	4.50	4.39	6. (25)		C1	4.25	3.83
		C2	3.21	1.94			C2	3.54	1.98
		C3	2.58	1.43			C3	2.42	1.37

2. (22)		C1	4.48	4.07	7. (7)		C1	4.19	3.84
		C2	3.20	2.02			C2	3.63	1.89
		C3	2.68	1.51			C3	3.23	1.58
3. (29)		C1	4.26	4.10	8. (21)		C1	4.58	4.62
		C2	3.76	1.76			C2	3.28	1.91
		C3	3.03	1.13			C3	2.82	1.41
4. (10)		C1	3.65	3.34	9. (13)		C1	3.41	3.83
		C2	3.44	1.84			C2	2.95	1.61
		C3	2.90	1.37			C3	2.48	1.26
5. (18)		C1	3.34	3.65	10. (23)		C1	3.48	4.31
		C2	2.92	1.67			C2	2.73	1.78
		C3	2.32	1.31			C3	2.46	1.45

Note. C1=Originality, C2=Fluency, C3=Flexibility. The number in ( ) is the original item number.

3.2. Reliability analysis

Cronbach's α coefficients for the AIT ranged from .95 to .97, and those for the AIT-short ranged from .90 to .94 (see Table 17).

Table 17. Reliability analysis of AIT and AIT-short (*N*=133)

AIT				AIT-short			
	M	*SD*	Cronbach's α		*M*	*SD*	Cronbach's α
Originality	3.83	2.48	0.95	Originality	3.85	2.68	0.91
Fluency	3.36	1.35	0.97	Fluency	3.26	1.37	0.94
Flexibility	2.73	0.94	0.95	Flexibility	2.68	0.95	0.90

3.3.Validity analysis

3.3.1. Item analysis

With Group (Low vs. High) as the between variable and the score of AIT as the dependent variable, we conducted MANOVAs to see whether there were differences between the groups on the performance of each of the test items. The cut-points of Group were the upper 27% and the lower 27%. The results revealed significant differences among all the test items. For Originality, Wilk's $\Lambda = .158$, $p = .000$, $\eta^2_p = .842$. For Fluency, Wilk's $\Lambda = .101$, $p = .000$, $\eta^2_p = .899$. For Flexibility, Wilk's $\Lambda = .106$, $p = .000$, $\eta^2_p = .894$.

With Group (Low vs. High) as the between variable and the score of AIT-short as the dependent variable, we conducted MANOVAs to see whether there were differences between the groups on the performance of

each of the test items. The cut-points of Group were the upper 27% and the lower 27%. The results revealed significant differences among all the test items. For Originality, Wilk's $\Lambda = .276$, $p = .000$, $\eta^2_p = .724$. For Fluency, Wilk's $\Lambda = .159$, $p = .000$, $\eta^2_p = .841$. For Flexibility, Wilk's $\Lambda = .130$, $p = .000$, $\eta^2_p = .870$

3.3.2. Criterion-related validity

The Digital Imagery Test (DIT) (Yeh & Lin, 2015), a divergent thinking test, was employed as the criterion of AIT and IT-short. The three indices of both AIT and AIT-short were highly correlated with the two criteria of DIT originality and fluency scores, indicating good criterion-related validity. The correlations ranged from .737 to .801 (see Table 18).

Table 18. Results of criterion-related validity (*N*=27)

	AIT			AIT-short		
	Originality	Fluency	Flexibility	Originality	Fluency	Flexibility
DIT originality	.744***	.800***	.763***	.753***	.795***	.764***
DIT fluency	.737***	.801***	.767***	.743***	.791***	.759***

***$p < .001$

3.3.3. Correlations between creativity indices

The three indices of AIT and AIT-short were strongly correlated with each other, ranging from .880 to .975 (see Table 19).

Table 19. Correlations between the indices of AIT and AIT-short (*N* = 125)

		AIT			AIT-short		
		Originality	Fluency	Flexibility	Originality	Fluency	Flexibility
AIT	Originality	1					
	Fluency	.927***	1				
	Flexibility	.913***	.970***	1			
AIT-short	Originality	.967***	.904***	.891***	1		
	Fluency	.906***	.975***	.947***	.919***	1	
	Flexibility	.880***	.936***	.966***	.898***	.961***	1

***$p < .001$

研究四、正念學習介入的效果和手機使用熱情、成長心向、固定心向和自我效能之群集型態

Study 4: The learning effects and cluster profiles of passion in smartphone use, growth creative mindset, fixed mindset, and self-efficacy in a mindful learning intervention

1. The present study

This study aimed at examining a smartphone-based mindfulness intervention effect in changes of passion in smartphone use, growth creativity mindset, fixed creativity mindset, and self-efficacy. In addition, this study sought to understand the profiles of passion in smartphone use, growth creativity mindset, fixed creativity mindset, and self-efficacy after the intervention through cluster analysis.

2. Method

2.1. Participants

All participants, aged from 20 to 29 years old, were recruited through an online ad posted on a campus website. Participants were 84 college students (17 males and 67 females; M_{age} = 21.21; SD_{age} = 1.56); they were rewarded with approximately $35 USD.

3.2. Instruments

3.2.1. Inventory of Passion towards Smart Phones (IPSP)

The Inventory of Passion towards Smart Phones (IPSP) was employed to measure the participants' passion towards using mobile phones. The IPSP is a 2-dimension (Harmonious-Obsessive and Intrapersonal-Interpersonal), 6-point Likert type scale with 1 point to 6 points, representing strongly disagree to strongly agree. With a total of 15 items, the IPSP includes four types of passion: Harmonious-Intrapersonal (H-Intra, 4 items), Harmonious-Interpersonal (H-Inter, 4 items), Obsessive-Intrapersonal (O-Intra, 4 items), and Obsessive-Interpersonal (O-Inter, 3 items). The Cronbach's α values of the IPSP and the four factors were .935, .910 (H-Intra), .876 (H-Inter), .903 (O-Intra), and .701 (O-Inter).

3.2.2. Creativity Mindset Inventory (CMI)

The CMI was employed to measure the participants' nature belief of creativity. The CMI originally included 12 test items with 3 items in each of the following dimensions: Growth-Internal control (GI), Growth-External control (GE), Fixed-Internal control (FI), and Fixed-External control (FE). The Cronbach's α coefficients for the Growth CM, GI, and GE were .747, .783, and .638, respectively. Regarding the reliability of Fixed CM (FI and FE), the item-total correlation ranged from .707 to .812. The Cronbach's α for the Fixed CM (FI and FE) were .914, .830, and.854, respectively.

3.2.3. Inventory of Self-Efficacy in Creativity

The Inventory of Creativity Self-Efficacy (ICSE) was employed to measure the participants' level of creativity self-efficacy. The ICSE is a 6-point Likert-type scale from 1 point to 6 points, representing strongly disagree to strongly agree. With a total of 9 items, the ICSE includes two factors: Ability to generate creative ideas (6 items) and Achievement of creative performance (3 items). Exploratory factor analysis revealed that the total variance explained by the two factors was 73.27%. The Cronbach's α coefficients of the ICSE and

the two factors were .927, .908, and .844, With factor loadings of .606 to .879, 73.27% of the total variance was explained by the two factors.

3.2.4. Creativity

In this study, we requested the participants to upload the photos they took to a designated website. For each photo, we requested the participant to write an imaginative narrative. Examples are shown as Figure 9. The imagination score, ranging from 0 points to 5 points, was rated by two trained coauthors based on their consensus.

3.3. Procedures and interventions for the experiment

In this study, we assume that after the smartphone-based mindfulness intervention which emphasized mindfulness, self-determination, and knowledge sharing online would enhance mindfulness and imagination toward surrounding things in everyday life. Such learning would further foster growth creativity mindsets, harmonious passion towards smartphones, and self-efficacy in creativity, as well as decrease fixed creativity mindsets and obsessive passion towards smartphones.

To understand the influence of the intervention effects, this study employed a pretest-posttest design. During the one-week experimental period, the participants were requested to use their smartphones to freely take photos and share the photos with imaginative narratives on a designated website.

4. Results

4.1. Learning effects

Using Test (pretest vs. posttest score of creativity mindset) as the dependent variables, we conducted repeated measure analysis of variance (Repeated measure ANOVA) to examine the effects of creativity mindsets, passion towards smartphones, and self-efficacy in creativity. Regarding creativity mindset, the participants improved their growth-internal mindset after the intervention, $F(1, 83) = 10.307$, $p = .002$, $\eta^2_p = .110$. Although there were no significant effects on fixed-internal and fixed-external mindsets, there was a trend that the participants decrease these fixed mindsets after the intervention. Regarding passion toward smartphones, the participants increased their harmonious intrapersonal passion, harmonious interpersonal passion, and obsessive interpersonal passion after the intervention, Fs(1, 83) = 8.508 to 13.218, ps < .05, $\eta^2_p = .093$ to .137. Finally, the participants enhanced their self-efficacy of creativity after the intervention, $F(1, 83) = 28.964$, $p < .001$, $\eta^2_p = .259$ (see Table 20).

Table 20. The effects of interventions on changes of creativity mindset, passion toward smartphones, and Self-efficacy of creativity

	ANCOVA				
Source	*MS*	*F* (1, 83)	*p*	η^2_p	Post hoc test
Creativity mindset					
CM-GI	2.461	10.307*	.002	.110	T2>T1
CM-GE	.239	1.186	.279	.014	
CM-FI	.677	3.642	.060	.042	
CM-FE	.720	3.539	.063	.041	
Passion toward smartphones					
H-intrapersonal	1.572	8.508*	.005	.093	T2>T1
H-interpersonal	1.670	13.218**	.000	.137	T2>T1
O-intrapersonal	.073	.453	.503	.005	
O-interpersonal	2.625	12.580**	.001	.132	T2>T1
Self-efficacy of creativity	2.766	28.964**	.000	.259	T2>T1

Note. T1 = pretest; T2 = posttest, $p <. 05$*, $p <.001$**.

4.2. Profile analysis

To understand the profiles of passion in smartphone use, growth creative mindset, fixed mindset, and self-efficacy after a mindful learning intervention, we employed a cluster analysis to achieve this goal. In this study, we employed k-means clustering, which gives a formal definition as an optimization problem: find the k cluster centers and assign the objects to the nearest cluster center so that the squared distances from the cluster are minimized (Cutillo, 2019). Four types of passion in smartphone use (Harmonious-Intrapersonal, Harmonious-Interpersonal, Obsessive-Intrapersonal, and Obsessive-Interpersonal), four types of mindsets (Growth-Internal control, Growth-External control, Fixed-Internal control, and Fixed-External control), and self-efficacy of creativity were included in the cluster analysis. Overall, the variables formed three significant clusters (C1, C2, and C3). The mean scores of the final cluster center for each of the variables are shown in Figure 10.

To further compare the differences between clusters, we conducted a multivariate analysis of variance (MANOVA) using the cluster groups (C1, C2, and C3) as between variables and all variables as dependent variables. The findings showed significant group effects on all the dependent variables, Wilks' $\Lambda = .175$, $p < .001$, $\eta_p^2 = .581$. The posthoc comparisons are shown in Table 21. The results revealed three patterns. C2, which had the highest creativity self-efficacy after the intervention, showed a high level of harmonious-intrapersonal and interpersonal passion in smartphone use, a medium level of obsessive-intrapersonal and interpersonal passion in smartphone use, a high level of growth-internal and external mindset, and a very low level of fixed-internal and external mindset. C3, which had a medium level of creativity self-efficacy after the intervention, showed a medium level of harmonious-intrapersonal and interpersonal passion in smartphone use, a medium level of obsessive-intrapersonal and interpersonal passion in smartphone use, a medium level of growth-internal and external mindset, and a medium level of fixed-internal and external mindset. Finally, C1, which had the lowest level of creativity self-efficacy after the intervention, showed a medium level of harmonious-intrapersonal and interpersonal passion in smartphone use, a high level of obsessive-intrapersonal and interpersonal passion in smartphone use, a low level of growth-internal and external mindset, and a high level of fixed-internal and external mindset (see Figure 11).

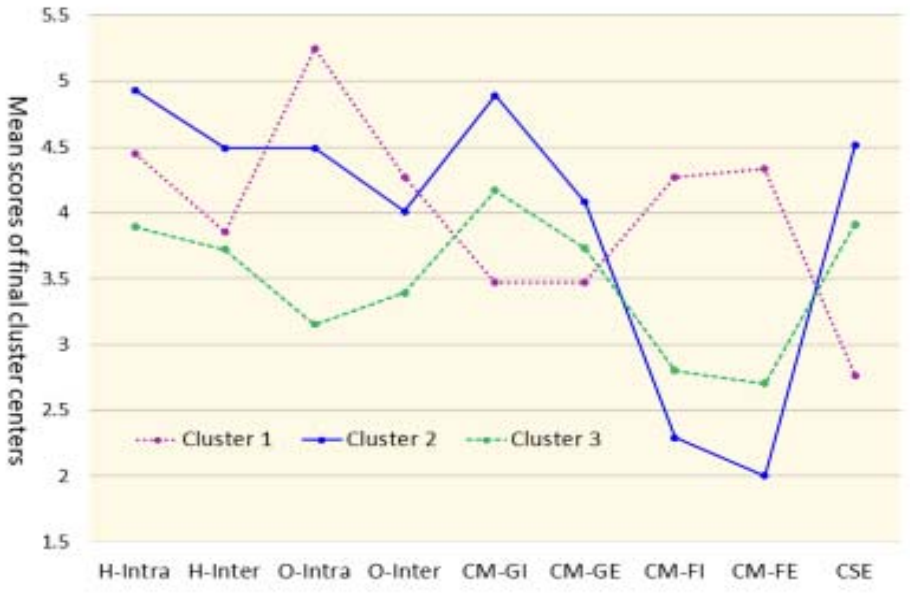


Figure 10. Final Cluster Centers

Table 21. Final Cluster Centers and ANOVA results

	Cluster			ANOVA			
	1	2	3	$F(2, 81)$	Sig.	η^2_p	Scheffé
H-Intra	4.45	4.93	3.89	27.568	.000	.405	C2 > C3
H-Inter	3.85	4.49	3.72	12.604	.000	.237	C2 > C3
O-Intra	5.25	4.49	3.15	26.878	.000	.399	C1, C2 > C3
O-Inter	4.27	4.01	3.39	8.889	.000	.180	C1, C2 > C3
CM_GI	3.47	4.89	4.17	23.491	.000	.367	C2, C3 > C1; C2 > C3
CM_GE	3.47	4.08	3.73	4.961	.009	.109	C2, C3 > C1; C2 > C3
CM_FI	4.27	2.29	2.80	21.444	.000	.346	C1 > C2, C3; C3 > C2
CM_FE	4.33	2.00	2.70	32.582	.000	.446	C1 > C2, C3; C3 > C2
CSE	2.76	4.51	3.91	15.442	.000	.276	C2, C3 > C1; C2 > C3

Note. Number of participants in each cluster: C1 = 5; C2 = 35; C3 = 44. Four types of passion towards smartphones: Harmonious-Intrapersonal (H-Intra), Harmonious-Interpersonal (H-Inter), Obsessive-Intrapersonal (O-Intra), and Obsessive-Interpersonal (O-Inter). Four types of creativity mindsets: Growth-Internal control (GI), Growth-External control (GE), Fixed-Internal control (FI), and Fixed-External control (FE). CSE: Creativity self-efficacy.

4. Discussion and conclusions

This study aimed at examining a smartphone-based mindfulness intervention effect in changes of passion in smartphone use, growth creativity mindset, fixed creativity mindset, and self-efficacy. The results suggest that the employed intervention that emphasizes mindfulness, self-determination, and knowledge sharing online can significantly enhance college student's growth-internal mindset, harmonious intrapersonal passion, harmonious interpersonal passion, and creativity self-efficacy. Interestingly, the results found that obsessive interpersonal passion was also enhanced after the intervention, suggesting obsessive interpersonal passion can coexist and positively correlate with harmonious passion. In addition, the intervention has a marginally

significant effect on decreasing fixed-internal and fixed-external mindsets. Mobile technology, such as smartphones or tablets, has been used in several classroom settings to enrich interactive teaching context, support collaboration, engagement, and enable efficient and meaningful learning (Alberto & Cruz-Martínez; 2017, Atwood-Blaine et al., 2019; Kacetl & Klímová, 2019). The results of this study support the findings that using smartphones can facilitate collaborative learning and higher-order thinking skills (Smith et al., 2016). To conclude, the smartphone-based mindfulness intervention can be effective in strengthening growth creativity mindset and harmonious passion in creativity learning.

On the other hand, this study sought to understand the profiles of passion in smartphone use, growth creativity mindset, fixed creativity mindset, and self-efficacy after the intervention through cluster analysis. The results emerged three groups: (1) high efficacious, harmonious passion, and growth mindset, but low fixed mindset group; (2) medium efficacious, harmonious passion, obsessive passion, growth mindset, and fixed mindset group; and (3) low efficacious and growth mindset, but high obsessive passion and fixed mindset group.

研究五、黑白曖昧圖片和彩色生活照片想像力神經網路之比較

Study 5: Comparisons of imagination neural network of ambiguous black-and-white versus color daily life photos

1. The present study

Only very few studies have requested the participants write down their creative thoughts inside the fMRI scanner. Moreover, no study has been conducted to compare the neural activations when participants were requested to engage in imagination tasks by watching ambiguous black-and-white versus color everyday life photos. This study aimed to make such a comparison.

2. Method

2.1. Participants

Twenty-five college students (12 Females and 13 Males; M_{age} = 21.5; SD_{age} = 1.8 years; Range of age: 20~27 years) were requested to take two types of creative tasks. All the participants were right-handers and none of them had any history of a neurological or psychiatric disorder. This study was approved by the Research Ethics Committee of National Chengchi University. Informed consent was obtained from all the participants. Approximately USD 30 was rewarded for participation.

2.2.Stimuli of creative thinking

Two types of stimuli were employed as creativity tasks: the black-and-white task adapted from the Ambiguous-photo Imagination Test (AIT) and the color photos selected from participants' work in Yeh, Chang, Ting, and Chen's study (2020). The original AIT included 20 photos and the measure of each photo included three indices: originality, fluency, and flexibility. In this study, we requested the participants to think about and draw out "One" original and valuable product; therefore, only originality was scored. The originality score for each photo was the score of "novelty of the prototype" plus "elaboration of the prototype." The score of novelty (X) is the frequency of a mentioned response divided by the total number of participants (0 point: X >= 16%; 1 point: X >= 5% and < 16%; 2 points: X >= 2% and < 5%; 3 points: X < 2%). Elaboration was scored based on the complexity of the description of each photo (o points: a description with no adjectives; 1 point = a description with simple adjectives; 2 points = description with compound adjectives or elaborated

situations). Based on a sample of 130 college students, the originality score of AIT significantly correlated with that of the Digital Imagery Test (DIT) (Yeh & Lin, 2015), r (131) = .744, suggesting a good criterion-related validity. Moreover, all test items of the originality had good discriminant validity through item analysis, Wilk's $\Lambda = .158$, $p = .000$, $\eta^2_p = .842$. Regarding reliability, the Cronbach's α coefficient for the originality score was .95.

As for the color photos, the 20 employed photos taken in daily life through smartphones were selected from 715 photos which were collected in a mindful learning study (Yeh et al., 2020); these photos were selected because they inspired imaginative narrative as evidenced by the creativity scores (Yeh et al., 2020). In this study, after watching a photo, we requested the participants to write down the most creative thoughts that came up to their mind. A creativity score, ranging from 0 points to 5 points, was rated for each photo. The scoring rubrics were as follows: 0: Roughly describes the content of the photo, but no associative thinking; 1: Associates the external features of the photo with some concrete objects/things/uses, but no descriptions of the situation; 2: Associates the concrete objects/things in the photo with self-experiences; 3. Associates the abstract concepts in the photo with self-experiences; 4: Associates the concrete objects/things or the abstract concepts in the photo with situations beyond one's own experiences; 5: Associates the concrete objects/things or the abstract concepts in the photo with situations beyond one's own experiences with vivid or touching descriptions (Yeh et al., 2020).

2.3.Experimental design and procedures

The creativity fMRI tasks were developed using the Spyder (python 3.7) software. An event-related design that included two runs (the black-and-white task and the color task) was employed. The whole experiment lasted approximately 60 minutes for one participant, and all the participants were requested to lay on the fMRI scanner to execute the tasks. In the beginning, participants were requested to practice using the MR-safe tablet for 2 minutes. Two additional experimental stimuli were employed as practice trials to help participants be familiar with the procedures of the experiment and the operation of writing inside the scanner. Then, the participants completed two runs of tasks; each run took about 20 minutes. A counterbalanced design was adopted to the order between the black-and-white task and the colorful task. Lastly, a 6-minutes T1 scanning was employed to explore individual brain structures (see Figure 15).

Each run comprised 20 experimental trials and 4 control trials. In the experimental condition, the participants were instructed to watch a photo (a black-and-white or color photo) and associate it with personal experiences, and then write down the most creative answer using the MR-safe tablet. In order to control the basic visuospatial and motor aspect, a counting test (a black-and-white or color photo) was presented as a control condition in which participants were asked to count the number of circles in a lot of geometry shapes. See Figure 16 for examples of the experimental and the control condition stimuli for the black-and-white and the color tasks. There were 24 trials in both the black-and-white and the color task, and the stimuli in each task were randomly arranged. For both types of tasks, each trial was separated by 0.5s fixation. Then, 20s of stimuli presentation, 5s for the best answer selection, 20s for writing the answer using the tablet, and 3~6 seconds jitter time with a random duration followed (see Figure 17).

Note. Task A: the black-and-white task; Task B: the color task

Figure 15. In-scan procedures

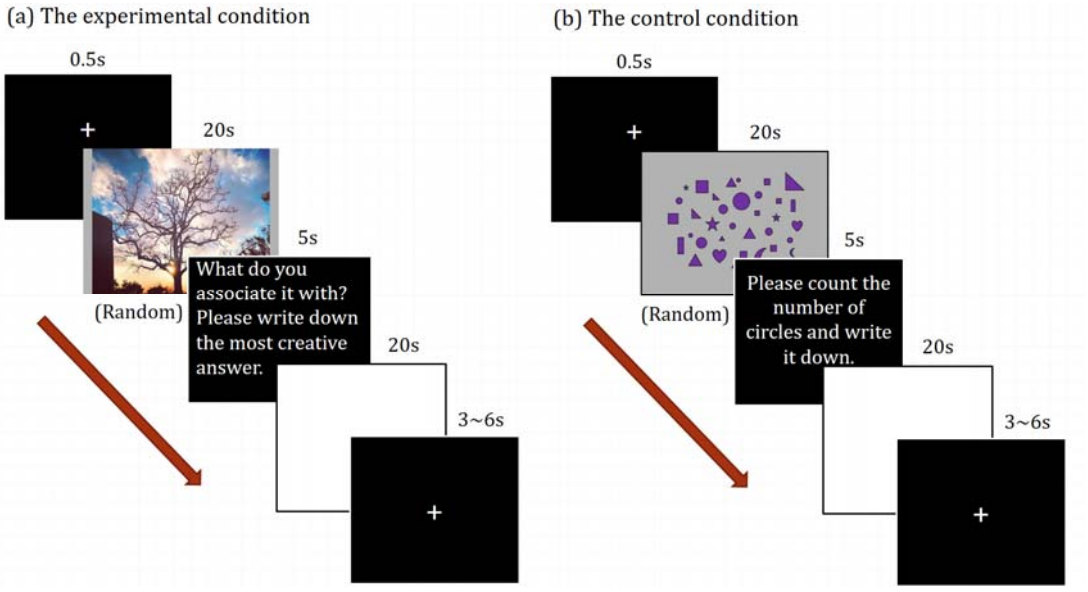


Figure 17. The procedures of one trial for the experimental and the control condition

2.4. Data acquisition

MRI Imaging data were collected with a 3 T scanner (Skyra, Siemens Medical Solutions, Erlangen, Germany) with a 64-channel head coil. Functional images used a T2*-weighted gradient echo-planar imaging (EPI) sequence with slice thickness = 3 mm, repetition time (TR) = 2000 ms, echo time (TE) = 25 ms, flip angle = 90o, with 41 axial slices acquired in ascending interleaved order, on a 64 × 64 matrix in a 216 × 216 mm field of view (FOV). T1-weighted anatomical images were acquired by a magnetization-prepared rapid gradient-echo sequence with slice thickness = 1 mm, TR = 2530 ms, TE = 3.03 ms, inversion time = 1100 ms, flip angle = 7°, 192 sagittal slices, on a 256 × 256 matrix in a 256 × 256 mm FOV.

2.5. Data analysis and statistical analysis

2.5.1 Brain activation analysis

The functional images were transferred to digital imaging and communications in medicine (DICOM) files by using Statistical Parametric Mapping 12 (SPM) (Wellcome Trust Centre for Neuroimaging, London, UK) software package in MATLAB 2016b (Math Works, Natick, Mass). Next, the DICOM files were sliced

timing, realigned, co-registered to individual structure image, normalized to Montreal Neurological Institute (MNI) space (MNI) standard space, and smoothed images with Gaussian kernel of 8 mm full-width at a half-maximum (FWHM). At the first level, the individual image data of establishing creative ideas were modeled by specifying the onset time and durations of stimuli. Moreover, the six parameters of the realignment were regarded as regressors of no interest. On the second level, we examined the differences between the black-and-white task and the color task with paired t-test analyses. All the threshold of the statistical parametric maps was at a voxel-wise intensity of $p < .001$ with a False Discovery Rate (FDR) corrected spatial extent threshold.

3. Results

3.1. Brain activations of two creativity tasks

These results revealed that both tasks activated the brain regions of ITG/MTG/Hippocampus (left), Hippocampus/ITG (right), and MOG/Angular gyrus (left). While the black-and-white additionally activated the right IFG, the color task additionally activated the left IFG, Fusiform gyrus, and SFG/MFG (see Table 24).

Table 24. Clusters of brain activation for the black-and-white and the color task

Model	Region	Cluster size (in voxels)	MNI			t value
			x	y	z	
Black-and-white task	L. ITG/L. MTG/ L. Hippocampus	6018	-48	26	-6	10.93
	R. Hippocampus/R. ITG	4448	26	-38	-16	9.72
	R. IFG	1089	50	32	-6	8.8
	L. ITG/L. MTG/L. Hippocampus	3710	-30	-36	-18	7.73
	L. MOG/L. Angular gyrus	490	-40	-68	26	6.83
Color task	L. Fusiform gyrus/L. Hippocampus/L. ITG	1393	-20	-14	-22	7.34
	L. MTG	367	-60	-46	-4	7.29
	L. IFG	1194	-32	34	-12	7.17
	R. Fusiform gyrus/R. Hippocampus	1157	34	-42	-10	7.16
	L. SFG/L. MFG	2088	-6	62	20	6.78
	L. Angular gyrus/L. MOG	614	-34	-76	46	6.22

Note. L, left; R, right; MNI, Montreal Neurological Institute. All coordinates are described according to the Montreal Neurological Institute system and Brodmann areas (BA) are given as well. Abbreviations: ITG = Inferior Temporal Gyrus, IOG = Inferior Temporal Gyrus, MTG = Middle Temporal Gyrus, IPL = Inferior Parietal Lobul, SPL = Superior Parietal Lobule, IFG = inferior frontal gyrus, SFG = superior frontal gyrus, MFG = middle frontal gyrus, MOG, middle occipital gyrus.

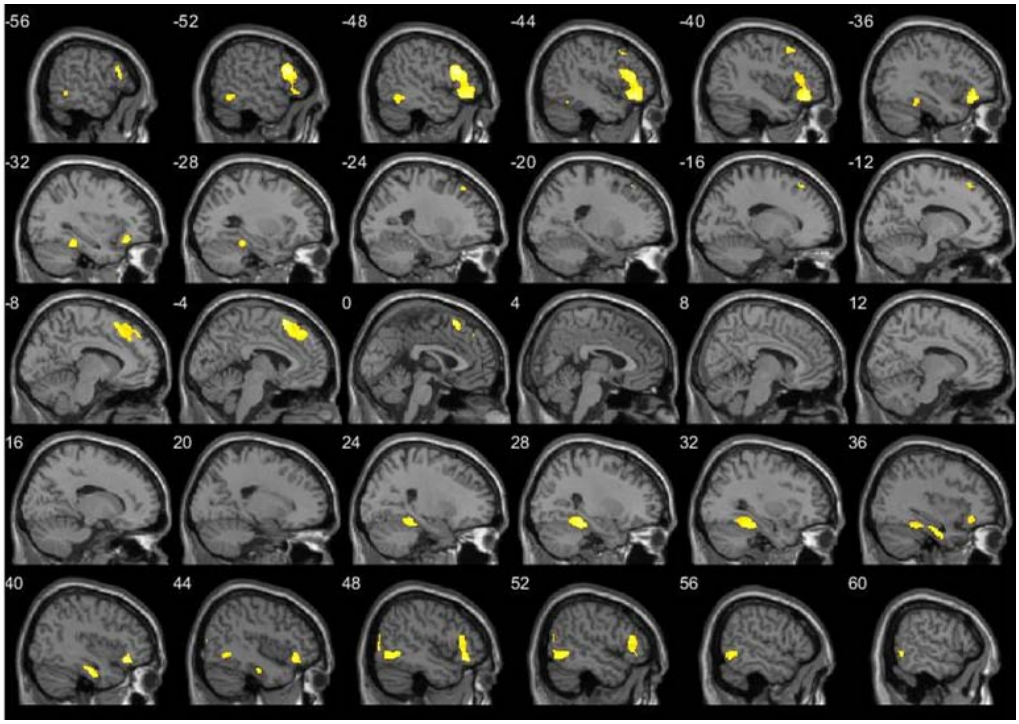


Figure 18. Brain activation during conducting black-and-white tasks

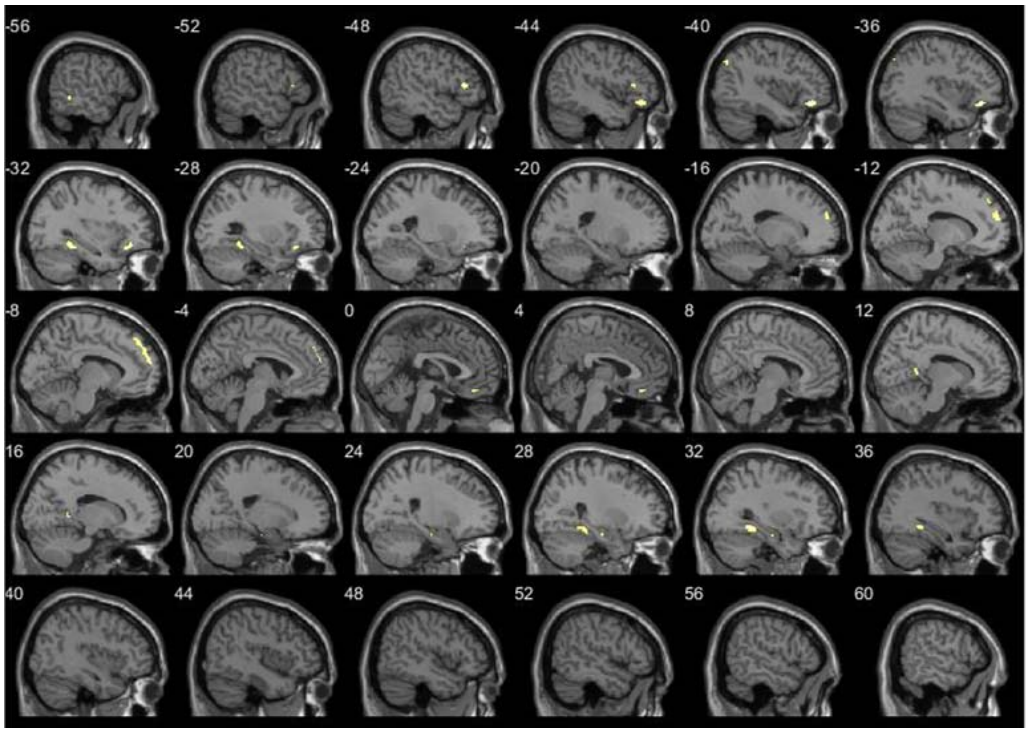


Figure 19. Brain activation during conducting color tasks

3.2. Comparisons of two creative thinking tasks

In order to examine the distinctive differences of different types of creativity tasks, we conducted two contrasts: black-and-white task minus color task as well as color task minus black-and-white. The former contrast showed that the black-and-white task stimulated greater brain activation in the sensorimotor system (precentral gyrus, postcentral gyrus), visual system (middle temporal gyrus, occipital gyrus), and default mode network (inferior parietal lobe) (see Table 25). No significant brain activation was found in the latter contrast.

Table 25. The differences of brain activation between the black-and-white task and the color task

Model	Region	Cluster Size (in voxels)	MNI			t value
			x	y	z	
Black-and-white minus color tasks	R. ITG/R. IOG/R. MTG	1033	48	-60	-6	9.96
	L. IOG/L. ITG/ L. Fusiform	405	-42	-64	-10	8.03
	R. IFGoper/R. Precentral gyrus	148	44	6	26	7.42
	R. Postcentral gyrus/R. IPL	156	48	-28	50	7.16
	R. SPL/R. Postcentral gyrus/R. IPL	47	38	-44	56	6.47

Note. L, left; R, right; MNI, Montreal Neurological Institute. All coordinates are described according to the Montreal Neurological Institute system and Brodmann areas (BA) are given as well. Abbreviations: ITG = Inferior Temporal Gyrus, IOG = Inferior Temporal Gyrus, MTG = Middle Temporal Gyrus, IPL = Inferior Parietal Lobul, SPL = Superior Parietal Lobule

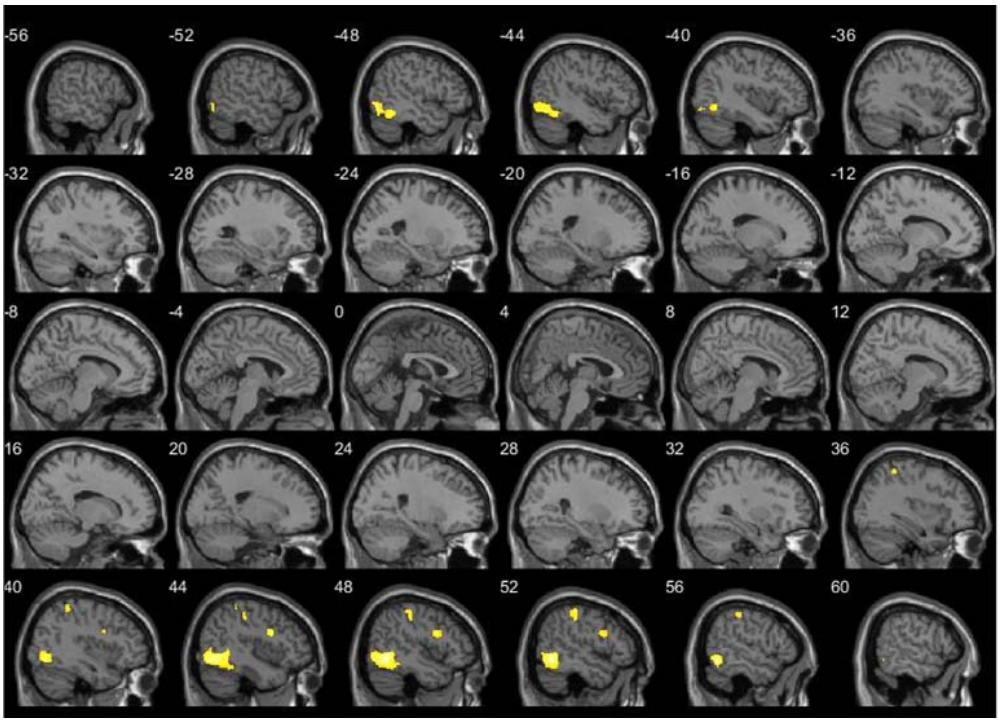


Figure 20. Grater brain activation in black-and-white tasks than in color tasks

4. Discussion and conclusion

These results revealed that during the creative thinking, both the black-and-white and the color tasks activated the brain regions of ITG/MTG/Hippocampus (left), Hippocampus/ITG (right), and MOG/Angular gyrus (left). While the black-and-white additionally activated the right IFG, the color task additionally activated the left IFG, Fusiform gyrus, and SFG/MFG. The results support past findings that the hippocampus plays a critical role in creative thinking (Duff et al., 2013). Hippocampus has been suggested as the critical brain structure that provides a relational database for creating and updating mental

representations (Eichenbaum & Cohen, 2001); it also processes relational information on the time-scale necessary to rapidly generate and combine mental representations. These hippocampus functions are essential aspects of creative thinking (Bristol & Viskontas, 2006).

In contrast to the black-and-white task minus the color task, the results revealed that the black-and-white task stimulated broader brain regions, including sensorimotor system, visual system, and default mode network. Notably, inferior parietal lobe, inferior occipital gyrus, and inferior frontal gyrus were activated. Inferior parietal lobe, a brain region of default mode network, is regarded as an important brain region for creative thinking; parietal lobe and frontal gyrus, which connects to the parietofrontal network (FPN), are related to working memory-related cognitive tasks. Accordingly, compared to the daily-life color tasks, the ambiguous black-and-white tasks seem to be more abstract, which requires more cognitive resources to identify the shape and characteristics, as well as employ more neural resources to generate creative ideas.

研究六、創造力學習的神經可塑性:正念學習的介入效果

Study 6: The neural plasticity of creativity learning: The intervention effect of mindful learning

1. The present study

Mindful learning emphasizes actively and consciously paying attention to the things they are curious about or interested in, and further, try to bring about new meanings or original thinking from these ordinary or special things. It can be a way to balance brain networks and optimize the creative process. However, no study has been performed to examine the neural plasticity concerning creativity after mindful learning interventions. In this study, we conducted a pretest-posttest design to investigate neurobiological correlation of creativity before and after a mindful learning intervention through a fMRI scanner.

2. Method

2.1 Participants

Twenty college students (10 Females and 10 Males; M_{age} = 21.7; SD_{age} = 1.9 years; Range of age: 20~27 years) were requested to take a pre-intervention brain scan, to receive a mindful learning intervention, and a posttest brain scan during a 10-day intervention. All the participants were right-handers and none of them had any history of a neurological or psychiatric disorder. This study was approved by the Research Ethics Committee of National Chengchi University. Informed consent was obtained from all the participants. Approximately USD 65 was rewarded for participation.

2.2. Stimuli of creative thinking

Twenty photos taken in daily life through smartphones were selected from 715 photos which were collected in a mindful learning study (Yeh et al., 2020); these photos were selected because they inspired imaginative narrative as evidenced by the creativity scores (Yeh et al., 2020). In this study, after watching a photo, we requested the participants to write down the most creative thoughts that came up to their mind. A creativity score, ranging from 0 points to 5 points, was rated for each photo. The scoring rubrics were as follows: 0: Roughly describes the content of the photo, but no associative thinking; 1: Associates the external features of the photo with some concrete objects/things/uses, but no descriptions of the situation; 2: Associates the concrete objects/things in the photo with self-experiences; 3. Associates the abstract concepts in the photo with self-experiences; 4: Associates the concrete objects/things or the abstract concepts in the photo with

situations beyond one's own experiences; 5: Associates the concrete objects/things or the abstract concepts in the photo with situations beyond one's own experiences with vivid or touching descriptions (Yeh et al., 2020).

2.3. Experimental design and procedures

A pretest-posttest experimental design was employed in this study. The participants took the in-scan creativity task on Day 1, took a mindful learning intervention from day 2 to day 10, and took the in-scan creativity task again on day 11 (see Figure 21). The in-scan creativity fMRI tasks were developed using spyder (python 3.7) software. An event-related design which included 24 trials was used in the present study. At the beginning, participants were requested to practice using the MR-safe tablet for 2 minutes. Two additional experimental stimuli were employed as practice trials to help participants be familiar with procedures of the experiment and the operation of writing inside the scanner. Then, the participants completed the tasks that took about 20 minutes. In the end, a 6-minutes T1 scanning was employed to explore individual brain structures.

The in-scan tasks comprised of 20 experimental trials and 4 control trails. In the experimental condition, the participants were instructed to watch a color photo and associate it with personal experiences, and then write down the most creative answer using the MR-safe tablet. In order to control the basic visuospatial and motor aspect, a counting test was presented as a control condition in which participants were asked to count the number of circles in a lot of geometry shapes. See Figure 22 for examples of the experimental and the control condition stimuli. The 24 trials were randomly arranged. each trial was separated by 0.5s fixation. Then, 20s of stimuli presentation, 5s for the best answer selection, 20s for writing the answer using the tablet, and 3~6 seconds jitter time with a random duration followed.

Our mindful intervention emphasized mindfulness, self-determination, and knowledge sharing online. Self-determination involves free choice, self-control, and self-management (Yeh et al., 2020; Peterson, et al., 2020). In this study, we employed the concept of self-determination by allowing participants to freely take photos. During the intervention, the participants were requested to take 2 photos and write creative narratives for each photo, and then share the two photos to an assigned website every other day by smartphones. They had to upload 10 photos in total during the intervention period.

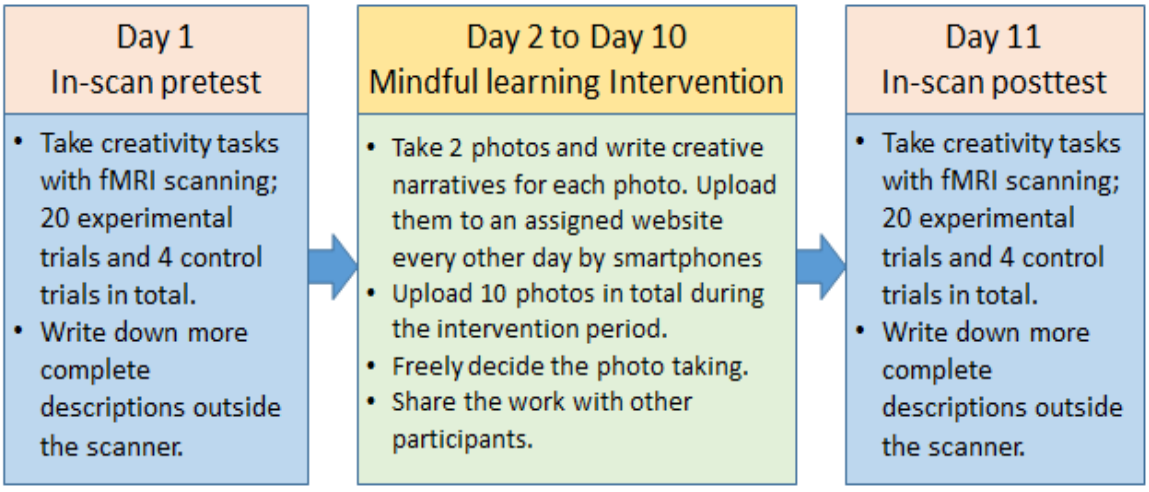


Figure 21. The procedures of the intervention experiment

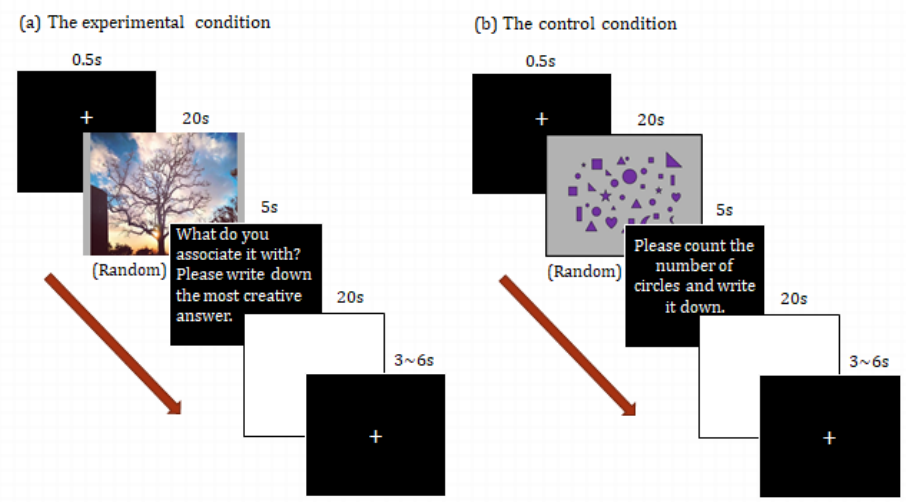


Figure 22. The procedures of one trial for the experimental and the control condition

2.4.Data acquisition

MRI Imaging data were collected with a 3 T scanner (Skyra, Siemens Medical Solutions, Erlangen, Germany) with a 64-channel head coil. Functional images used a T2*-weighted gradient echo-planar imaging (EPI) sequence with slice thickness = 3 mm, repetition time (TR) = 2000 ms, echo time (TE) = 25 ms, flip angle = 90o, with 41 axial slices acquired in ascending interleaved order, on a 64 × 64 matrix in a 216 × 216 mm field of view (FOV). T1-weighted anatomical images were acquired by a magnetization-prepared rapid gradient-echo sequence with slice thickness = 1 mm, TR = 2530 ms, TE = 3.03 ms, inversion time = 1100 ms, flip angle = 7°, 192 sagittal slices, on a 256 × 256 matrix in a 256 × 256 mm FOV.

2.5. Data analysis and statistical analysis

2.5.1. Brain activation analysis

The functional images were transferred to digital imaging and communications in medicine (DICOM) files by using Statistical Parametric Mapping 12 (SPM) (Wellcome Trust Centre for Neuroimaging, London, UK) software package in MATLAB 2016b (Math Works, Natick, Mass). Next, the DICOM files were sliced timing, realigned, co-registered to individual structure image, normalized to Montreal Neurological Institute (MNI) space (MNI) standard space, and smoothed images with Gaussian kernel of 8 mm full-width at a half-maximum (FWHM). At first level, the individual image data of establishing creative ideas were modelled by specifying the onset time and durations of stimuli. Moreover, the six parameters of the realignment were as regressors of no interest. On the second level, we compared the changes before and after intervention with paired t-test analyses.

2.5.2 Brain structural analysis

The acquired T1 images were transferred to DICOM files by using MRIcron (Chris Rorden, Columbia, SC, USA) software. The DICOM files were then analyzed through voxel-based morphometry (VBM; Ashburner & Friston, 2000) for the computational analysis of differences in local GMV using the CAT12 toolbox in SPM12 software package in MATLAB 2016b. VBM analysis was conducted as follows: discarded the scans with head motion, normalized images on the template with International Consortium for Brain Mapping (ICBM) East Asian brains, removed outliers by checking data quality, and smoothed images with Gaussian kernel of 8 mm FWHM. The paired t-test was used to examine the alternation of gray matter volume between pretest and posttest. All the threshold of the statistical parametric maps was at a voxel-wise intensity of $p < .001$ with a False Discovery Rate (FDR) corrected spatial extent threshold.

3. Results

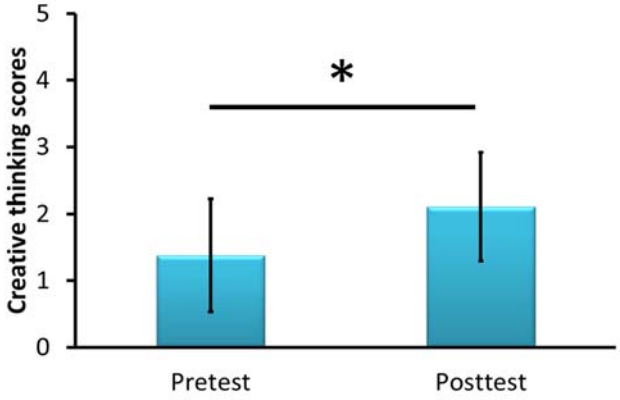
3.1. Behavior results

Using creativity scores (pretest vs. posttest score) as the dependent variables, we conducted a repeated measure analysis of variance (Repeated measure ANOVA) to examine the learning effect. The results revealed that the participants improved their creativity after the intervention, $F(1, 18) = 21.727$, $p < .001$, $\eta^2_p = .547$. (see Table 26).

Table 26. Effects of interventions on changes of creativity total

Source	ANCOVA				Post hoc test
	MS	*F* (1, 18)	*p*	η^2_p	
Creativity	1.181	21.727***	.000	.547	*T2>T1*

Note. T1= pretest; T2 = posttest, *** p <.001.



* p<.05

Figure 23. The significantly higher creative thinking scores compared with the pretest was found after the 10-day mindful learning intervention.

3.2. Brain activation changes before and after 10-days mindful learning

To investigate the effect of the 10-days mindful learning on brain activation of creative thinking, we compared the functional images of pretest and posttest. The results revealed that greater activation of the cluster containing the bilateral anterior cingulate cortex (ACC) and the right supplementary motor area (SMA) in posttest than in pretest (see Fig 24; Table 26). No significant cluster was found for the contrast of pretest minus posttest.

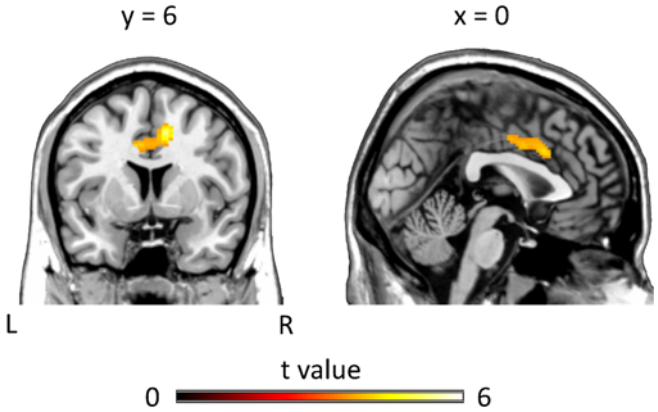


Figure 24. Greater activation in the bilateral anterior cingulate cortex

with the contrast of posttest minus pretest during creative thinking task

Table 26. Comparisons of brain activation in photo task before and after mindful learning

Model	Region	Cluster size (in voxels)	MNI			t value
			x	y	z	
Post - Pre	L. ACC/R. ACC/R. SMA	713	10	6	44	5.448

3.3. Alternation of gray matter volume (GMV)

The brain structural plasticity during mindful learning was examined by using VBM analysis to compare the gray matter volume in the pretest and posttest. As Figure 22 and Table 27 show, GMV of the cluster from the right precentral gyrus extending to the supplementary motor area considered as sensorimotor network decreased after a 10-day mindful learning intervention. However, the higher GMV in the left cerebellum 8 was found in the posttest than in pretest.

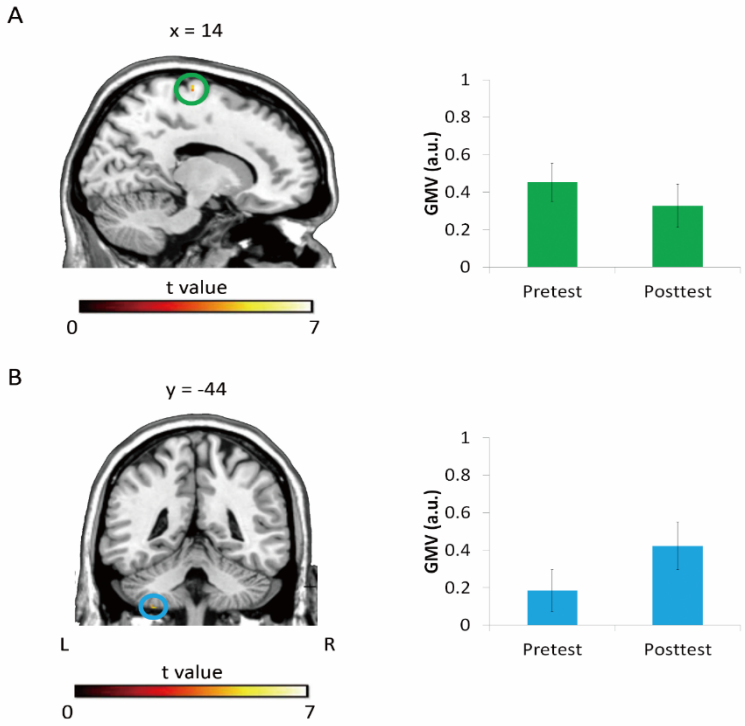


Figure 22. After a 10-day intervention, decreased gray matter volume in the right precentral gyrus extending to the supplementary motor area, while increased in the left cerebellum area 8 were found.

Table 27. Changes of gray matter volume by 10-day mindful learning

Model	Region	Cluster size (in voxels)	MNI			t value
			x	y	z	
Pre - Post	R. precentral gyrus/ R. SMA	9	13.5	-19.5	75	5.076
Post - Pre	L. cerebellum (8)	8	-33	-45	-57	4.615

4. Conclusion

The results showed that mindful learning was associated with better creativity scores as well as increased brain activation in bilateral dorsal and ventral anterior cingulate cortex. Dorsal anterior cingulate cortex involves a top-down control mechanism that contributes to the process of evaluating generated creative ideas. Highly activation of this area may be related to inhabiting the stereotypical thinking in order to explore an original idea. In addition, ventral part of anterior cingulate cortex plays an important role in emotional regulation and self-control. The findings of this study suggest the employed mindful learning intervention contributes to facilitating creativity by enhancing the inhibition of non-creative ideas, self-control, and emotional regulation.

This study found that the participants' gray matter volume (GMV) activation in the right supplementary motor area decreased significantly after receiving mindfulness intervention. The results indicate that the participants reduced sensory nerve actions and planned actions of resource recruitment. However, the degree of activation of the participants in the same brain region was significantly increased after the intervention, and their creative performances were also improved. These findings suggest that, after a 10-day intervention, the brain uses fewer neural resources for efficient neural actions to achieve better creativity performance after the intervention. The findings of this study suggest the employed mindful learning intervention contributes to facilitating creativity by enhancing the inhibition of non-creative ideas, self-control, and emotional regulation.

Conclusion of the project

This project conducted four behavioral studies and two fMRI studies. Study 1 developed five inventories which have good reliability and validity. Followed the instrument development, study 2 explored the effectiveness of technology-oriented mindfulness learning intervention on enhancing creativity. During the one-week experiment. The results showed that the group that was asked to take photos based on their interests and share them on the website as well as the group that was asked to take photos of different categories based on their interests and share the photos on website had better creativity improvement than the group that was asked to take photos based on their interests and uploaded them to the website without sharing the photos. Moreover, those who had a more positive attitude towards using mobile devices to promote creative learning had better creative learning effects. The findings of this study suggested that applying technology-oriented mindfulness learning intervention in daily life has the potential to promote creative learning among college students. Study 3 developed an Ambiguous-photo Imagination Test that included a longer version of twenty test items and a shorter version of ten test items; both tests had good validity and reliability. Study 4 explored the learning effects and cluster profiles of passion in smartphone use, growth creative mindset, fixed mindset, and self-efficacy. The findings revealed that the college students significantly improved their growth-internal and external creativity mindset, harmonious-intrapersonal passion, harmonious-interpersonal passion, and creativity self-efficacy. In addition, the cluster analysis results that included the concerned personal traits emerged three distinctive patterns. Study 5 compared the participants' imagination neural network of ambiguous black-and-white versus color daily life photos. The results indicated some shared activated brain regions for conducting the black-and-white and the color tasks. However, the black-and-white tasks showed more active brain regions than the color photos. The results suggest the black-and-white tasks require more cognitive resources to recognize the shapes and characteristics in the photos and use more neural resources to generate novel and creative ideas. Study 6 examined the effectiveness of a 10-day mindful learning intervention on the neuroplasticity of creative learning. The findings suggest that the brain uses fewer neural resources for efficient neural actions to achieve better creativity performance after the intervention.

To conclude, the findings of this project support that neuroscience helps people understand how to practice the creative process and mindfulness goes hand in hand with creativity (Goh, 2017). The empirical results of this project demonstrate the possibility and valuableness in integrating mind, brain, and learning in creativity.

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一、參加會議經過

The EdMedia World Conference on Educational Media and Technology is an international conference, organized by the Association for the Advancement of Computing in Education (AACE). This annual conference serves as a multi-disciplinary forum for the discussion and exchange. The main theme of this year was EdMedia + Innovate Learning for advancement and innovation. The conference covered the following nine topics: (1) Advanced Technologies for Learning and Teaching; (2) Assessment and Research; (3) Educational Reform, Policy, and Innovation; (4) Evaluation and Quality Improvement Advances; (5) Global Networks, Partnerships, and Exchanges; (6) Innovative Approaches to Learning and Learning Environments; (7) Open Education; (8) Technologies for Socially Responsive Learning; (9) Virtual and Distance Education.

Due to COVID-19, the conference of this year was an online only conference. The conference was from 6/23-6/26. On June 23rd, I watched the presentation "Making connections: Equipping the next generation of teachers for educational technology use". This presentation addresses questions about how to best connect teachers' competencies and institutional culture in the digital age, including which strategies are effective to train teachers? How can they develop the competencies to adequately use technology in specific subject areas? Can we address the complex systemic nature of digital technology integration at the school level? On June 24th, I joined the keynote speech "Quo Vadis TPACK? Scouting the Road Ahead". It talked about the Technological Pedagogical Content Knowledge (TPACK) theories and issues. I also attended the presentation "Digital Fluency: Moving Beyond Literacy to Prepare our Learners to Solve Big, Bold Problems". On June 25th, I joined the presentation "Digital Wayfaring". This presentation proposed an alternative post humanist reading of digital literacies which centers embodiment, materiality, mobilities, and spatiality into our understanding of emergent digital knowledge practices.

On June 26, there were many virtual presentations. I presented two papers: (1) Paper ID #56704: The influences of creativity mindset on self-efficacy in game-based creativity learning; and (2) Paper ID #56705: Enhancing creativity through computer-based mindfulness interventions of aesthetic experience.

Enhancing creativity through computer-based mindfulness interventions of aesthetic experience

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The influences of creativity mindset on self-efficacy in game-based creativity learning

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發表證明

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Association for the Advancement of Computing in Education
Celebrating 30+ Years of Service to the Educational Technology Community

CONFERENCE CERTIFICATE OF PARTICIPATION

Please allow the following to certify that:

Name: Yu-chu Yeh
Organization: Institute of Teacher Education, National Chengchi University

Attended and presented the following papers:

Paper ID #56704: **The influences of creativity mindset on self-efficacy in game-based creativity learning**
Paper ID #56705: **Enhancing creativity through computer-based mindfulness interventions of aesthetic experience**

Conference: EdMedia + Innovate Learning 2020 Online
Dates: June 23-26, 2020
Location: Online, Netherlands.

The EdMedia annual world conference on Educational Media & Technology (EdMedia), sponsored by the Association for the Advancement of Computing in Education (AACE). AACE is a non-profit, international organization whose purpose is to advance the knowledge and quality of learning and teaching at all levels through the encouragement of scholarly inquiry related to information technology and education and the exchange of research results, developments, and their applications through publications and conferences for its members. This conference serves as multidisciplinary forum for the discussion and exchange of information on the research, development, and applications on all topics related to multimedia, hypermedia and telecommunications/distance education. Participation in EdMedia included the Keynote, Invited, Paper, SIG Discussions, Interactive Sessions, Poster and Corporate Demo Sessions of this international forum. All presentation proposals are reviewed and selected by a respected international Program Committee, based on merit and the perceived value for attendees. If any further information is required, please contact the AACE office.

Best regards,

Conference Services EdMedia /AACE Representative

二、與會心得

Due to the COVID-19, the conference was changed to online conference. It's the first time I joined such online international conference. Although digital technology is convenient, I like the face-to-face interaction instead. However, it was a great chance for inspiring ideas for future research in such special time.

三、考察參觀活動(無是項活動者省略)

This an online conference; no visiting activities.

四、攜回資料名稱及內容

Online proceedings.

107年度專題研究計畫成果彙整表

計畫主持人：葉玉珠			**計畫編號：**107-2511-H-004-002-MY2		
計畫名稱：數位科技導向的正念學習介入對提升創造力之效果：神經可塑性之探究					
成果項目			量化	單位	質化 （說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）
國內	學術性論文	期刊論文	0	篇	
		研討會論文	2		1. 丁毓珊、葉玉珠（2020, Oct）。國中生心向與學習適應之關係：以自我調整學習維中介變項。台灣心理學會，中央研究院民族學研究所。 2. 丁毓珊、葉玉珠（2020, Oct）。國中生成長心向課程之學習效果。台灣心理學會，中央研究院民族學研究所。
		專書	0	本	
		專書論文	0	章	
		技術報告	2	篇	1.葉玉珠（2019，5月）。數位科技導向的正念學習介入對提升創造力之效果：神經可塑性之探究(1/2)。科技部專案(MOST 107-2511-H-004 -002 -MY2) 2.葉玉珠（2020，10月）。數位科技導向的正念學習介入對提升創造力之效果：神經可塑性之探究(2/2)。科技部專案(MOST 107-2511-H-004 -002 -MY2)
		其他	0	篇	
國外	學術性論文	期刊論文	1	篇	Yeh, Y.*, Chang, C.-Y., Ting, Y.-S., & Chen, S.-Y. (2020, Sep). Effects of mindful learning using a smartphone lens in everyday life and beliefs toward mobile-based learning on creativity enhancement. Educational Technology & Society, 23(4), 45–58. (IF: 2.086; 5-year IF: 2.720; Rank: 83/263, Education & Educational Research)
		研討會論文	12		1.Yeh, Y.*, Chen, S. Y., Rega, E. M., Lin, C. S., Lin, Y. J., & Hsieh, Nichu. (2019, July). Exploring mediators of mindful learning experience and mastery experience during creativity game-based learning. Paper presented at International Conference on Science Technology and Management, July 18th-19th, 2019, Holiday Inn Los Angeles – LAX Airport, Los Angeles, USA.

					2.Yeh, Y.*, Sai, N. P., & Chuang, C. H. (2020, February). The influence of self-determination on mastery experience in a creativity game-based learning. Paper presented at the Southeast Asian Conference Education, February 7th-9th, Singapore EXPO & MAX Atria, Singapore. (MOST 104-2511-S-004 -002 -MY3) 3.Yeh, Y.* Chen, Y. F., Chang, C. Y., & Ting, Y. S. (2020, February). Implementing mindful learning intervention to enhance creativity. Paper presented at the Southeast Asian Conference Education, February 7th-9th, Singapore EXPO & MAX Atria, Singapore. (MOST 107-2511-H-004 -002 -MY2) 4.Yeh, Y.* & Ting, Y. S. (2020, June). The influences of creativity mindset on self-efficacy in game-based creativity learning. Paper presented at the EdMedia + Innovate Learning 2020 Online, June 23-26, 2020. (MOST 107-2511-H-004 -002 -MY2 & MOST 107-2410-H-004 -079 -SS2) 5.Yeh, Y.*, Hsu, W. C., & Yastrubinskiy, E. (2020, June). Enhancing creativity through computer-based mindfulness interventions of aesthetic experience. Paper presented at the EdMedia + Innovate Learning 2020 Online, June 23-26, 2020. (MOST 107-2511-H-004 -002 -MY2 & MOST 107-2410-H-004 -079 -SS2) 6.Yeh, Y.*, Chang, C. Y., Hsu, W. C., & Chang, J. Y. (2020, July). Can the intervention of SCAMPER bring about changes of neural activation while taking creativity tasks? Paper presented at the European Conference on Education (ECE2020) online, July 16-19, 2020. London, UK. (MOST 107-2511-H-004 -002 -MY2) 7.Chang, C. Y., Yeh, Y.*, Chang, J. Y., & Ting, Y. S. (2020, Oct). The neural plasticity of creativity learning: An intervention of

					mindful learning. Society for NeuroEconomics Virtual 18th Annual Meeting, October 7 - 9, 2020. (MOST 107-2511-H-004 -002 -MY2) 8.Ting, Y. S., Yeh, Y.*, & Chang, J. Y. (2020, Oct.). The mediation effect of hope belief on mindful learning in game-based creativity learning. SITE Interactive Online 2020 Conference, October 26-28, 2020. (MOST 107-2410-H-004 -079 -SS2) 9.Yeh, Y.*, Chang, C. Y., Ting, Y. S., & Hsu, W.C. (2020, Oct). The effect of smartphone-based mindfulness intervention on passion in smartphone use and creativity mindset. SITE Interactive Online 2020 Conference, October 26-28, 2020. (MOST 107-2410-H-004 -079 -SS2) 10.Yeh, Y.*, Ting, Y. S., Chang, H. L., Lin, Y. J. (2020, Oct-Nov). Improvement of elementary school students' creativity mindset through game-based learning. The Asian Conference on Education (ACE2020), October 30, 2020 to November 2, 2020, Toshi Center Hotel, Tokyo, Japan. 11.Sai, N. P.*, & Yeh, Y. (2020). Comparing the Effect of Emotions on Hope Between Vietnamese and Taiwanese College Students. The Asian Conference on Education (ACE2020), October 30, 2020 to November 2, 2020, Toshi Center Hotel, Tokyo, Japan. 12.Sai, N. P.*, & Yeh, Y. (2020). The Influence of Emotion on College Student Resilience in Taiwan. The Asian Conference on Education (ACE2020), October 30, 2020 to November 2, 2020, Toshi Center Hotel, Tokyo, Japan.
		專書	0	本	
		專書論文	0	章	
		技術報告	0	篇	
		其他	0	篇	
參與	本國籍	大專生	0	人次	

計畫人力		碩士生	0		
		博士生	3		張芝雁、張瑞岩、許維欽
		博士級研究人員	0		
		專任人員	3		丁毓珊、陳韻帆、陳思伃
	非本國籍	大專生	0		
		碩士生	0		
		博士生	1		Evgenii Iastrubinskii
		博士級研究人員	0		
		專任人員	0		
其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）			1.2020年與澳洲雪梨大學心理系博士後研究合作進行跨國資料收集與比較。 2.協助第一年聘任的專任助理已順利至美國奧克拉荷馬州立大學博士班。 3.獲國立政治大學107學年度研究特優獎。 4.獲107-108學年度科技部獎勵特殊優秀人才獎勵。 5.與澎湖教育處合辦工作坊，分享創造力教育的理念。		