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Influences of Growth Mindset, Fixed Mindset, Grit, and Self-determination on Self-efficacy in Game-based Creativity Learning

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ABSTRACT: Creativity mindset (CM), grit, and self-determination have been defined as critical motivational variables affecting learners' self-efficacy. Therefore, this study pioneers the examination of the relationship between these motivational variables and creativity self-efficacy (CSE) during game-based learning. A Creativity Mindset Inventory (CMI) and a game-based learning intervention were employed. Participants for developing the CMI were 281 3rd to 6th graders, and those for the intervention were 114 3rd and 4th graders. The result revealed that the CMI included four constructs (growth-internal control, growth-external control, fixed-internal control, and fixed-external control). Moreover, the employed intervention enhanced the children's growth CM and CSE. Regression analysis results suggest that self-determination mediates the influence of growth CM and grit on CSE. Additionally, growth CM, especially the growth-internal control CM, is a powerful predictor of self-determination and CSE. In contrast, fixed CM (the overall fixed CM, the fixed-internal control CM, or the fixed-external control CM) does not have any significant influence on self-determination or CSE. Notably, the findings of this study support that growth CM can be enhanced through a well scaffolded educational game. This study contributes to the field of game-based learning by developing a CM inventory, demonstrating a growth CM intervention, and clarifying influential factors to CSE during game-based training. While game-based learning has become popular among elementary school students, the findings of this study provide important insights into the design of game-based learning and creativity training.

Keywords: Creativity, Game-based learning, Growth mindset, Grit, Self-determination

1. Introduction

In well-known theories of creativity (Amabile, 1996; Sternberg & Lubert, 1999), motivation is regarded as a critical element for creative learning. Creativity mindset (CM), grit, and self-determination have been defined as critical motivational variables (e.g., Karwowski, 2014; Hochanadel & Finamore, 2015; Yeh et al., 2020;) affecting learners' self-efficacy. In addition, recent studies have proposed that well-scaffolded digital game-based learning (DGBL) facilitates learning outcomes and motivation effectively (e.g., Bainbridge et al., 2022; Yang & Chen, 2021). We, therefore, tried to examine how these motivational variables stimulate creativity self-efficacy (CSE) during game-based learning.

CSE refers to one's belief in his/her ability to produce creative ideas or solutions and confidence in achieving creative performance (Hass et al., 2016). CM refers to how people perceive their creative ability; it has been divided into the growth and the fixed mindset (Karwowski, 2014). However, identifying more specific types of CM may be required for effective training. Grit, a recently popular concept in psychology, has never been studied in game-based learning; it is defined as the perseverance and passion for long-term goals (Hochanadel & Finamore, 2015; Wang et al., 2018). Self-determination involves the concepts of autonomy, relatedness, and competence (Ryan & Deci, 2000). When self-determination needs are satisfied, personal growth and optimal functioning can be achieved (Millsa et al., 2018).

With the rapid development of technology, creativity has been recognized as a crucial ability (Puccio, 2017). As such, cultivating creativity to adapt to modern society is an imperative educational objective for children. Although many short-term intervention programs have been implemented to enhance children's creativity (e.g., Hoffmann et al. 2021), there is still a relative lack of integration of digital games in creativity training (Yeh et al., 2019; Stolaki & Economides, 2018). Digital game-based learning is effective in stimulating children's problem-solving, critical thinking, and specifically, creativity (Behnamnia et al., 2020; Hooshyar et al., 2019). Such promising game components to foster children include fantasy, curiosity, and challenge (Behnamnia et al., 2020) that target intrinsic motivation among children.

To date, few digital game-based learning interventions have been developed to enhance children's growth CM, even though it has been viewed as a new form of learning with great potential in recent years (Chen et al., 2020; Israel-Fishelson et al., 2021). In the only qualitative study (White & McCoy, 2019) we found, the results showed that students who acquired a growth mindset in creative mathematic game-based learning developed a positive learning attitude and increased their self-efficacy. A well-designed game-based intervention can effectively enhance children's mindful learning, enjoyment, self-determination, and mastery experience while fostering creativity (Yeh et al., 2019, Yeh et al., 2020). These cognitive processes are considered in our digital game-based learning to enhance children's CM. Additionally, no study has examined how children's CM and grit influence their self-determination and, further, affect their CSE during game-based creativity learning. This study attempted to pioneer such research. To achieve our goal, we first developed the Creativity Mindset Inventory (CMI). Then, we employed an intervention of growth CM through game-based learning, by which we investigated the relationships of the concerned variables after the intervention.

2. Theoretical framework

2.1. Creativity mindset constructs

2.1.1. Development of creativity mindset theory

The theory of mindset was originated by examining people's implicit beliefs of intelligence (Dweck, 2007). Based on the malleability and stability of traits, mindsets can be divided into a fixed mindset and a growth mindset (Dweck, 2007; Dweck, 2015). More recently, some researchers have implemented the concept of mindset in creativity studies, which is known as "creativity mindset" (CM) (Karwowski, 2014). CM refers to beliefs or implicit theories about the nature of creativity, and it has been divided into the growth and the fixed creativity mindset (e.g., Hass et al., 2016; Karwowski, 2014; Karwowski et al., 2019; Puente-Díaz & Cavazos-Arroyo, 2019). People with a fixed CM regard creativity as innate and unchangeable. In contrast, people who hold a growth CM see creativity as malleable and able to be developed through learning or practice.

To date, it is still a lack of consensus on whether the growth CM and the fixed CM are two independent constructs or two opposites of the same continuum constructs. O'Connor et al. (2013) considered CM a construct with one end of the continuum constituting the fixed CM and the other the growth CM. On the other hand, some researchers (e.g., Hass et al., 2016; Karwowski; 2014; Karwowski et al., 2019) supported that the fixed and the growth CM are two independent dimensions. Recent studies have shown more evidence supporting the independent-dimension theory (Karwowski et al., 2019; Puente-Díaz & Cavazos-Arroyo, 2017; Zhou et al., 2020). For example, Karwowski (2014) developed a CM inventory that includes two relatively independent yet negatively correlated scales: the growth CM and the fixed CM. Most CM studies have employed such a two-type theory of CM. Moreover, most existing CM inventories have been developed based on adult samples. This study, therefore, sought to identify children's CM and to further understand the relationship between CM and its outcome variables.

2.1.2. An integrated CM theory with learning plasticity and locus of control

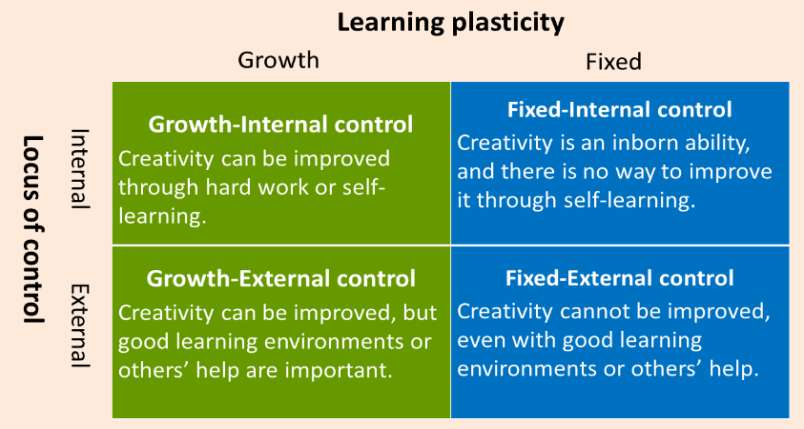
The concept of locus control, derived from the attribution theory, was first proposed by Heider (1958). The attribution theory explains how people interpret the causes of events and how such explanations can be linked with behavior and thinking. Based on a series of attribution studies (Kelley, 1973; Rotter, 1966), Weiner (1985) proposed that causes of success and failure can be divided into three dimensions: locus (internal or external factors), stability (fluctuate or constant), and controllability (controllable or non-controllable). In this study, we tried to integrate the concept of locus of control into our CM theory.

Rotter (1966) defined locus of control as an individual's perception of reinforcement in their life; people interpreted reinforcement in two ways, namely, internal locus of control and external locus of control. Internal control people tend to perceive the outcome as an event depending on their efforts, and they can do anything if they set their mind to it. In contrast, external control people are inclined to believe that the outcome is controlled by external factors, such as chance, fate, and powerful others (Rotter, 1966; Weiner, 1985).

A few researchers have suggested that the concept of mindset overlaps with that of locus of control (Burgoyne et al., 2018; Huillery et al., 2021; Tan et al., 2021). For example, Burgoyne et al. (2018) found a significant relationship between mindset and locus of control. They suggested that growth mindset training could enhance

internal locus of control, challenge-approach motivation, and self-determination. Moreover, internal locus of control was found to be related to creativity performance (Pannells & Claxton, 2008). People with an internal locus of control have a stronger motivation for improvement and try more for getting innovative thoughts and actions than those with an external locus of control (Asgari & Vakili, 2012). These findings advocate that people with growth CM tend to hold an internal locus of control. However, it has been claimed that both internal factors (e.g., knowledge, imagination, attitude, skills) and external factors (e.g., resources, culture, environment, and habitat) are critical to creativity improvement and creativity mindsets (Seelig, 2015; Sternberg & Lubart, 1999; Yeh, 2017). Accordingly, instead of seeing CM as two independent constructs (the growth vs. the fixed mindset), we propose the concept of integrating locus of control into CM. People with different attitudes towards learning plasticity (the growth CM vs. the fixed CM) may simultaneously hold an internal locus of control and an external locus of control. This study, therefore, tried to combine the concepts of learning plasticity and locus of control to develop a more elaborate instrument for measuring CM. Specifically, we propose the following concepts: (1) People who hold a growth-internal control (GI) CM believe that self-learning can improve creativity. (2) People who hold a growth-external control (GE) CM believe that creativity can be enhanced under supportive learning environments or through others' help. (3) People who hold Fixed-Internal control (FI) CM believe that creativity is an inborn ability and that there is no way to improve it through self-learning. (4) People who hold a fixed-external control (FE) CM believe that creativity cannot be improved even under supportive learning environments or with others' help. Notably, the growth CM comprises GI and GE, whereas the fixed CM consists of FI and FE (see Figure 1).

Figure 1. The framework of two-dimensional creativity mindsets



2.2. CM and grit

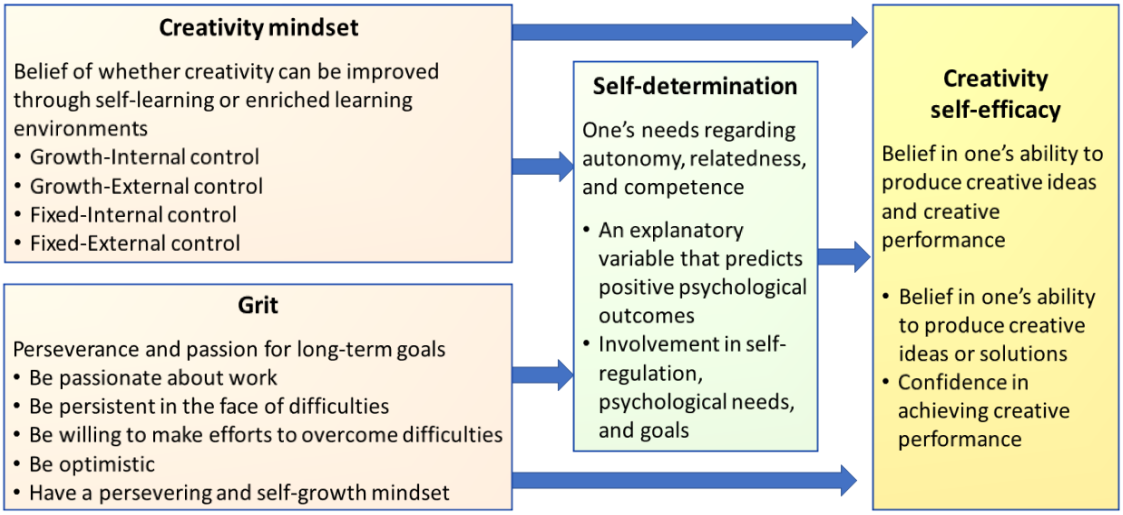
Grit refers to an individual's passion for long-term goals (Duckworth et al., 2007). Duckworth et al. (2007) conceptualized grit as a two-factor structure, namely consistency of interests and perseverance of effort. Empirical findings revealed that grit is related to motivation variables, including future-oriented motivation, self-efficacy, task values, and goal orientations outcomes (Duckworth et al., 2007), especially for grit's perseverance component (Allen et al., 2021; Muenks et al., 2018).

Related studies have shown that individuals with a stronger growth mindset tended to be grittier (Hochanadel & Finamore, 2015). They were more willing to put in efforts to overcome difficulties and had a greater chance of achieving long-term goals (Burgoyne et al., 2018). Similarly, it was found that a growth mindset played an essential role in cultivating a student's trait of grit (Wang et al., 2018). While previous studies have identified the relationship between grit and mindset (Burgoyne et al., 2018; Wang et al., 2018; Zhao et al., 2018), less is known about the association between grit and CM. In studies of personal creativity traits, it has been found that the key concepts of grit (i.e., the passion for long-term goals, consistency of interest, and perseverance of efforts) were central personal traits of creative people (Fisher & Amabile, 2009; Grohman et al., 2017). Creative individuals are persistent and passionate about their work (Fisher & Amabile, 2009); such passion and perseverance successfully predict their creativity (De Clercq et al., 2017). We, therefore, assumed that mindset and grit would interact and then influence the learning of creativity.

2.3. CM, grit, self-determination, and CSE

Creativity self-efficacy (CSE) refers to the belief in one's ability to produce creative ideas or solutions and the confidence in achieving creative performance (Yeh & Lin, 2018; Hass et al., 2016). It has been found that students with a growth mindset usually have stronger motivation to participate and persevere in a task (Zander et al., 2018), whereas children with a fixed mindset have a lower level of self-efficacy (Lee et al., 2022). In the domain of creative studies, it has been suggested that beliefs influence self-perceptions of creativity about the nature of creativity, which involves a person's implicit theory about whether the creative ability is set and unchangeable or can be nurtured. Higher scores on beliefs in the malleability of creativity predicted better scores on a divergent creativity thinking test (O'Connor et al., 2013). These findings suggest that a growth CM may contribute to CSE during game-based creativity learning. Few studies have investigated how grit might be related to children's CSE, especially in the context of game-based learning. In a study investigating children's academic success, Usher et al. (2019) suggested that grit is related to early adolescents' success, particularly when self-efficacy is simultaneously considered. Related studies (Alhadabi & Karpinski, 2019; Muenks et al., 2018) also found that grit correlated positively with students' self-efficacy. We proposed that during game-based creativity learning, grit would help students stay focused and maintain their passion for learning, which would further contribute to CSE. In addition to growth CM and grit, self-determination may influence CSE during game-based creativity learning. On the other hand, fixed CM may have a negative influence on self-determination and CSE. Self-determination has been regarded as a type of intrinsic motivation; it is closely related to self-regulation, psychological needs, and goals (Deci & Ryan, 2008). It has been found that self-determination and self-efficacy are closely related (Martinek & Kipman, 2016).

Figure 2. The theoretical framework of this study



To date, no study has investigated the relationship between CM, grit, self-determination, and CSE during digital game-based learning when interventions of growth CM are employed. Burgoyne et al. (2018) found that measures of mindset, grit, and locus of control loaded onto a common self-determination factor, and the intervention of mindset enhanced learners' growth mindset and self-determination. Participants who received a mindset intervention reported higher scores on growth mindset, internal locus of control, challenge-approach motivation, and self-determination. Similarly, it was found that a growth mindset intervention had a positive influence on the motivation of adolescents (Rhew et al., 2018) and a growth mindset was positively correlated with self-efficacy, task values, and goal orientation (Bai et al., 2021; Dweck, 2007). Additionally, research findings have suggested that growth CM is positively related to creativity performance (Royston & Reiter-Palmon, 2019) and CSE (Puente-Díaz & Cavazos-Arroyo, 2017); in contrast, fixed CM is negatively related to these variables (Karwowski et al., 2019; Puente-Díaz & Cavazos-Arroyo, 2019). Given the aforementioned relationship between growth CM, fixed CM, grit, self-determination, and self-efficacy as well as the negative relationship between fixed CM and growth CM (Hass et al., 2016; Karwowski, 2014; Karwowski et al., 2019; Lee et al., 2022), we assumed that grit and growth CM would enhance CSE directly or indirectly through self-determination, whereas fixed CM would decrease CSE directly or indirectly through self-determination during game-based creativity learning (see Figure 2).

2.4. The present study

To explore the relationship between growth CM, fixed CM, grit, self-determination, and CSE during game-based creativity learning, we developed the Creativity Mindset Inventory and designed a 5-session game-based creativity learning program as the intervention to enhance growth CM and CSE. Empirical findings (Rissanen et al., 2019) have suggested that process focus, mastery orientation, persistence, and individualized student support are core features of growth mindset pedagogy. A recent study (Yeh et al., 2020) has also suggested that the enjoyableness of the game, the encouraging feedback, and the autonomy of gameplay facilitate pupils' motivation and confidence, which further contributes to their improvement of creativity. Therefore, a growth CM and CSE can be built upon mastery and successful experiences. We incorporated these concepts or strategies into our intervention in this study. Notably, since it has been suggested that people with an internal locus of control have a stronger motivation for improvement than those with an external locus of control (Asgari & Vakili, 2012), we assumed that the growth-internal control CM (GI) would be a better predictor of self-determination and CSE than the growth-external control CM (GE). On the other hand, the fixed-internal control CM (FI) would be more detrimental to self-determination and CSE than the fixed-external control CM (FE). The following hypotheses were proposed:

H_1: Growth CM (especially GI) and grit would positively influence self-determination and CSE during game-based creativity learning.

H_2: Fixed CM (especially FI) would negatively influence self-determination and CSE during game-based creativity learning.

H_3: Self-determination would positively influence CSE during game-based learning.

3. Method

3.1. Participants

In developing the CMI, we included 281 3rd to 6th graders (150 boys and 131 girls) from six elementary schools in Taiwan to conduct reliability analysis and confirmatory factor analysis (CFA). Among these pupils, 155 were 3rd and 4th graders (55.2%), and 126 were 5th to 6th graders (44.8%). Written informed consent was obtained from all participants' parents, and each participant was rewarded with a gift valued at 5 USD. In examining path models, 114 3rd and 4th graders (58 boys and 56 girls) from four elementary schools in Taiwan participated in the experimental instruction.

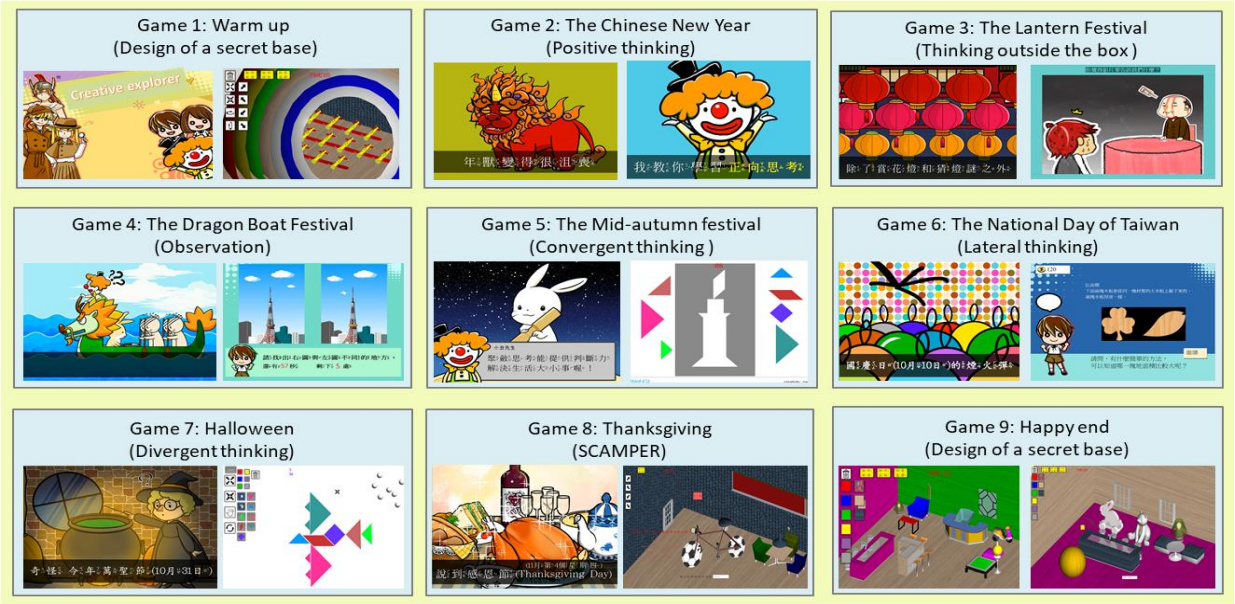
3.2. Instruments

This study employed a game-based creativity learning system and four 6-point Likert type scales (see below) from 1 point to 6 points, representing "strongly disagree" to "strongly agree." Instead of using a 5-point scale, a 6-point Likert scale was employed to avoid the tendency of choosing the middle score of "3." We also designed a reflection questionnaire to understand further the participants' feelings toward the game-based creativity learning program.

3.2.1. Creativity learning system

The learning system of "Digital Game-Based Learning of Creativity-Version A" (DGLC-A), developed for elementary school students (Yeh et al., 2019), was adapted and employed as an instrument to enhance growth CM. The DGLC-A, consisting of nine games, was a story- and game-based learning program. Each game ranged from 10 minutes to 15 minutes. The DGLC-A consisted of the learning of comprehensive creativity strategies and dispositions, such as 3-D creative design, positive thinking and attitude, thinking outside the box, sensitivity in observation, divergent thinking, convergent thinking, lateral thinking, SCAMPER (substitution, combination, adaptation, modification, putting to other uses, elimination, and reversing) and mind mapping (see Figure 3 for example screens). These creativity strategies or dispositions were practiced through 3-D drawing, animations, short stories, open-ended questions, observations, product creation, and problem-solving. We expected that, through mastering creativity skills and positive thinking, the participants would feel self-determined and enhance their growth CM and CSE.

Figure 3. Example screens of the digital game-based learning of creativity-A



3.2.2. Creativity Mindset Inventory (CMI)

The CMI originally included 16 test items with four items in each of the following dimensions: GI, GE, FI, and FE. After reliability and construct validity analysis, one test item in each category was deleted. Twelve test items remained and have good reliability and construct validity (see result session for details). The data was collected in class by the teacher with no time constraints. More details are shown in the results session.

3.2.3. The Grit Scale

An adapted Grit Scale was employed to measure the participants' trait of grit. The original Grit Scale, with 12 items, was developed by Duckworth et al. (2007). With permission, the Grit Scale was translated, adapted, and validated by reliability and factor analysis based on 338 3rd to 6th graders. Four items were deleted after exploratory factor analysis and reliability analysis. The adapted Grit Scale included two factors: perseverance of effort (4 items) and consistency of interest (4 items). The test items included statements such as "I finish whatever I begin" and "New ideas and projects won't distract me from previous ones." The Cronbach's α coefficients for the whole inventory and two factors (perseverance of effort and consistency of interest) were .906, .872, and .813, respectively (Yeh, 2020).

3.2.4. Inventory of self-determination in digital games

The Inventory of Self-Determination in Digital Games (ISD-DG) (Yeh et al., 2019) was employed to measure the participants' level of self-determination during the game-based creativity learning. The ISD-DG, with 13 items, consists of two factors: autonomy and self-regulation (7 items) and competence (6 items). The test items included statements such as "I had many chances to make free choices" and "I could achieve the scores or goals that I set." The Cronbach's α coefficients for the two factors and the total score of the IDS-DG were .887, .881, and .933, respectively.

3.2.5. Inventory of self-efficacy in creativity digital games

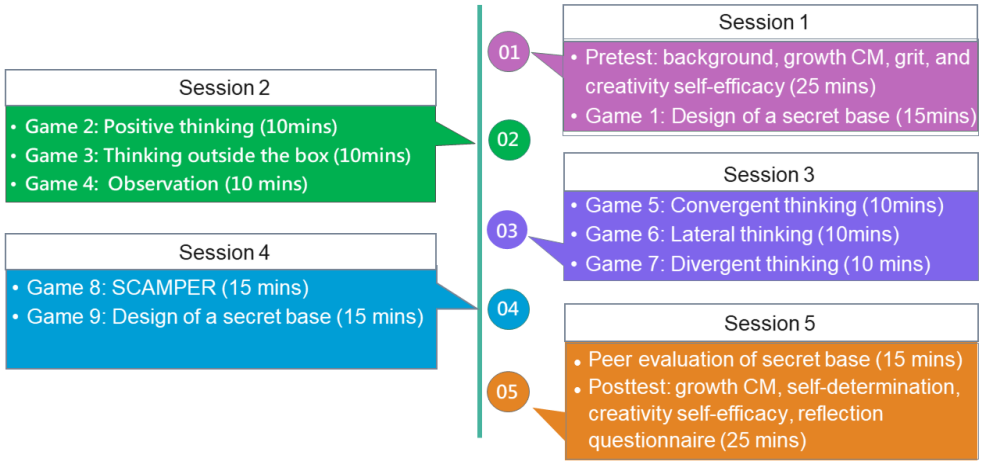
The Inventory of Self-Efficacy in Creativity Digital Games (IS-CDG) (Yeh & Lin, 2018) was employed to measure the participants' level of self-efficacy after game-based creativity learning. The IS-CDG contains nine items, including two factors: the ability to generate creative ideas (6 items) and achievement of creative performance (3 items). The test items included statements such as "I believe that I can come up with many creative ideas" and "I am more creative than most of my classmates." The Cronbach's α coefficients for the two factors and the total score of the ISE-DG were .908, .844, and .927, respectively.

3.3. Experimental design and procedures

All participants completed the experiment in the computer laboratory at their school during their flexible learning time or computer class. The participants were asked to complete nine games in the DGLC-A in 5 class sessions within a week; each session was 40 minutes. Before starting the session, all participants took the pretest, including background information, growth CM, grit, and CSE. After completing the DGLC-A, students were asked to conduct peer evaluation, then completed the posttest, which included growth CM, self-determination, CSE, and the reflection questionnaire. Participants of the same class completed each session as a group (see Figure 4).

Aside from embedding strategies to boost students' creative ability and dispositions, the features of DGLC-A also incorporated other instructional strategies, including scaffolding to challenge their creativity skills, offering chances for self-determination (free choice of game order), providing constructive feedback for answers, utilizing verbal encouragement for performance, and providing peer evaluation for creative design. Peer evaluations were employed to rate the popularity and creativity of the designed products in game 1 and game 9, during which observational learning was expected. These teaching strategies were employed to potentially enhance the participants' growth CM, which is in line with the suggestions that mindset can be enhanced through process focus, mastery orientation, persistence, and individualized student support (Rissanen et al., 2019). Specific experimental procedures are illustrated in Figure 4.

Figure 4. Procedures and interventions for the experiment



4. Results

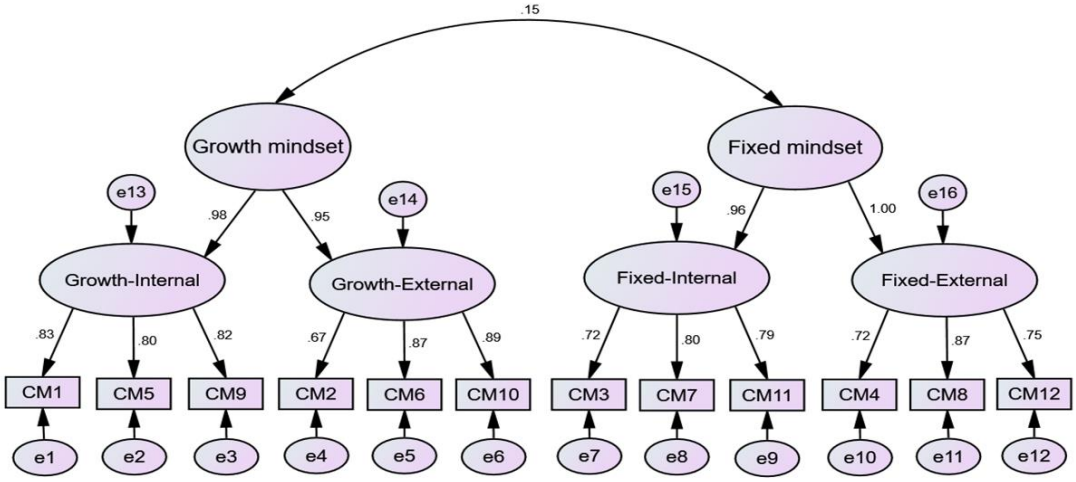
4.1. The development of the CMI

The CMI includes the growth CM (GE and GI) and the fixed CM (FI and FE). The exploratory factor analysis (EFA) was first conducted to examine the construct validity of the CMI using a random split-half of the sample (N = 135, 62 boys and 73 girls). Then, the confirmatory factor analysis was employed to validate the CMI using the second split-half sample (N =146, 88 boys and 58 girls). Principal Component Analysis and direct varimax were employed in factor extraction and rotation when conducting EFA (see Table Appendix 1). With factor loadings ranging from .409 to .909, 71.22% of the total variance was explained by GI and GE, and 86.03% of the total variance was explained by FI and FE. Regarding internal-consistency reliability, the Cronbach's α coefficients for growth CM, GI, and GE were .911, .859, and .850, respectively. The Cronbach's α for the fixed CM, FI, and FE were .952, .877, and .924, respectively. Moreover, the item-total correlation coefficients ranged from .622 to .907.

A second-order CFA model (see Figure 5) was examined based on variance-covariance matrices and maximum likelihood estimation through Amos. The following criteria were employed to examine the model fit: a non-significant chi-square degree of freedom ratio (χ^2/df), the comparative fit index (CFI) higher than .90, the root mean square error of approximation (RMSEA) lower than .10, and the standard root mean squared residual (SRMR) less than .08 (Iacobucci, 2010; Kenny et al., 2015). Our CFA results were as follows: χ^2 (N = 146, df = 51) = 107.832, p < .001, the SRMR = .070, the RMSEA = .088, and the CFI = .947. Due to the ratio of χ^2 is sensitive to the sample size, $\chi^2/df \leq 3$ is acceptable (Iacobucci, 2010). The composite reliability (ρ_c) for GI, GE,

FI, and FE were .86, .86, .82, and .83, respectively. The average variance extracted (ρ_v) values for the four factors were .67, .67, .60, and .62, respectively. These results support that the CMI has good reliability and construct validity; moreover, M is composed of growth and fixed CM, with two sub-types of CM (internal-control and external control) under each construct.

Figure 5. Confirmatory factor analysis results of the inventory of creativity mindset



Lastly, using all the samples (N = 281) to conduct Pearson correlation analysis, we found that the total score of the growth CM and the fixed CM were slightly correlated (r = .213, p < .001). GI and GE were moderately correlated (r = .433, p < .001). While GE was moderately related to FI or FE, GI was not related to any type of fixed mindset. On the other hand, FI and FE were highly correlated (r = .841, p < .001) (see Table 1).

Table 1. The correlations among the growth CM, the fixed CM, and the four sub-types of CM

Variable	FI	FE	Fixed CM	GI	GE	Growth CM
FI	1					
FE	.841***	1				
Fixed CM	.958***	.961***	1			
GI	-.046	-.054	-.052	1		
GE	.400***	.377***	.405***	.433***	1	
Growth CM	.214***	.195**	.213***	.841***	.852***	1

Note. $^{**}p < .01$; $^{***}p < .001$.

4.2. Preliminary analysis of intervention

Since the relationships of the concerned variables were investigated through the game-based learning intervention we developed, it was necessary to examine whether the vehicle was effective. Therefore, we conducted a repeated measure analysis of variance to separately examine whether the participants enhanced their growth CM (GI and GE) and CSE after the game-based creativity learning. The results showed that the participants' growth CM had leveled up, $F(1, 113) = 7.463$, $p = .007$ $\eta^2_p = .062$, and $F(1, 113) = 8.614$, $p = .004$, $\eta^2_p = .071$ for GI and GE, respectively. In addition, the results showed that the participants' overall CSE had been enhanced, $F(1, 113) = 4.860$, $p = 030$, $\eta^2_p = .041$ (see Figure 6 for Ms and SEs). These findings suggest that the game-based learning intervention was effective.

4.3. Relationship of CM, grit, self-determination, and CSE

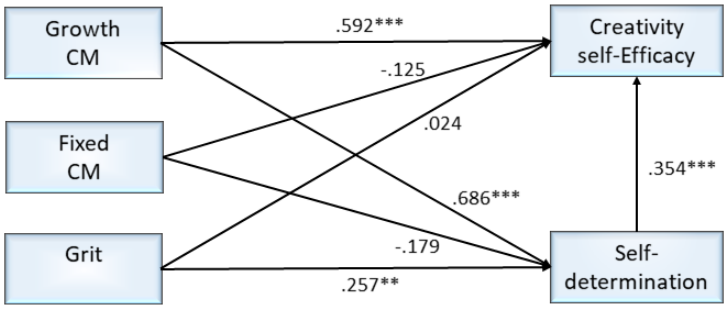
To investigate the relationships between grit, CM, self-determination, and CSE after game-based learning, we conducted stepwise multiple regression analyses. The factor loadings, Cronbach's alpha, and composite reliability (CR) were assessed for the internal consistency; the convergent validity of the scales based on the average variance extracted (AVE) was also measured (see Table 2). A mean-centered approach was employed for each construct prior to the analysis to support the use of all the information (Marsh et al., 2007).

Results of stepwise regression analyses revealed that when using growth CM, fixed CM, and grit to predict self-determination, only GI and grit could significantly predict self-determination, $F(1, 111) = 48.165$, $p < .001$; the

variance explained was 46.5 %. When using growth CM, fixed CM, grit, and self-determination to predict CSE, only growth CM and self-determination could significantly predict CSE, $F(2, 111) = 91.064$, $p < .001$; the variance explained was 61.5 % (see Table 3). Figure 6 visualized the results from the regressions analyses.

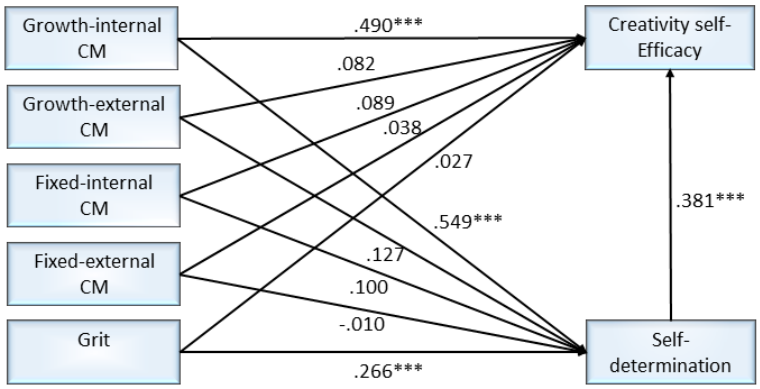
When using the two constructs of growth CM, the two constructs of fixed CM, and grit to predict self-determination, only GI and grit could significantly predict self-determination, $F(1, 111) = 48.307$, $p < .001$; the variance explained was 46.5 %. When using the two constructs of growth CM, the two constructs of fixed CM, grit, and self-determination to predict CSE, only GI and self-determination could significantly predict CSE, $F(2, 111) = 91.398$, $p < .001$; the variance explained was 61.5 %. (see Table 4). Figure 7 visualized the results from the regressions analysis.

Figure 6. The standardized regression coefficients of the overall growth CM, fixed CM, grit, and self-determination on CSE



Note. $^{**}p < .01$. $^{***}p < .001$.

Figure 7. The standardized regression coefficients of the two constructs of growth CM, the two constructs of fixed CM, grit, and self-determination on CSE



Note. $^{**}p < .01$. $^{***}p < .001$.

Table 2. The factor loadings, Cronbach's alpha, CR, and AVE values of the model

Construct	Factor loadings	Cronbach's α	CR	AVE
Growth CM	.699 to .833	.873	.904	.613
Growth-external control (GE)	.784 to .835	.759	.861	.675
Growth-internal control (GI)	.846 to .880	.827	.896	.743
Fixed CM	.854 to .935	.958	.966	.828
Fixed-external control (FE)	.924 to .947	.925	.952	.869
Fixed-internal control (FI)	.898 to .934	.904	.940	.839
Grit	.458 to .833	.850	.886	.501
Perseverance	.549 to .854	.727	.830	.555
Consistency of interest	.572 to .789	.769	.854	.600
Self-determination	.716 to .844	.955	.960	.651
Autonomy & self-regulation	.717 to .869	.915	.932	.665
Competency	.761 to .868	.915	.934	.703
Creativity self-efficacy	.808 to .907	.956	.962	.739
Ability	.838 to .905	.947	.958	.791
Achievement	.926 to .943	.926	.953	.872

Table 3. Result of multiple regression analyses with the overall growth CM and fixed CM

Model	IVs	β	t	p	VIF	R	R^2	F	R^2 Change	F change
Self-determination as the dependent variable										
1	Growth CM	.635	8.702***	.000	1.000	.635	.403	75.732***	.403	75.732***
2	Growth CM	.550	7.481***	.000	1.119	.682	.465	48.165***	.061	12.692***
	Grit	.262	3.563***	.001	1.119					
CSE as the dependent variable										
1	Growth CM	.731	11.343***	.000	1.000	.731	.535	128.658***	.535	128.658***
2	Growth CM	.489	6.467	.000	1.676	.788	.621	91.064***	.087	25.420***
	Self-determination	.381	5.042	.000	1.676					

Note. ***$p < .001$.

Table 4. Result of multiple regression analyses with factors of growth CM and fixed CM

Model	IVs	β	t	p	VIF	R	R^2	F	R^2 Change	F change
Self-determination as the dependent variable										
1	GI	.686	6.366***	.000	1.000	.634	.402	75.205***	.402	75.205***
2	GI	.549	7.496***	.000	1.113	.682	.465	48.307***	.064	13.210***
	Grit	.266	3.635***	.000	1.113					
CSE as the dependent variable										
1	GI	.732	11.355***	.000	1.000	.732	.530	128.940***	.535	128.940***
2	GI	.490	6.494***	.000	1.671	.789	.615	91.398***	.087	25.569***
	Self-determination	.381	5.057***	.000	1.671					

Note. ***$p < .001$.

5. Discussion

5.1. Development of the CMI

Mindset is typically divided into a growth mindset and a fixed mindset (Dweck, 2007). Some researchers assume that the growth mindset and the fixed mindset are independent factors (e.g., Karwowski, 2014), whereas some postulate that people may endorse both mindsets depending on circumstances (Hass et al., 2016). In this study, we propose a 2-dimensional CM theory (learning plasticity and locus of control) in which four types of mindsets are identified: Growth-Internal control (GI), Growth-External control (GE), Fixed-Internal control (FI), and Fixed-External control (FE). The results of this study suggest that the CMI has good reliability and construct validity. Additionally, the results of second-order CFA support our two-dimensional constructs of CM. The results support the claim that mindset overlaps with that of locus of control (Huillery et al., 2021; Tan et al., 2021), growth mindset and internal locus of control are related (Price et al., 2018), and both internal factors and external factors are critical to creativity improvement and creativity mindsets (Seelig, 2015; Yeh, 2017).

Correlation analyses suggest that the overall growth CM and fixed CM have a low positive correlation. However, while GE has a moderate positive relation with FI and FE, GI did not have such a positive relation. These results manifest the importance of our attempt to identify specific types of CM beyond overall growth and fixed CM. The findings suggest that children may simultaneously hold the growth CM and the fixed CM. Although these two concepts are relatively independent (Puente-Díaz & Cavazos-Arroyo, 2019), they are not necessarily the opposite. The results support Karwowski's (2014) argument that people can hold both an entity and an incremental view of creativity; they can be convinced that great creators are enabled by an inborn power and agree that personal effort can increase their creative potential.

Moreover, this study found that the belief that CM can be improved in an enriched environment or through others' help (i.e., Growth-External control CM), in a way, overlaps with fixed CM. This result does not support the findings of Hass et al. (2016), in which fixed and growth mindsets were negatively related in a college student sample. Our participants were 3rd and 4th-grade students. Previous findings that background factors (e.g., age, life experience) affect people's locus of control development (Cummins & Nistico, 2002; Pannells & Claxton, 2008) may explain the difference. The positive relationship between growth-external CM and fixed CM may imply that children perceive external resources as restrictions they cannot control. How to transform such a mindset of limitation into resources has become vital. Altogether, the findings of this study suggest that, although the four types of CM can be explained by two factors (growth CM and fixed CM), the four-factor structure can better describe children's CM and children's beliefs about growth fixed CM co-exist.

5.2. Relationship of growth CM, fixed CM, grit, self-determination, and CSE

Before testing our hypothesis regarding the relationship between growth CM, fixed CM, grit, self-determination, and CSE during game-based learning, we examined the effects of the game-based intervention. This process ensures a valid intervention and provides a reliable basis for our further investigation of the relationship among the concerned variables. The results suggest that our incorporated strategies (i.e., task design, scaffolding, self-determination opportunities, constructive and immediate feedback, verbal encouragement, and peer evaluation) in the DGLC-A successfully boost the children's growth CM and CSE. These features effectively enhanced pupils' growth CM and CSE during game-based learning. The results also align with past findings that game-embedded animations effectively promote conceptual understanding (Bainbridge et al., 2022), and adequately integrating learning strategies into digital games can effectively improve students' learning achievement (Yang & Chen, 2021).

In this study, we proposed three hypotheses to examine the relationship between growth CM, fixed CM, grit, self-determination, and CSE. The findings of multiple regression analyses suggest that growth CM (especially GI) and grit positively influence self-determination and CSE during game-based learning; moreover, self-determination positively influences CSE during game-based learning. These results support our hypotheses 1 and 3. However, our hypothesis 2 is not supported. We found that fixed CM could not predict self-determination or CSE, which is consistent with Karwowski's (2014) finding. However, the finding is contradictory to Lee et al.'s (2022) finding that children's fixed mindset negatively influences their self-efficacy. Specifically, the findings of this study suggest that growth CM (especially the GI) is a strong predictor of self-determination and CSE, whereas the overall fixed CM or the two constructs of fixed CM cannot predict self-determination or CSE during game-based learning. These results also suggest that enhancing growth-internal CM is critical to pupils' development of CSE.

To date, no study has examined the relationship between growth CM, grit, self-determination, and CSE during game-based learning. The relationship between grit, growth CM (especially GI), and CSE found in this study support previous findings that growth mindset and self-efficacy are related (Karwowski & Kaufman, 2017; Price et al., 2018), and grit is positively related to self-growth mindset (Hochanadel & Finamore, 2015). Our findings also support that a growth mindset and grit are interconnected dispositions (Keesey et al., 2018), grit correlated positively with students' self-efficacy (Alhadabi & Karpinski, 2019; Muenks et al., 2018), and a growth mindset, grit, and SD are closely associated (Burgoyne et al., 2018). However, we found that growth CM (especially GI) was a more important predictor of self-determination and CSE than grit after the game-game-based learning.

Notably, the findings in the regression models suggest that self-determination serves as a mediator of growth CM and creativity self-efficacy during game-based creativity learning. Two major indicators of self-determination are autonomy and competence (Ryan & Deci, 2000). When people believe that creativity can be improved, they may be more confident and willing to take challenges to pursue autonomy and obtain competencies during game-based learning, by which their CSE is enhanced. These results are in line with past findings that self-determination and self-efficacy are positively related (Develos-Sacdalan & Bozkus, 2018) and that grit is important in learning outcomes (Duckworth, & Quinn, 2009; Muenks et al., 2018). The results also support that self-determination (Millsa et al., 2018) is critical to the effectiveness of game-based learning. When self-determination needs are satisfied, personal growth and optimal functioning can be achieved (Millsa et al., 2018).

6. Conclusions

As creativity is crucial to future success and growth CM is critical to creative learning, there is a need to develop an enjoyable growth CM intervention to help children build up their CSE. Meanwhile, understanding influential factors in such interventional learning is essential. The existing construct of CM (the growth vs. the fixed CM) may not be specific enough to identify children's CM and, accordingly, provide effective interventions. Therefore, we proposed four types of CM (GE, GI, FI, and FE) under the growth and the fixed CM construct, by which we developed the Creativity Mindset Inventory (CMI) based on a 2-dimensional CM (learning plasticity and locus of control) theory and developed a game-based learning intervention. How growth CM, fixed CM, grit, and self-determination may influence CSE was examined. The results suggest that the CMI is a valid instrument for measuring children's CM, and it can help distinguish children's specific beliefs toward CM.

In addition, this study contributes to game-based learning by clarifying the relationships among different types of growth CM and fixed CM, grit, self-determination, and CSE during game-based creativity learning. The results suggest that self-determination is a vital mediator between the concerned variables, which provides evidence for

learning processes. This study also sheds light on how growth CM (especially GI) can be improved to enhance CSE in game-based creativity learning through embedded concrete instructional strategies. As game-based learning has become popular among elementary school students during the COVID-19 pandemic era, the findings of this study provide important insights into the design of game-based learning and creativity training.

7. Limitations and implications

Because the perceptions of self-determination during game playing cannot be measured before the intervention, self-determination's learning effect was not examined. Further studies can extend the intervention and measure self-determination at different time points, by which the dynamic influence of self-determination can be added to path models. Moreover, owing to the difficulty of convincing elementary schools to allocate more experimental time, only five sessions (40 mins each) of training were employed. A longer experimental duration may better enhance the growth CM and CSE. Nevertheless, the positive learning effect of this short intervention was confirmed through the repeated measure analysis of variance and the responses from the reflection questionnaire. Further studies can also include a control group to double-check the learning effect if enough participants are recruited.

In this study, we identified four types of CM and accordingly developed the CMI, which serves as an effective instrument for measuring CM. Moreover, this study found that pupils' beliefs of growth-internal (M = 4.44, SD = 1.09) and growth-external CM (M = 3.99, SD = 1.22) were much stronger than that of fixed-internal (M = 3.12, SD = 1.23) and fixed-external CM (M = 2.81, SD = 1.41), suggesting that children are optimistic toward their creative development and that there is great learning plasticity if an enriched environment can be provided. Therefore, instructors or researchers can use the CMI to obtain specific information about learners' beliefs of different types of growth or fixed CM, by which effective training or instruction can be designed to maximize learning effects.

Furthermore, growth CM promotes a positive attitude and willingness to try new ideas and new things. The strong influence of growth CM (especially GI) on CSE through self-determination suggests that when children believe that creativity can be improved through self-learning in a well-facilitated environment, they may be more autonomous and competent during game-based learning. As a result, they may become substantially more creative. The positive intervention results of this study suggest that developing effective interventions to enhance growth CM through game-based learning is an efficient and enjoyable way to achieve this goal. Researchers in education and game designers can cooperate in developing more game-based learning programs to enhance the growth CM, especially GI.

Self-efficacy is a vital precursor to successful performance (e.g., Schunk & DiBenedetto, 2016), and a growth CM is positively related to CSE (Karwowski & Kaufman, 2017). This study suggests that incorporating strategies such as scaffolding for challenging their creativity skills, chances for self-determination, constructive and immediate feedback, verbal encouragement for performance, and peer evaluation for creative design can enhance growth CM and CSE. These strategies can also be implemented in classroom teaching. Moreover, we enhanced the children's growth CM and CSE mainly through practicing creative strategies and dispositions in this study. Future studies can incorporate more strategies for enhancing growth CM in game-based learning.

Finally, different from past related studies, we identified four types of CM under two constructs (growth CM and fixed CM). We found that the growth-internal CM has stronger correlations with the other concerned variables than the growth-external control. People who hold a growth-internal control CM believe that self-learning can improve creativity; such a belief is more important than ever during the COVID-19 pandemic. This worldwide pandemic has revealed the importance of self-learning through digital vehicles. Our development of the CM instrument and the digital game-based intervention, which can be completed through self-learning, provides unique contributions and implications in this critical era.

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Appendix A The employed inventories

Table A1. The test items and Cronbach's α of the creativity mindset inventory

Items		Factor loading
Growth Mindset (α = .911)		
Factor 1: Growth-Internal locus of control (GI) (α = .859)		
9	I can be more creative as long as I am willing to learn.	.855
1	As long as I work hard, my creativity can be greatly improved.	.801
5	I can improve my creative ability through self-learning.	.700
Factor 2: Growth-External locus of control (GE) (α = .850)		
2	My creativity can be improved with the help of good teachers.	.849
10	My creativity can be substantially improved when I have sufficient learning opportunities.	.789
6	I am willing to learn creativity and I can become more creative when there is a good learning environment.	.753
Fixed mindset (α = .952)		
Factor 3: Fixed-Internal locus of control (FI) (α = .877)		
3	It is hard to improve my creativity even if I work hard to improve it through self-learning.	.872
7	Even if I am willing to learn creativity, it is hard for me to become more creative.	.522
11	Even if I work hard by myself, my creativity won't be substantially improved.	.476
Factor 4: Fixed-External locus of control (FE) (α = .924)		
12	Even if I have sufficient learning opportunities, my creativity won't be substantially improved.	.909
8	Even if there is someone to tutor me, it's hard for me to become more creative.	.741
4	It is hard to improve my creativity even if I have good luck and meet good teachers.	.409

Note. Sources of construct development: Dweck (2007), Karwowski (2014), and Rotter (1966).

Table A2. The test items and Cronbach's α of the Grit Scale (α = .872)

No.	Factor 1: Perseverance of Effort (α = .872)
3	I am diligent.
4	I am a hard worker.
1	I finish whatever I begin
6	Once I am obsessed with a certain idea or project, I won't lose interest.
	Factor 2: Consistency of Interest (α = .813)
2	Setbacks don't discourage me.
7	I can maintain my focus on projects that take more than a few months to complete.
8	New ideas and projects won't distract me from previous ones.
5	Once I set a goal, I will try to pursue it and won't give up easily.

Note. Sources of construct development: Duckworth and Quinn (2009) and Duckworth et al. (2007).

Table A3. The test items and Cronbach's α of the Inventory of Self-Determination in Digital Games (α = .933)

No.	When playing the game,
	Factor 1: Autonomy and self-regulation (α = .887)
8	I could freely choose the avatar in the game.
13	I could freely employ my problem solving strategies.
12	I had many chances to make free choices.
3	I could soon forget negative feelings from getting low scores and focus on the next game.
4	I had abundant opportunities to develop my own thoughts.
6	I could understand why I failed and immediately adapt to get a higher score.
9	I could decide the order of game playing
	Factor 2: Competence (α = .881)
2	I could think of the answer quickly.
11	I could quickly figure out methods for problem solving.
1	I performed well.
7	I could achieve the scores or goals that I set.
10	I could quickly learn how to achieve high scores.
5	I felt that the problems or challenges matched my ability level.

Note. Sources of construct development: Yeh et al. (2019) and Bandura (1977).

Table A4. The test items and Cronbach's α of the inventory of self-efficacy in creativity digital games (α = .927)

No	When playing the game,
	Factor 1: Ability to generate creative ideas (α = .908)
8	I believe that my creativity can be improved as long as I try hard to learn.
5	I believe that my creativity can be constantly improved.
6	I believe that I can come up with many creative ideas.
4	I believe that I can come up with many creative problem-solving solutions.
7	I believe that I can become a creative person.
9	I believe that I can produce creative works.
	Factor 2: Achievement of creative performance (α = .844)
2	I feel that I am more creative than most of my classmates.
1	I feel that I am a creative person.
3	I feel that "being creative" is one of my characteristics.

Note. Sources of construct development: Yeh and Lin (2018), and Ryan and Deci (2000)