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Differentiating between the "Need" for and the "Experience" of Self-determination Regarding Their Influence on Pupils' Learning of Creativity through Story-based Digital Games

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ABSTRACT

Self-determination (SD) and game-based learning have attracted great attention, and recent investigation studies have shown that SD is closely related to flow and mastery experience. This study pioneered at developing a game-based learning program with an emphasis on SD intervention, in which comprehensive creativity strategies within a story context were presented. Through this training program, we further differentiated between the ways that the SD need before the training and the SD experience during the training influenced flow and mastery experience pertaining to creativity. The participants were 82 third and fourth graders. The results showed that the SD experience was a better predictor of the pupils' flow and mastery experience than the SD need, suggesting the importance of implementing SD intervention to maximize the game-based creativity learning. The developed training program and the proposed theoretical framework provide valuable implications for the instruction of creativity.

1. Introduction

Research has found that educational digital games or game-based learning have many positive benefits including attracting learners' attention and enhancing learning (Boyle et al., 2011; Brezovszky et al., 2019; Gil-Doménech & Berbegal-Mirabent, 2019; Khowaja & Salim, 2019; Inal & Cagiltay, 2007; Starks et al., 2014). With the clear potential use of digital games as tools in education, researchers are investigating how to efficiently create attractive and efficient digital games in varied disciplines.

As creativity is regarded as an important educational goal, many studies have been conducted to train creativity through game-based learning (Celume et al., 2019; Stolaki & Economides, 2018). Creativity refers to the process of generating contextually or culturally original and valuable products; its performance involves a set of dispositions and strategies (Yeh, 2017). A recent study suggests that learning/pedagogical aspects and game factors are the most essential attributes for the design phase of digital games (Tahir & Wang, 2019). To date, creativity training through digital games is still developing. However, most developed games are focused on very limited skills or divergent thinking only, while the cultivation of creativity requires training of varied thinking dispositions and strategies.

In addition, measuring player experience is becoming an area of focus among game researchers and developers (Denisova et al., 2016; Johnson et al., 2018). Investigation studies have suggested that self-determination (SD) (Millsa et al., 2018; Rogers, 2017) and flow experience (Hawlitschek & Joeckel, 2017; Hamari et al., 2016) are critical to the effectiveness of game-based learning. To date, most SD intervention effects have been investigated in the general education classroom (e.g., Shogren et al., 2012, 2017). Moreover, it has been suggested that sense of SD can be regarded both as an explanatory variable and an outcome variable (Benita et al., 2014); how these two types of SD influence learning process have not been clarified yet. Defining the former as SD need and the latter as SD experience, we pioneered at examining the differential effects between how the SD need (SD before training) and the SD experience (SD during training) influence the flow and mastery experience pertaining to creativity in digital game-based environments. To clarify the interactive relationships among these personal traits or player experiences, we developed a comprehensive and game-based training program in which mechanisms of enhancing SD as well as a set of dispositions and thinking strategies of creativity were included.

1.1. Related work

1.1.1. SD theory and interventions

Researchers have identified motivation as a key factor in explaining learning. Among the numerous models of motivation, SD theory has proved to be one of the most relevant. SD theory emphasizes three basic psychological needs: autonomy, competence, and relatedness (González-Cutre et al., 2014; Ryan & Deci, 2000a). Autonomy refers to the need to have personal control over one's life, competence refers to the

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feeling of completing different challenges in an effective way, and relatedness refers to the need of interacting with and being accepted by others (Ryan & Deci, 2000b; Zhou et al., 2017). Findings, conducted with children, adolescents, and adults, have revealed the central roles of these three basic needs in SD (Podlog et al., 2015; Rutten et al., 2012; Zhou et al., 2017). When these needs are satisfied, personal growth and optimal functioning are achieved, the basic psychological needs are unmet, and people experience well-being (Millsa et al., 2018).

SD theory has been used in various research fields (Sepehr & Head, 2018). Based on the SD theory, a few inventories have been developed to conduct empirical studies, such as player's Experience of Need Satisfaction (Ryan & Deci, 2000b) and the Game Experience Questionnaire (IJsselsteijn et al., 2013). These related findings suggest that experiences that satisfy the need of SD are more likely to result in the intrinsic motivation of engagement in activities as well as positive outcomes (Bartholomew et al., 2011; Millsa et al., 2018). Notably, SD theory had not been employed in digital game studies until 2006 when researchers (Ryan et al., 2006) were trying to explain how SD theory might explain the motivational pull of video games.

A few SD interventions have been employed to enhance SD in digital games. Rogers (2017) noted that a video game can satisfy some aspects of SD but not all. However, Millsa et al. (2018) suggest that video games have the potential to satisfy all the three needs of SD, which in turn contributes to greater enjoyment in digital games. A few studies showed that when different attributes of a game were salient, different needs of SD were enhanced (Oliver, Bowman, Woolley, Rogers, Sherrick, & Chung, 2016; Rogers, 2017; Rogers et al., 2017). It has been suggested that emphasizing character and story facilitates feelings of relatedness, and providing intuitive controls leads to feelings of competence and autonomy (Oliver et al., 2016; Rogers, 2017; Tamborini et al., 2010). These findings showed SD can be improved through digital games. Nevertheless, similar studies focused on creativity are still hardly seen.

1.2. SD, flow, and mastery experience in creativity game-based Learning

Digital game-based learning refers to a close connection between any educational content and computer games (Perrotta et al., 2013; Prensky, 2001). They are developed to engage players in an activity, which produces a common good or teaches something valuable to the player (Ciman et al., 2018). Digital games or video capture students' attention and enhance their motivation because they contain elements of fantasy, curiosity, and challenge; moreover, they have a positive impact on problem-solving skills and broader knowledge acquisition (Hsiao et al., 2014; Inal & Cagiltay, 2007; Perrotta et al., 2013). Accordingly, game-based learning provides valuable tools for facilitating intrinsic motivation and learning effects.

SD, which involves human needs of autonomy, competence, and relatedness (González-Cutre et al., 2014; Ryan & Deci, 2000b), has been regarded as intrinsic motivation. Some researchers have investigated the need of players on digital games based on SD (e.g., Oliver et al., 2016; Rogers, 2017; Ryan et al., 2006; Tamborini et al., 2010). However, few empirical studies have endeavored to differentiate between how the SD need before training and the SD experience during training influence the mastery experience of creativity in game-based learning. Mastery experience is the personal experience with success; it has been suggested as an important mechanism for enhancing self-efficacy (Huang & Yeh, 2016; Bandura, 1997). Notably, sense of SD can be regarded both as an explanatory variable – a motive that predicts positive psychological outcomes – and as an outcome variable promoted by a supportive socializing context (Benita et al., 2014). Incorporation strategies to enhance the SD feelings or motivation should contribute to the achievement of mastery experience of creativity during game playing.

Internal locus, volition, and perceived choice are identified as three qualities of self-determination (Reeve et al., 2003). To the extent that people experience SD as an internal locus, conditions that facilitate an internal perceived locus of causality should increase both SD and intrinsic motivation (Reeve et al., 2003). It is also argued that it is the experience of choosing what one is doing that conveys the sense of autonomy and volition; conditions that encourage feeling free or that encourage perceived choice should increase SD (Benita et al., 2014; Ryan & Deci, 2000b). Therefore, digital game-based learning can be an effective tool for facilitating SD experience, and furthermore, can enhance mastery experience of creativity if the elements of SD are incorporated.

During game-based learning of creativity, SD may also influence mastery experience through flow experience. The theory of flow is inherently related to learning (Shernoff & Csikszentmihalyi, 2009); it has been found that flow can positively affect students' skill development, satisfaction, and perceived learning of the subject matter (Buil et al., 2018). Such positive effects have also been found in different contexts, such as online learning, computer-based environments, and game-based learning (Barzilai & Blau, 2014; Bressler & Bodzin, 2013; Esteban-Millat et al., 2014; Hamari et al., 2016; Wang & Hsu, 2014). Flow refers to a state of total absorption in an activity and the non-self-conscious enjoyment of it (Deci & Ryan, 2000a), which relates to aspects such as challenge–skill balance, action-awareness merging, clear goals, unambiguous feedback, concentration on the task at hand, a sense of control, loss of self-consciousness, time transformation, and autotelic experience (Beard, 2015; Csikszentmihalyi, 1990; Hamari & Koivisto, 2014). Because enjoyment motivates the continuation of work and study, whether or not the player experiences enjoyment or flow should be seen as a key criterion in determining a game's effectiveness (Fong-Ling et al., 2009).

SD is, in essence, closely related to flow experience during the learning of creativity. Researchers suggested that during productive tasks, optimal experience is characterized by freedom and wish to do the activity (Haworth & HilL, 1992). Flow aims to capture the state in which people are highly immersed in their activity and feel intensely involved; when the balance between challenge and skill in a task is achieved, a deeply engaging experience appears (Sepehr & Head, 2018).

Along the same lines, a recent inventory investigation study (Yeh & Lin, 2018), concerning pupils' general experience in playing creativity games, revealed that SD need was positively related to flow and mastery experience. In the current study, we have taken a step forward to develop digital games pertaining to creativity and compared whether such general impressions of SD need and the concrete SD experience while playing creativity games would have different influences on flow experience and mastery experience.

1.3. Aims and hypotheses of this study

This study aimed at developing a training program called Digital Game-based Learning for Creativity with Self-Determination, level A (DGLC-SD-A) for 3rd and 4th graders. Through this program, we employed an experimental instruction to investigate the enhancement effect on self-determination, as well as the relationships among SD, flow, and mastery experience. According to SD theory, sense of SD can be regarded both as an explanatory variable and an outcome variable (Benita et al., 2014). The present research defined the former as SD need and the latter as SD experience. In addition, we incorporated many strategies (see Figure 1) to enhance the SD experience, assuming such experience would strengthen flow experience, and, further, contribute to the achievement of mastery experience of creativity during the game-based learning. Our theoretical framework is illustrated in Figure 1.

Specifically, our hypotheses were as follows:

H1: The participants' SD would be enhanced after the learning through the DGLC-SD-A.

H2: Both the participants' need of SD measured at the beginning of the game-based learning (SD need) and the experience of SD measured at the end of the game-based learning (SD experience) would have significant influences on their achievement of mastery experience of creativity, but the effect of SD need would not be as strong as that of SD experience.

H3: Both the participants' SD need and the SD experience would have significant influences on their flow experience during the game-based learning, but the effect of SD need would not be as strong as that of SD experience.

H4: The participants' flow experience would have significant influences on their achievement of mastery experience of creativity during the game-based learning.

2. Method

2.1. Participants

Purposive sampling was employed to include 82 third and fourth graders, composed of 36 boys (43.9%) and 46 girls (56.1%). Written informed consent was obtained from all participants' parents and each participant was rewarded with a gift of their choice valued at 10 USD.

2.2. Instruments

2.2.1. Digital Game-based Learning for Creativity (DGLC-SD-A)

The DGLC-SD-A, developed by PHP, MySQL, Unity, C#, and Flash, was employed to investigate whether the SD need and the SD experience would carry different levels of influence on the participants' flow experience and mastery experience during the game-based creativity learning when SD was emphasized. The DGLC-SD-A, developed for 3rd and 4th graders,

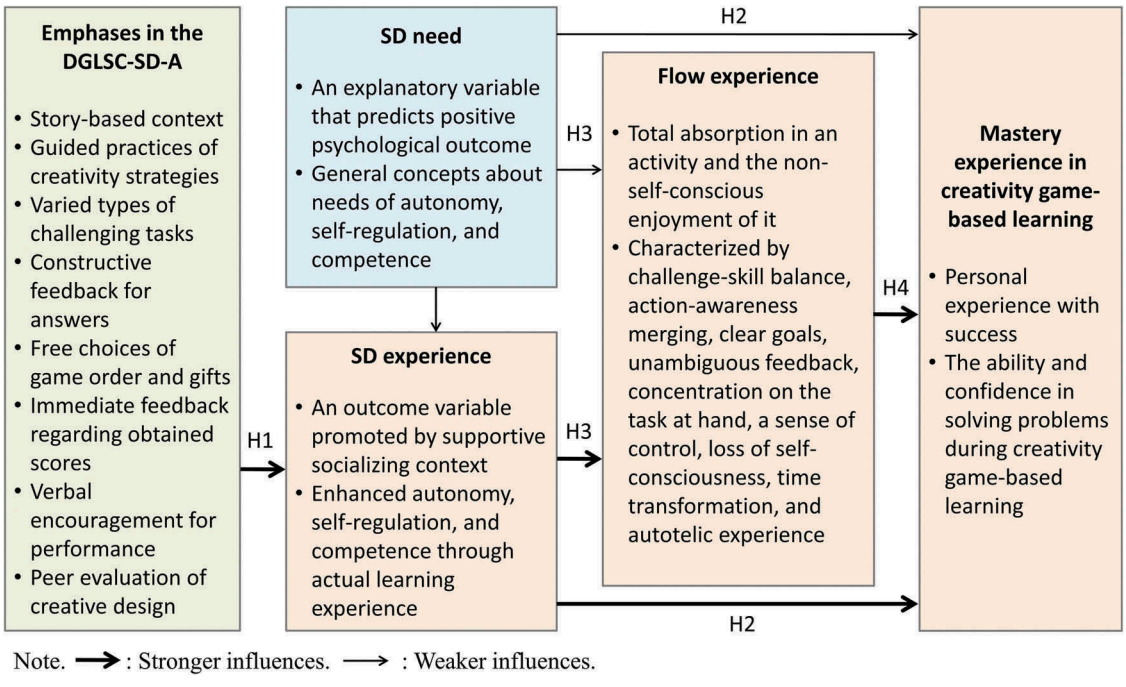

Figure 1. The theoretical framework of this study.

was composed of a story entitled "Searching for the clown's color balls" that was connected through important festivals in Chinese and American culture. The DGLC-SD-A included nine games, ranging from 10 minutes to 15 minutes for each game. The percentage of correct answers (index of difficulty) of test items in the game ranged from.0271 to .948, with an average difficulty of .718. Some screenshots of the DGLC-SD -A are shown in Figure 2. The nine games included the strategies for enhancing creativity dispositions and creativity, including positive thinking and attitudes, thinking outside the box and reverse thinking, sensitivity in observation, convergent thinking, lateral thinking, divergent thinking, SCAMPER (substitution, combination, adaptation, modification, putting to other uses, elimination, and reversing) and mind mapping, and design of secret base through 3-D drawing.

To enhance SD experience of competence and autonomy, we connected the games with stories; we also provided many guided practices of creativity strategies, varied types of challenging tasks, constructive feedback for answers, free choices of game order and gifts, immediate feedback regarding obtained scores, verbal encouragement for performance, and peer evaluation for creative design.

2.2.2. Inventories

The employed inventories were the *Inventory of Self-determination in Digital Games* (ISD-DG), the *Inventory of Flow Experience in Digital Games (IFE-DG)*, and the *Inventory of Mastery Experience in Creativity Digital Games* (IME-CDG) (Yeh & Lin, 2018). All the questionnaires were 6-point Likert scales with response options ranging from "totally disagree" to "totally agree." (See Appendix A Table A1–A3)

The ISD-DG measured the participants' level of SD need as well as the SD experience in game playing. ISD-DG includes two factors: autonomy and self-regulation (7 items) and competence (6 items). The Cronbach's α coefficients were .933, .887, and .881 for the whole scale and the two factors, respectively. When the ISD-DG was employed to measure the SD need, the test items for SD experience included statements such as "When playing a game, I hope I can decide the order of game playing." and "When playing a game, I hope I can achieve the scores or goals that I had set." When the ISD-DG was employed to measure the SD experience, the test items for SD experience included statements such as "When playing the game, I could decide the order of game playing." and "When playing the game, I could achieve the scores or goals that I had set." Confirmatory factor analysis (CFA) indicated that the ISD-DG had good construct validity and reliability, χ^2 (N = 176, df = 26) = 79.867 (p < .05). Moreover, the GFI = .919, AGFI = .860, RMR = .076, and RMSEA = .109 (Yeh & Lin, 2018).

The IFE-DG measured the participants' flow experience during game playing. The IFE-DG includes two factors: confidence and concentration (5 items) and fun and challenge (4 items). The Cronbach's α coefficients were .914, .885, and .857 for the whole scale and the two factors, respectively. The test items included statements such as "When playing the game, I temporarily forgot what was bothering me in my life." and "When playing the game, the voice and images in the game increased my interest in playing the game." The CFA revealed that the IFE-DG had good construct validity and reliability, χ^2 (N = 176, df = 64) = 149.474 (p < .05). Further results were as follows: GFI = .884, AGFI = .836, RMR = .095, and RMSEA = .087 (Yeh & Lin, 2018).

The IME-CDG measured the participants' level of mastery experience while playing creative games. The IME-CDG includes two factors: ability to problem-solving (5 items) and confidence in problem-solving (3 items). The Cronbach's α coefficients were .903, .860, and .819 for the whole scale and the two factors, respectively. The test items included statements such as "When playing the game, I quickly came up with answers." and "When playing the game, I was confident in my ability to think creatively and solve problems." Additionally, the CFA revealed that the IME-CDG had good construct validity.

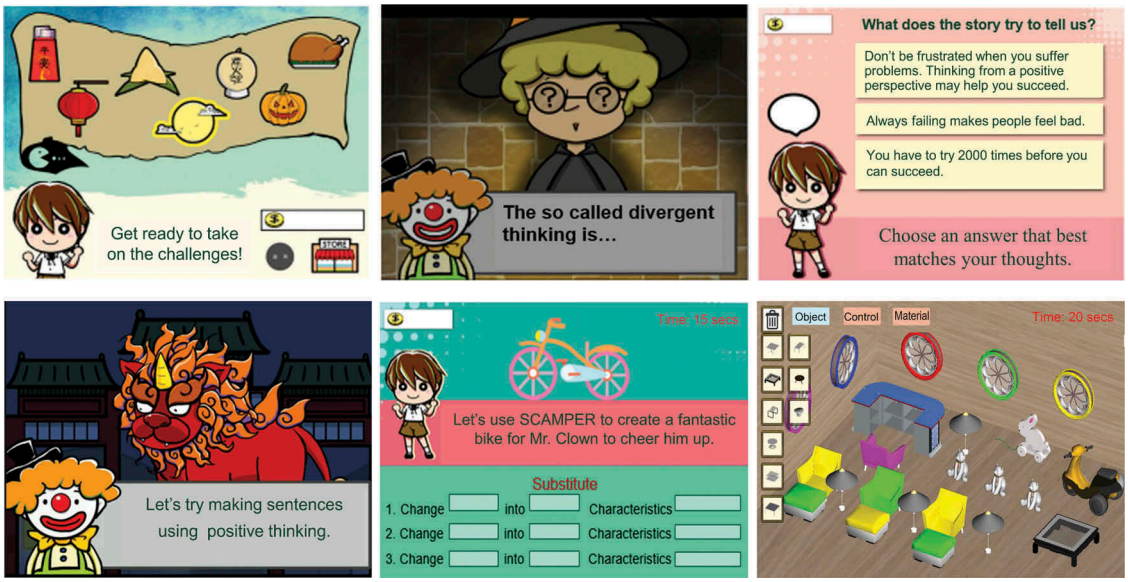

Figure 2. Screenshots of DGLC-SD-A.

2.2.3. Experimental design and procedures

All the experimental procedures were completed through the DGLC-SD-A. The participants were recruited through classroom announcement and they completed the experiment in the computer laboratory at their school during their flexible learning time. The participants were informed at the beginning that if they played the games seriously and competed all the games, they would obtain gifts valued at 10 USD.

With nine games in total, the participants completed their learning in five classes throughout one week. The participants completed the inventory of SD need and the design of a secret base through a 3D interface in the first class. Then, they played the creativity games from the second to the fourth class; they designed secret bases again in the fourth class. In the fifth class, they completed the inventory of SD experience as well as the inventories of flow experience and mastery experience of creativity. Notably, peer evaluations of the secret base design in game 1 and game 9 were employed in the fifth class to share creative ideas. Before the participants began the design activity, they were informed that they could win an additional gift valued at 5 USD if their secret base design was rated as the most creative product. Finally, six participants from each grade were rewarded based on peer evaluation. The training focuses on the DGLC-CD-A and specific experimental procedures are illustrated in Figure 3.

3. Results

3.1. Learning effects and enhancement of SD through the DGLC-SD-A

Five reflection questions were employed to understand the participants' feelings toward the game. The *M*s and *SD*s are shown in Table 1. The results showed that the participants' feelings toward the training were positive (The *M*s were all above 5 points in the 6-point Likert type questionnaire). The participants felt that the game was interesting and it enhanced their creativity. Moreover, they responded that the encouraging feedback, the gifts for better performance, and the free choice of game order contributed to their motivation and confidence during the game playing.

A person correlation analysis showed that the SD need and the SD experience were positively correlated, $r(81) = .258$, $p = .019$. Moreover, using the scores of SD need and SD experience as within-group variables, we conducted a repeated measure analysis and found that the participants significantly enhanced their SD after the game play, Wilks' $\Lambda = .951$, $p = .045$, $\eta_p^2 = .049$. The means were 4.492 for SD need (*SE* = .123) and 4.785 for SD experience (*SE* = .104).

3.2. The effects of SD need, SD experience, and flow experience on mastery experience

Using MANOVA, we first examined the influences of SD need, SD experience, and flow experience on mastery experience during the game play of the creativity games. We separately used the score of SD need, SD experience, and flow as the independent variable, and used the indices of mastery experience (ability to problem-solving and confidence in problem-solving) as dependent variables to conduct one-way MANOVA. In these analyses, the independent variable was divided into the "Low" and "High" groups by the cutoff points of the median. Figure 4 shows the *M*s and *SE*s for the groups with different levels of independent variables.

The results showed marginal group effects of SD need on mastery experience, Wilks' $\Lambda = .949$, $p = .127$, $\eta_p^2 = .051$. However, ANOVA revealed significant SD need effects on "ability to problem-solving," $F(1, 81) = 4.267$, $\eta_p^2 = .051$, $p = .042$. Comparisons of the means revealed that participants with a high level of SD need had higher scores in "ability to problem-solving." On the other hand, the results showed an overall significant SD experience effect on mastery experience,

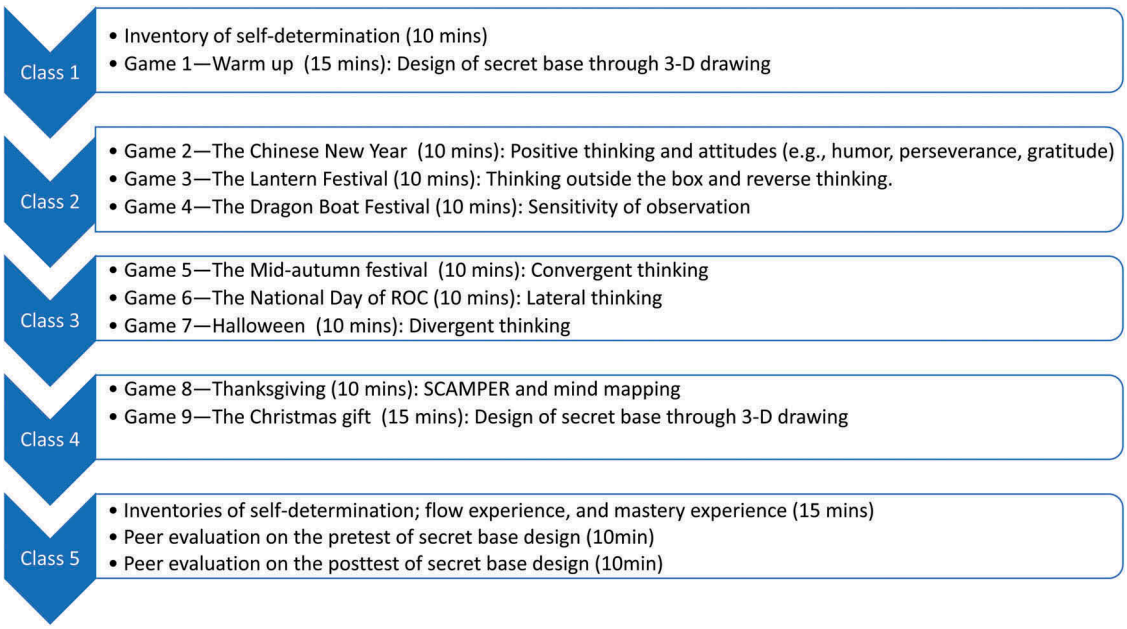

Figure 3. Training focus and procedures of the DGLC-SD-A.

Table 1. *M*s and *SD*s in the reflection questionnaire.

Items	*M*	*SD*
1. I felt that this creativity game was interesting.	5.21	1.29
2. This creativity game increased my creativity.	5.01	1.27
3. The encouraging feedback given during the game playing made me feel more confident.	5.12	1.32
4. The chance to receive a gift because of a high score motivated me to try harder.	5.10	1.40
5. Being able to decide the game order by myself made the game more interesting and it motivated me to move on to the next game.	5.16	1.16

Table 2. The effects of SD need, SD experience, and flow on mastery experience.

	ANOVA				
Source	*MS*	*F*	*p*	η^2_p	Comparison
		SD need			
Ability	4.456	4.267	.042*	.051	High > Low
Confidence	3.190	2.783	.099	.034	
		SD experience			
Ability	32.770	47.464	.000***	.372	High > Low
Confidence	42.517	64.934	.000***	.448	High > Low
		Flow			
Ability	31.857	58.300	.000***	.428	High > Low
Confidence	28.752	43.427	.000***	.358	High > Low

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

Wilks' Λ = .545, p < .001, η_p^2 = .455. The following ANOVA revealed significant SD experience effects on "ability to problem-solving" and "confidence in problem-solving," F(1, 81) = 47.646, η_p^2 = .372, and F (1, 81) = 64.934, η_p^2 = .448, ps < .001 (see Table 2). Comparisons of the means revealed that participants with a high level of SD experience had higher scores in both indices of mastery experience than those of their counterparts.

In addition, the results showed an overall significant flow effect on mastery experience, Wilks' Λ = .560, p < .001, η_p^2 = .440. The following ANOVA revealed significant flow effects on "ability to problem-solving" and "confidence in problem-solving," F(1, 79) = 58.300, η_p^2 = .428, and F (1, 79) = 43.427, η_p^2 = .358, ps < .001 (see Table 2). Comparisons of the means revealed that participants with a high level of flow experience had higher scores in both indices of mastery experience than those of their counterparts.

3.3. The effects of SD need and SD experience on flow experience

Using MANOVA, we examined the influences of SD need and SD experience on flow experience during the game play of the creativity games. We separately used the score of SD need and SD experience as the independent variable and used the indices of flow experience (confidence and concentration; fun and challenge) as dependent variables to conduct a one-way MANOVA. In these analyses, the independent variable was divided into the "Low" and "High" groups by the cutoff points of the median. Figure 5 shows the *M*s and *SD*s for the groups with different levels of independent variables.

The results showed an overall significant SD need effect on flow experience, Wilks' Λ = .853, p = .002, η_p^2 = .147. The following ANOVA revealed significant SD need effects on "confidence and concentration" and "fun and challenge," F (1, 81) = 12.525, p = .001, η_p^2 = .135, and F (1, 81) = 4.809, p = .031, η_p^2 = .057 (see Table 3). Comparisons of the means revealed that participants with a high level of SD need had higher scores in both indices of flow experience. Similarly, the results showed an overall significant SD experience effect on flow experience, Wilks' Λ = .556, p < .001, η_p^2 = .444. The following ANOVA revealed significant SD experience effects on "confidence and concentration" and "fun and challenge," F (1, 81) = 57.70, p = .001, η_p^2 = .419, and F (1, 81) = 49.788, p < .001, η_p^2 = .384 (see Table 3). Comparisons of the means revealed that participants with a high level of SD experience had higher scores in both indices of flow experience than those of their counterparts.

4. Discussion

Game playing is a natural behavior of children, which implies a basic need in human nature. Given this natural attraction to game playing, it is important that educators take advantage of games to capitalize on desirable behaviors for effective learning. Due to the importance of creativity and self-determination in life-long learning and development, as well as the lack of

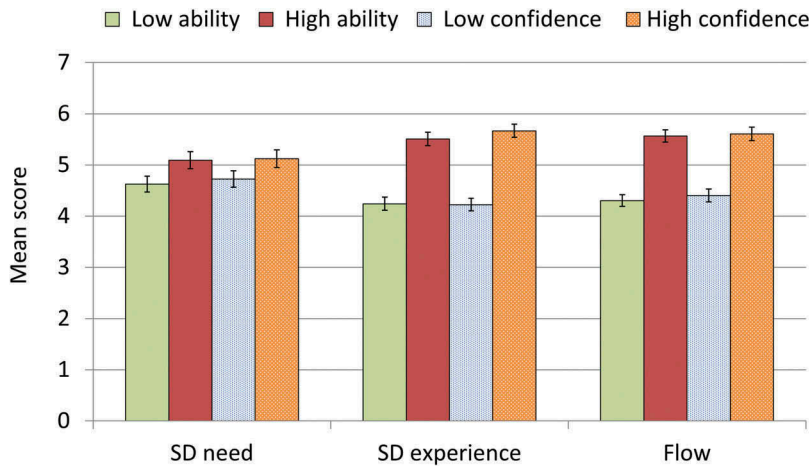

Figure 4. Ms and SEs of mastery experience with different levels of SD need and SD experience.

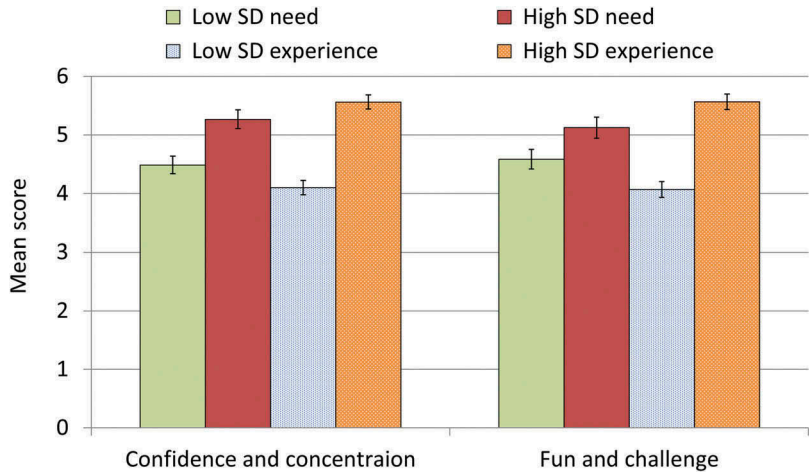

Figure 5. Ms and SEs of flow experience with different levels of SD need and SD experience.

Table 3. The effects of SD need and SD experience on flow experience.

	ANOVA				
Source	*MS*	*F*	*p*	η^2_p	Comparison
		SD need			
Confidence and concentration	12.471	12.525	.001***	.135	High > Low
Fun and challenge	5.941	4.809	.031*	.057	High > Low
		SD experience			
Confidence and concentration	38.603	57.700	.000***	.419	High > Low
Fun and challenge	40.194	49.788	.000***	.384	High > Low

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

a comprehensive game-based creativity learning system for young pupils, we developed the DGLC-SD-A. Through this learning system, we employed an experimental instruction period of one week in this study. We first examined the enhancement effects of SD intervention. Then, we investigated the relationship among SD need, SD experience, flow, and mastery experience. We proposed four hypotheses and all of the hypotheses were fully supported, except for the hypothesis concerning the direct influence of SD need on mastery experience – this hypothesis was only partially supported.

The findings revealed that, after the game-based learning, the pupils' SD experience was significantly enhanced, and such enhancement contributed to strengthening the positive relationship between SD, flow experience, and mastery experience. These findings support the hypothesis that intrinsic motivation is critical to creativity performance (Amabile, 1996; Liu et al., 2011), as well as that digital games help arouse curiosity to solve tasks and can be an effective tool for cultivating creativity (Hsiao et al., 2014). To enhance the pupils' SD need of competence and autonomy, we employed stories, guided practices, challenging tasks, constructive and immediate feedback, free choices, verbal encouragement, and peer evaluation of creative design. The results of MANOVA and reflection questions indicated the effectiveness of these mechanisms on the improvement of SD, flow, and mastery experience in creativity game-based learning, which is in line with related findings in digital games (Oliver et al., 2016; Rogers, 2017; Ryan et al., 2006; Tamborini et al., 2010). Notably, the participants' feelings toward the training were very positive (The *M*s were all above 5 points in the 6-point Likert type questionnaire), suggesting the interestingness of the game, the encouraging feedback, the gifts for better performance, and the free choice of game order facilitated their motivation and confidence during the game playing, which contributed to their improvement of creativity.

SD may function as an explanatory variable as well as an outcome variable (Benita et al., 2014). To clarify how these two types of SD influence learning process during game-based learning, we defined the former as SD need and latter as SD experience. The findings of this study indicate that pupils with a higher level of SD experience perceived stronger flow experience as well as achieved a higher level of mastery experience, and those who had a stronger flow experience achieved a higher level of mastery experience than their counterparts did in the game-based creativity learning. These results suggest that SD experience carries both direct and indirect influences on mastery experience. On the other hand, the need for SD only had an indirect influence on mastery experience through flow experience. In addition, the effect size that resulted from SD experience was far larger than that of SD need. Therefore, although the SD need and the SD experience were positively correlated, they carried different magnitudes of influence on flow and mastery experience through different routes during the game play. These findings help clarify the differences between SD as an explanatory variable and as an outcome variable (Benita et al., 2014). Notably, the results of this study revealed that SD experience could better differentiate and predict the level of flow and mastery experience than SD need in digital games, suggesting the importance of enhancing SD experience to maximize the learning effects in game-based creativity learning. In addition, the findings suggest that flow experience plays a mediator between SD experience and mastery experience during the game-based learning.

Past findings have demonstrated the importance of flow in game-based learning research (Buil et al., 2018). It has been suggested that computer games can foster learners' continued interest and intrinsic motivation to improve their skills and engagement through elevated concentration, interest, and enjoyment (Papanastasiou et al., 2017). From a framework

of motivation theories, we believe that SD interventions of autonomy, self-regulation, and competence would help engage students in the state of "flow," as many characteristics of flow overlap those of SD, such as challenge–skill balance, a sense of control, and autotelic experience (Beard, 2015; Hamari & Koivisto, 2014). The positive relationship between SD and flow experience found in this study supports our belief. Moreover, this finding lends support to the argument that digital games have the potential to satisfy the needs of SD, which in turn contributes to greater enjoyment in digital games (Johnson et al., 2016; Mills & Fullagar, 2008; Millsa et al., 2018).

Notably, one of the most powerful mechanisms of digital games is the ability to provide interactive feedback in real time, such as instant feedback, real-time score updating, and constant progress reports, which can help learners monitor frustration and cognitive skills so as to maximize intrinsic motivation and flow (Jin, 2012; Yeh & Lin, 2018). This is similar to the idea of dynamic assessment in education, and all of these mechanisms were employed in our training program. Dynamic assessment is interactive and concerns an exploration of a person's actual level of development as well as their level of proximal development (Dörfler et al., 2009); it involves the identification and detailing of interventions that assist and encourage the process of learning. With the elaborative design of the DGLC-SD-A, it can serve as a tool for dynamic assessment to help pupils achieve mastery experience in creativity.

5. Conclusion

Creativity has been regarded as one of the most important educational goals for elementary school students. Although some digital games of creativity have been developed, most of them are only focused on very limited thinking strategies or divergent thinking; it is imperative to develop a more comprehensive digital game-based learning system for the third and fourth graders on the basis of recent theories of creativity. This study therefore tried to develop story-based DGLC-SD -A, which covers the training of critical creativity dispositions, a wide range of creativity thinking strategies, 3D product design, as well as mechanisms that enhance self-determination, flow experience, and mastery experience. The findings suggest that the DGLC-SD-A is an effective vehicle for improving young pupils' learning of creativity, and that flow experience acts as a critical mediator of SD experience and mastery experience during the game-based creativity learning.

To date, no studies have tried to distinguish the influences of SD need versus SD experience in game-based learning, not to mention creativity learning. This study compared these two types of SD and found their differential influences on flow and mastery in game-based learning of creativity. The findings of this study suggest that a well-designed game-based learning system can significantly level up young pupils' SD experience regarding autonomy, self-regulation, and competence, and that this SD experience has better discriminant validity in predicting the degree of flow experience and mastery experience than the SD need during game-based creativity learning. To conclude, SD theory opens up a space for researchers to develop effective interventions and SD experience and it is critical for the success of creativity training through game-based learning. The developed training program, the proposed theoretical framework, and the employed mechanisms for SD enhancement in this study provide a valuable vehicle or implications for game design and the instruction of creativity through game-based learning.

6. Limitations and suggestions

Due to the difficulty of finding cooperative schools for such multi-class instruction and the limitation of computer availability in these schools, only the manipulations of autonomy and competence of SD were employed in the computer-based learning. Relatedness of self-determination involves cooperation or interaction among players. Future research efforts can incorporate such a game feature into the experimental instruction and examine its influence on the learning of creativity. Further studies can also compare the learning effects of digital game-based learning with blended learning, in which classroom discussion follows digital game-based learning at the end of each game session. This method will provide more evidences and implications for effective classroom teaching and game design.

In addition to game design and challenges, game types may influence enjoyment or flow (Dondi & Moretti, 2007; Fong-Ling et al., 2009; Inal & Cagiltay, 2007). Future studies can compare the effects of digital games, table games, and traditional games on flow and mastery experience. Moreover, the findings of this study suggest a possible path model of how SD need and SD experience influence flow and mastery experience; further studies can include a larger sample size to confirm the interactive relationship among these variables through Structural Equation Modeling.

Finally, this study is a quantitative study; qualitative data for learning processes were not collected. To get a better understanding of learning process and the effects of interventions, however, we designed five reflection questions regarding the participants' feelings toward the interventions and learning processes (see Table 1). Although the results of reflection questions supported our quantitative findings and the effectiveness of our interventions incorporated in the DGLC-SD-A, we did not include qualitative methods in our study due to the time constraint for getting qualitative data. The findings of this study suggest that guided practices, challenging tasks, constructive and immediate feedback, free choices, verbal encouragement, and peer evaluation of creative design are important mechanisms for enhancing SD experience, flow experience, and mastery experience in game-based creativity learning. Further studies can interview players and teachers to get more detailed and in-depth information regarding how these mechanisms work and what mechanisms may be added, which will provide instructors and game designers more specific guidelines.

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Appendix A. Employed inventories

Table A1. The test items and factor loadings of ISD-DG (N = 130).

	Factor and item	Factor loading	
No.	When playing the game,	F1	F2
	Factor 1: Autonomy and self-regulation		
8	I could freely choose the avatar in the game.	.827	
13	I could freely employ my problem solving strategies.	.769	
12	I had many chances to make free choices.	.750	
3	I could soon forget negative feelings from getting low scores and focus on the next game.	.704	
4	I had abundant opportunities to develop my own thoughts.	.652	
6.	I could understand why I failed and immediately adapt to get a higher score.	.569	
9.	I could decide the order of game playing	.560	
	Factor 2: Competence		
2	I could think of the answer quickly.		.886
11	I could quickly figure out methods for problem solving.		.807
1	I performed well.		.661
7	I could achieve the scores or goals that I set.		.630
10	I could quickly learn how to achieve high scores.		.601
5	I felt that the problems or challenges matched my ability level.		.519

Table A2. The test items and factor loadings of IFE-DG (N = 130).

	Factor and item	Factor loading	
No.	When playing the game,	F1	F2
	Factor 1: Confidence and attention		
5	I immediately knew whether or not I could successfully complete a mission.	.836	
9	I temporarily forgot what was bothering me in my life.	.799	
7	I immediately knew how I performed (e.g., scores or rankings).	.792	
8	I became competent during the process of taking on challenges.	.759	
6	I completed the missions with my full attention.	.682	
	Factor 2: Fun and challenge		
3	The voice and images in the game increased my interest in playing the game.		.901
2	I understood the mission in the game right at the beginning.		.769
1	I felt that it was interesting.		.731
4	I felt that the mission in the game was not too difficult, nor too easy.		.724

Table A3. The test items and factor loadings of IME-CDG (N = 130).

	Factor and item	Factor loading	
No.	When playing the game,	F1	F2
	Factor 1: Ability to problem solving		
4	I quickly came up with answers.	.773	
6	I was able to solve the problems well.	.756	
2	I was competent in my ability to think creatively.	.654	
8	I quickly became familiar with how to play the game.	.593	
7	I gained some new knowledge.	.538	
	Factor 2: Confidence in problem solving		
1	As long as I kept trying, I could come up with creative ideas to solve the problems.		.937
5	I was confident in my ability to think creatively and solve problems.		.624
3	I found that solving problems creatively was not as hard as I had thought.		.544