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Effects of Game-Based Formative Assessment on Elementary School Students' Mathematics Learning

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Abstract

This study explored the effects of using digital game-based formative assessment (GBFA) in mathematics learning in elementary school. For the fraction unit in mathematics, we developed a digital game-based formative assessment system to adapt to different teaching objectives and teaching activities. This study employed a quasi-experimental research method, dividing the participating students into two groups, namely the experimental group using the GBFA learning mode and the control group using a general formative assessment learning mode. To understand the different effects of GBFAs and general classroom formative assessments on students' learning achievements, self-efficacies, cognitive load and learning attitude. The designed teaching process comprised three cycles, each consisting of 20 minutes of mathematics concept teaching and 5 minutes of formative assessment. Each teaching content of the three cycles was delivered in ascending order of difficulty. The results revealed that the GBFA learning mode significantly enhanced student learning achievement, and the learning attitudes of the students using the GBFA learning mode were more favorable than those of the students using the general formative assessment learning mode. Moreover, the GBFA

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learning mode resulted in a lower mental load on students during the learning activity than that produced by the general formative assessment learning mode, indicating that the GBFA learning mode can more effectively satisfy student learning needs.

Keywords: game-based learning, formative assessments

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探究遊戲式形成性評量對國民小學學生學習數學之影響

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摘要

本研究旨在探究國小數學課程中利用數位遊戲模式進行形成性評量對學生學習數學的影響。本研究特別針對國小數學科分數單元，分別配合不同的教學目標，設計一套數位遊戲式學習系統。為了解遊戲式形成性評量和一般課堂形成性評量在學習成效、自我效能、認知負荷及學習態度上的差異，本研究採準實驗研究法，將學生分為兩組，實驗組使用「遊戲式形成性評量學習模式」，控制組使用「一般形成性評量學習模式」。教學設計採用三次循環，每次循環會先進行20分鐘數學分數概念的教學，再搭配5分鐘的形成性評量。三次教學循環會由淺到深介紹分數單元的學習內容。研究結果顯示，遊戲式形成性評量學習模式能顯著提升學習者的學習成效，且在學習態度方面接受遊戲式形成性評量學習模式的學生，顯著優於接受一般形成性評量學習模式的學生。而接受遊戲式形成性評量學習模式的學生之心智負荷顯著低於一般形成性評量學習模式的學生，顯示此種模式更適合學習者的需求。

關鍵字：遊戲式學習、形成性評量

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Introduction

Assessment is a critical element of teaching and it is part of teachers' daily routine. Using formative assessments, teachers can gather information on students' performances and each student learning processes and difficulties, and thereby adapt their teaching approaches to improve students' learning performance (Black & Wiliam, 1998a; Sadler, 1989; Wiliam & Black, 1996). Formative assessments are usually conducted in written form, which is the form most familiar to students, and can aid them in engaging in mastery learning. However, students are generally less willing to perform paper and pen (P&P) assessments, which they tend to regard as uninteresting (Castellar, All, de Marez, & Van Looy, 2015). Moreover, teachers must attend to many students simultaneously and consider course progress and time pressure, they cannot always provide timely and meaningful feedback on each assessments (Wang, 2011). However, feedback is an essential factor in formative assessment (Sadler, 1989). Timely feedback effectively enhances student learning and encourages students to voluntarily improve their learning self-efficacy (Marriott, 2009; Tsai, Tsai, & Lin, 2015; Wilson, Boyd, Chen, & Jamal, 2011). By contrast, conventional paper-based formative assessments involve numerous problems.

Following the rapid progress of technology and the Internet, computer-based assessments (CBAs) and online assessments have gained increasing popularity (McDonald, 2002). Terzis, Moridis, and Economides (2012) summarized the advantages of CBAs, such as satisfactory accuracy and fairness, timely feedback, and high repeatability. Nevertheless, previous studies have suggested that the same assessments conducted using both P&P and CBA modes may not necessarily yield the same outcomes. Therefore, test mode effects cannot be ignored (Clariana & Wallace, 2002). Similarly, McDonald (2002) reported that CBAs and P&P assessments afford different experiences for testers; individual differences, such as the experience of and anxieties and attitudes toward computer use, can lead to varied assessment results. Wu, Kuo, Jen, and Hsu (2015) also found that the visual representation (i.e., dynamic or static) of CBA items can complicate assessment, which only senior students who have more mature cognitive judgment can manage. Therefore, how different assessment approaches affect learning should be reviewed. According to Wang (2008), replacing P&P formative assessments with web-based formative assessments will not necessarily cause substantial differences in student learning achievement. Moreover, CBAs and online assessments tend to cause the same problems as discussed by Tsai et al. (2015); that is, the deficiency in interpersonal interactions and timely assistance can reduce the motivation of learners to learn.

Responding to the rise in game-based learning in recent years, game elements have been integrated into students' learning processes. Such digital game-based learning (DGBL) is mostly advantageous in eliciting students' intrinsic motivation and interest in learning (Malone & Lepper, 1987; Ricci, Salas, & Cannon-Bowers, 1996). Information technology (IT)-based equipment has been introduced into campuses, causing DGBL to gradually gain popularity among students and thus be adopted as a new learning mode (Aldrich, 2004; Becker, 2007; Prensky, 2001; Squire, 2005). DGBL can be combined with assessment. Attali and Arieli-Attali (2015) applied a game scoring-mechanism into an assessment and found the problem-solving speed of testers was accelerated. Tsai et al. (2015) and Ventura and Shute (2013) have suggested that combining formative assessment and DGBL can stimulate learner motivation for undertaking assessment and yield accurate feedback that learners can use to maximize learning achievement according to learning ability.

Moreover, previous studies have discovered that most types of DGBL can stimulate a flow experience among learners (Hwang, Chiu, & Chen, 2015; Hwang, Wu, & Chen, 2012) that can enhance learning achievement (Barzilai & Blau, 2014; Domínguez et al., 2013; Sung, Hwang, & Yen, 2015), promote learning attitudes and self-efficacy (Sung & Hwang, 2013), and reduce cognitive load (Hwang, Yang, & Wang, 2013). Therefore, this study explored whether DGBL combined with formative assessment can enhance learning achievement. Moreover, the proposed game-based formative assessment (GBFA) was compared with a general formative assessment to investigate the different effects on student learning. This study mainly focused on the fraction learning of elementary school students to conduct an experiment addressing the following two research questions:

1. Can students using the GBFA learning mode attain a significantly enhanced achievement and develop a substantially more active attitude and improved self-efficacy in fraction learning than can students using the general formative assessment learning mode?

2. Are students using the GBFA learning mode subject to a significantly lighter cognitive load than are students using the general formative assessment learning mode?

Literature Review

DGBL and Math Learning

Numerous previous studies have suggested that DGBL exerts positive effects on learning. Prensky (2007) noted that it can improve learner visual concentration. According to Chen and Chen (2009), when performing single-player or group activities in an interactional DGBL setting, learners can enhance their learning achievement by communicating with peers and receiving feedback from the DGBL system. Moreover, the DGBL system can easily create a natural problem-solving scenario, enabling students to experience meaningful learning (Hwang et al., 2015).

In recent years, the DGBL mode has been tentatively integrated into various disciplines. Tsai and Fan (2013) summarized recent studies regarding online DGBL and concluded that DGBL applications were mainly focused on the following fields: science and social studies learning (41.6%), system design exploration (29.2%), an unspecified field (16.7%), language learning (8.3%), and mathematics learning (4.2%). Therefore, more research is required to investigate the efficacy of DGBL in assisting learning in mathematics disciplines.

Previous studies have strongly confirmed that DGBL benefits mathematics learning, regardless of the level of mathematics concepts or the individual differences among elementary and junior high school students. Bai, Pan, Hirumi, and Kebritchi (2012) recruited 437 eighth-grade students, conducting an experiment involving a three-dimensional math game; the results revealed that gaming can enhance student mathematics knowledge acquisition and sustain motivation in mathematics learning. Moreover, Shin, Sutherland, Norris, and Soloway (2012) investigated the effect of game technologies on student's mathematics learning in elementary schools. They discovered the students performed more favorably in technology-enhanced games than in paper-based games, and the game acted as an effective learning means enabling the students to acquire new knowledge according to prior knowledge and experience. Furthermore, digital games can be used to strengthen student's mathematics calculation skills. Castellar, Van Looy, Szmalec, and de Marez (2014) and Castellar et al. (2015) have compared students who used a commercial mathematics game, *Monkey Tales*, to practice mathematics calculations with students undertaking P&P mathematics calculation practice. The results revealed that game-based practice accelerated problem-solving speed while improving accuracy, and enhanced the learning enjoyment and working memory of the students.

In the mathematics curriculum of elementary schools, numbers and quantity concepts account for a large proportion of the teaching content, and the fraction section is particularly extensive. A relevant study verified that students' ability to learn fractions affects their overall mathematics achievement and is key to future algebra learning; thus, improving fraction learning ability can enhance students' overall mathematics performance (Bailey, Hoard, Nugent, & Geary, 2012). Therefore, this study, focusing on fraction learning in an elementary school, investigated the following aspects: discriminating proper fractions, improper fractions, and mixed fractions; converting between improper fractions and mixed fractions; and adding fractions. Formative assessment was combined with digital games to enhance student learning motivation and achievement.

DGBL and Formative Assessment

Formative assessment provides a means of continually monitoring learner knowledge construction (Hsu, Chou, & Chang, 2011) and is indispensable in assessing learners' learning states. Black and Wiliam (2009) revealed that formative assessment is key in teaching, which is often affected by student assessment results. Therefore, studies have suggested that after an assessment, teachers can review their teaching content according to the assessment feedback and adapt their instructional strategies accordingly (Bell & Cowie, 2001; Chen & Chen, 2009). Hence, many studies (Barron et al., 1998; Black & William, 1998b; Bransford, Brown, & Cocking, 2000; Brown & Knight, 1994; Buchanan, 2000) have emphasized the importance of formative assessment in student learning.

Recently, game elements have been widely employed in teaching practice. However, studies exploring games combined with formative assessment are limited. Such studies have only involved single-tester tests and examined the test results without using a control group for comparison. Hudson and Bristow (2006) employed the television quiz show, *Who Wants to Be a Millionaire*, to design a formative assessment for testing first-year medical school students on physiological concepts related to growth and adolescence. Consequently, the students were interested in the formative assessment, which not only provided feedback, but also enabled them to express and clarify misconceptions. Moreover, Schlegel and Selfridge (2014), focusing on medical school students, created a competitive, interactive quiz game, the feedback function of which received a positive response from both teachers and students; the game was considered able to promote teaching.

In addition, Cuomo, Fuccella, and Murano (2010) developed a portal for an online formative test system using games to render multiple-choice question practice. A built-in database in the system enables teachers to quickly and randomly select questions. During a test, all student answers are recorded, and teachers can promptly adapt teaching approaches, thus creating a positive cycle.

Other studies have emphasized investigating the difference in the game mode, feedback mode, and assessment type of GBFAs. Tsai et al. (2015) used a board game, *Trisq*, to develop a GBFA and explore various game and feedback modes, revealing that no substantial differences in acquiring knowledge were found for either single-player or multiplayer games. However, an immediate elaborated feedback mode can enhance learner knowledge acquisition without reducing learner enjoyment. By contrast, Wang (2008), involving four crucial concepts related to plants in elementary school curricula, developed a multiple-choice Web GBFA system featuring a uniquely designed ask-hint strategy, and investigated the efficacy of this feature in promoting student learning. The results revealed that the students using such a system more actively participated in the test than did those who used a general Web-based test; replacing a P&P test with a Web-based test did not cause considerable differences in the efficacy of the formative assessment.

In summary, formative assessment combined with game-based learning can enhance assessment efficacy. However, there appear to be no available studies focusing on analyzing learner self-efficacy and cognitive load, and few studies have compared different assessment approaches. Therefore, in addition to integrating a feedback mechanism into the game design, this study primarily investigated the difference between two types of formative assessment in affecting learner self-efficacy and cognitive load.

Experiment Design

This section presents the design of a DGBL-based formative assessment system that involves using the fraction section of a fourth-grade mathematics course as a design platform, and conforms to the present elementary school curriculum. This system comprises three formative assessment games to facilitate three sequential activities during fraction learning.

The first game is mainly to practice distinguishing proper fractions, improper fractions and mixed numbers (Figure 1). Students can control the characters around the screen, and answer the fraction type for each number on the screen. If the type is correct, students can get points. The second game (Figure 2) is designed to practice exchanging the improper fractions and mixed fractions. If students answer correctly, they can get gold through the missile launch. The third game (Figure 3) is designed to practice fraction addition and subtraction. Students can throw darts at balloons to answer questions.

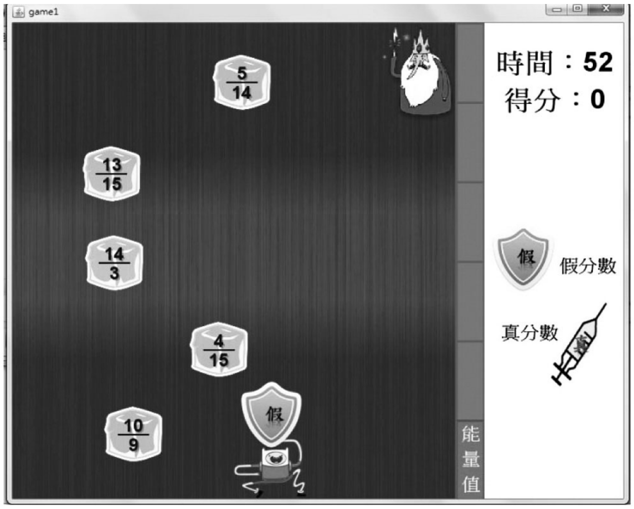

Figure 1 Game 1: practice distinguishing fractions.

Figure 2 Game 2: practice exchanging fractions.

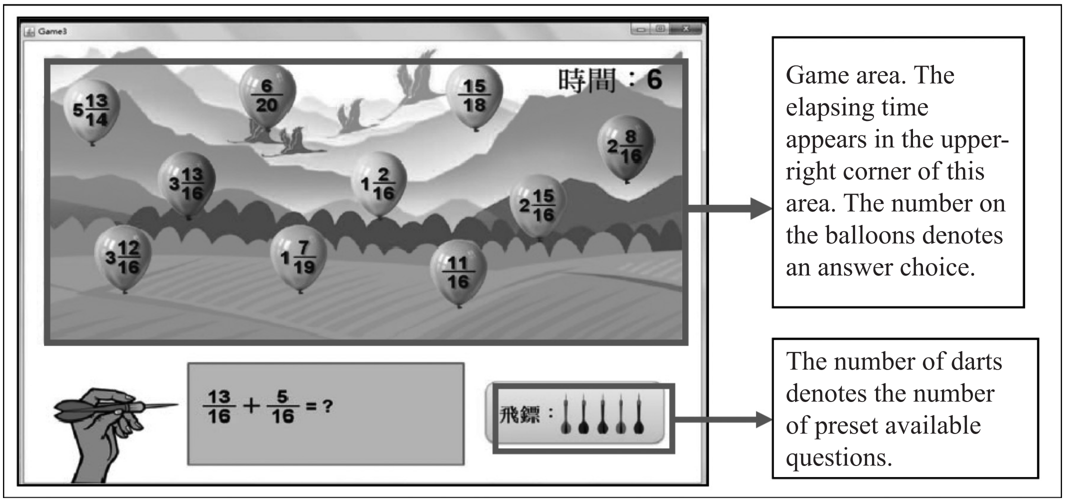

Figure 3 Game 3: practice fraction addition and subtraction.

Instant feedback displayed on the game screen is available in all three games, and a replay function was embedded in Game I to enable repeated practice for students to master basic concepts in a unit. Moreover, there are three checkpoints in Games II and III that correspond with easy, medium, and hard levels. Accumulating five correct answers leads to the next checkpoint, and thereby students are challenged with an increasing degree of difficulty.

Participants

The participants comprised 131 fourth-grade students at an elementary school in northern Taiwan. The students were allocated into different classes following an S-type normal distribution that yielded an equal overall learning ability among the classes. The participants all possessed basic IT competency. This study involved a quasi-experimental design, in which the experimental group undertaking the GBFA learning mode comprised 65 participants (34 boys and 31 girls) and the control group undertaking a general formative assessment consisted of 66 participants (38 boys and 28 girls).

Research Tools

This study involved several research tools, such as pre- and post-assessment mathematics concept test sheets, pre- and post-assessment learning attitude questionnaires, pre- and post-assessment learning self-efficacy questionnaires, and a cognitive load questionnaire. Conforming to the mathematics curriculum, the pre- and post-assessment mathematics concept question sheets contained questions on discriminating proper fractions, improper fractions, and mixed fractions; converting between improper fractions and mixed fractions; and adding fractions with the same denominators.

The pre- and post-assessment mathematics concept question sheets were formed by modifying the learning motivation questionnaire of Hwang et al. (2013). These question sheets involved 7 questions evaluated on a 5-point Likert scale for measuring participant willingness and confidence in learning mathematics. The 5-point scale ranged from 1 (strongly disagree) to 5 (strongly agree), and the Cronbach's $\alpha = .79$.

The pre- and post-assessment self-efficacy questionnaires were created by modifying the collective efficacy questionnaire of Wang and Hwang (2012) and adopting 8 questions evaluated on a 5-point Likert scale. A higher score on the scale indicated more active self-efficacy for mathematics learning. The Cronbach's $\alpha = .916$.

The cognitive load questionnaire was adapted from the study of Hwang et al. (2013) to examine participant mental load (5 questions) and mental effort (3 questions). A 7-point Likert scale was adopted, and a higher score indicated a greater cognitive load. The Cronbach's $\alpha = .85$ for the mental effort measurement and .86 for the mental load measurement.

Experiment Procedure

To understand how various formative assessment learning modes affected the learners' learning achievement and attitude, self-efficacy, and cognitive load differently, all the test students were divided into two groups, namely the experimental group undertaking the GBFA learning, and the control group undertaking general formative assessment (i.e., P&P) learning.

Before the teaching activities were conducted, the students in both groups were pretested on mathematics concepts and answered the learning attitude and self-efficacy pre-assessment questionnaires. Subsequently, three cycles of tests were conducted; each cycle comprised 20 minutes of fraction concept teaching and 5 minutes of formative assessment. For the formative assessment, the experimental group used the GBFA whereas the control group used the P&P test. Students who use the GBFA also have papers and pens to calculate the math question.

Finally, all students were post-tested on the mathematics concepts and completed the learning attitude and self-efficacy post-assessment questionnaires and the partial close-ended cognitive load questionnaire.

Results

Analysis of Mathematics Concept Learning Achievements

An independent samples *t* test was performed to analyze the scores of the pre- and post-assessments of mathematics concepts. The pre-assessment results revealed no significant difference between the experimental and control groups (t = .69, p> .05), which indicated that the two groups had an equal level of cognition and prior knowledge. By contrast, the post-assessment results indicated a significant score difference between the two groups (t = 2.31, p< .05), and the Cohen's d = .4. This result implied that GBFA learning can assist students in attaining a significantly greater learning achievement than can P&P-based formative assessment learning.

Analysis of Mathematics Learning Attitude

The scores of the pre- and post-assessments of learning attitude were analyzed using the independent samples *t*-test. Table 1 exhibits that at the pre-assessment stage, these two learning modes differed non-significantly in learning attitude (t = .89, p> .05), and Cohen's d = .27. This result was consistent with the initial expectation in this study. By contrast, the learning attitude in the post-assessment stage differed significantly between the two groups (t = 1.42, p< .05), and Cohen's d = .21. This result revealed that GBFA learning promoted a significantly more active learning attitude than did P&P-based formative assessment learning.

Table 1

Pre- and Post-assessment t-test Values of Mathematics Learning Attitude

Questionnaire type	Formative assessment mode	Number of participants	**Average score**	Standard deviation	*t* value	*d*
Pre-assessment of learning attitude	GBFA	65	**4.13**	5.17	0.89	.27
	P&P	66	**3.99**	4.89		

（continued）

Table 1

Pre- and Post-assessment t-test Values of Mathematics Learning Attitude

Questionnaire type	Formative assessment mode	Number of participants	**Average score**	Standard deviation	*t* value	*d*
Post-assessment of learning attitude	GBFA	65	**4.31**	6.76	1.42*	.03
	P&P	66	**4.11**	6.15		

* $p < .05$

Analysis of Mathematics Learning Self-efficacy

An independent samples *t*-test was conducted to analyze the pre- and post-assessments of mathematics self-efficacy; Table 2 presents the results. The pre-assessment (t = 1.71, p> .05) and post-assessment (t = -.42, p> .05) scores of the two groups for self-efficacy differed non-significantly. The results implied that the students in both groups had the same self-efficacy level before participating in the teaching activities, and neither type of formative assessment significantly affected student self-efficacy improvement after the teaching activities.

Table 2

Pre- and Post-assessment t-test Values of Mathematics Self-efficacy

Questionnaire type	Formative assessment mode	Number of participants	**Average score**	Standard deviation	*t* value
Pre-assessment of self-efficacy	GBFA	65	**3.95**	5.17	1.71
	P&P	66	**3.93**	4.89	
Post-assessment of self-efficacy	GBFA	65	**3.97**	6.76	-.42
	P&P	66	**4.03**	6.15	

Analysis of Cognitive Load

A similar *t*-test was conducted for cognitive load analysis. The result revealed a significant difference between the two groups (t = 2.09, p< .05), and Cohen's d = .37. This result indicated that GBFA learning exerts a relatively low cognitive load and is thus a satisfactory learning mode.

This study also analyzed two dimensions of cognitive load separately. In the mental load dimension, the experimental and control groups differed significantly (t = -2.44, p< .05), and Cohen's d = .43. Therefore, the GBFA learning mode exerted a lower mental load on the students than did the P&P learning mode; in other words, integrating game elements in learning enabled the students to perceive that the teaching materials were easier. In the mental effort dimension, the two groups differed non-significantly (t = 1.28, p> .05), which implies that learners using either of these two learning modes must expend an equal degree of mental effort.

Analysis of the Open-ended Questionnaire

According to the answers to the open-ended questions, the students in the GBFA group responded positively and considered the computer-based mathematics learning to be enjoyable. Moreover, by participating in the experiment, the students spontaneously perceived the evident differences between GBFA learning and conventional P&P formative assessment learning. "I think it's fun using games to solve mathematics problems, because I can learn while playing" (Student A). "This activity was really interesting. The learning improved my reactions, which made me feel happy" (Student B). "It's my first time using a computer to learn mathematics. It's fun and not boring at all" (Student C). "I can be more concentrated and learn faster while learning" (Student D).

However, some of the students raised concerns about the game design and time settings. The emphasis of fraction learning is for students to master fraction conversion and calculation. Because of individual differences in mathematics ability, some of the students believed that the questions related to fraction conversion and calculation were too difficult, and they felt pressured by the time limit. "The difficult thing was that the conversion required a lot of time" (Student E). "Sometimes I got stuck during the calculations" (Student F). "The game rules shouldn't be so complicated, so that I can have more fun playing" (Student G).

Moreover, some students in the control group shared similar opinions regarding the general formative assessment, and proposed that additional time should be provided for the test. "The time was too short for me to write down all the answers" (Student H). "More time should be given to finish the answers" (Student I).

Discussion and Conclusion

This study revealed that a GBFA learning mode used to teach fraction concepts to elementary school students is significantly more able to promote student learning achievement and attitude than is a general formative assessment learning mode. However, in the self-efficacy dimension, the inter-group and within-group comparison of the ability of the two learning modes to enhance learner self-efficacy differed non-significantly.

The experimental group outperformed the control group in learning achievement. This finding indicates that the proposed GBFA system can enhance student learning of fraction concepts, and integrating digital games into formative assessment can aid students in developing mathematics ability. This study involved both fraction concepts and calculation skills, and the results confirmed the findings of previous studies, that digital games benefit mathematics learning and can improve calculation skills and accuracy (Bai et al., 2012; Castellar et al. 2014; Castellar et al., 2015; Shin et al., 2012). Moreover, the instant feedback function embedded in the proposed GBFA learning mode was a key factor in enhancing the students' learning achievement. Hudson and Bristow (2006), Schlegel and Selfridge (2014), and Tsai et al. (2015) have revealed that the GBFA providing instant feedback can promote knowledge acquisition. The finding that the GBFA learning mode can improve student learning achievement was also reflected in a study by Wang (2008).

The learning attitude of the experimental group was more positive than that of the control group, implying that in contrast to students engaging in general formative assessment learning, students engaging in GBFA learning showed a more active learning attitude. Before this study, relevant research has mostly focused on discussing game-based learning, with less exploration of its combination with formative assessment. According to Sung and Hwang (2013), applying cooperative game-based learning in school study can promote learning attitudes. Pilli and Aksu (2013) employed repeatable practice software *Frizbi Mathematics 4*, which features an adventure game as a blueprint, and found that using this software can promote both mathematics learning achievement and attitude. Therefore, we anticipate that the empirical research conducted on GBFA in the present study can be referenced for future research.

In contrast to the results of previous studies, neither type of formative assessment learning mode in this study enhanced student self-efficacy. According to Sung and Hwang (2013), applying cooperative game-based learning in school study can promote learner self-efficacy. Bandura (1994/1998) suggested that self-efficacy is mostly affected by four sources, among which the most effective is mastery experiences that produce successful experiences. Therefore, we posit that the learning modes in our study did not promote student self-efficacy, possibly because of the short timeframe for applying the formative assessments in the teaching process. Students in both groups engaged in the formative assessments three times for 5 minutes each time. In such a short practice period, the students cannot have mastery experiences or gain enough confidence for enhancing their self-efficacy. This result was also reflected in the survey of the open-ended questionnaire (e.g., "The difficult thing was that the conversion required a lot of time"). Therefore, we recommend that the time period should be regarded as a crucial consideration or dependent variable to be discussed in future studies.

In the cognitive load aspect, the experimental group outperformed the control group, which implies that the GBFA learning mode is satisfactory because it elicits a relatively low cognitive load. According to Hwang et al. (2013), well-designed, game-based learning can mitigate cognitive load, benefiting learning. Our study revealed that the experimental group had a lower mental load than did the control group. Although the same content was to be learned, by using different formative assessments, the students engaging in GBFA learning considered the learning content to be relatively simple. This result was also confirmed in the survey of the open-ended questionnaire (e.g., "By using this method to learn, nothing felt difficult" and "I understood the teaching content even faster"). However, in the mental effort dimension, the two groups differed non-significantly; the learners expended an equal amount of effort learning new mathematics concepts regardless of the learning mode they used. This result might be attributed to the nature of the teaching material used. Marcus, Cooper, and Sweller (1996) proposed that three basic factors in a teaching process can affect cognitive load, and the nature of material is one such factor. For fourth-graders, the concepts of improper fractions and mixed numbers are new and involve basic mathematic calculations (i.e., addition, subtraction, multiplication, and division), increasing the difficulty of learning. Therefore, although the game was designed to simplify the teaching material, the students still had to endeavor to master the teaching content.

In summary, integrating digital games into a formative assessment, we used the positive effects of digital games on enhancing learning achievement and attitude, and overcame the shortcomings of conventional P&P formative assessment (e.g., no timely feedback and low learning motivation). Therefore, this GBFA learning mode is worth promoting in school education practice. Moreover, future studies should consider the assessment time when designing games to enable adequate time for student practice, although a prolonged practice time is still subject to the class period. We expect that using IT devices (i.e., tablets, mobile phones) in learning activities can free students from temporal and spatial limitations. Furthermore, we did not investigate the variations in the different formative assessments from the teacher's viewpoint; therefore, teacher opinions may also be explored.

This study is limited by the time constraints; only three digital games were designed for the fraction unit in mathematics. Therefore, future research can consider increasing the teaching courses and time; in this way, we believe that the effectiveness of the proposed system or self-efficacy will have a more significant impact.

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