Promoting Students' Math Learning Performance and Engagement: A Help-seeking Mechanism-based Mobile Gaming Approach

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Abstract

Mobile game-based learning systems are generally expected to be interactive, connectable, and recordable. Researchers have indicated that it is important to promote interaction between peers during mobile learning activities in class. In this study, an interactive mobile math game with a help-seeking mechanism is proposed to improve elementary school students' learning achievements, learning motivation and social interactions. To evaluate the effectiveness of the proposed approach, an experiment was conducted in an elementary school mathematics course. A total of 59 third graders from two classes participated in the experiment. One class with 30 students was assigned to the experimental group learning with the interactive mobile math game with the help-seeking mechanism, while the other class with 29 students was assigned to the control group learning with the conventional mobile gaming approach. Based on the empirical results, it was found that the proposed approach effectively promoted the students' learning achievement and learning motivation. A follow-up analysis of the experimental results further showed that the proposed approach benefited the students with low mathematics self-efficacy more than those with high self-efficacy, indicating the potential of the approach for helping students with low self-efficacy improve their mathematics ability.

Keywords: Mobile learning, Digital game-based learning, Help-seeking mechanism, Learning motivation, Fraction

1 Introduction

In recent years, digital game-based learning has been recognized as a novel computer-supported learning approach in science and technology education to motivate students to learn, which is an important factor for promoting students' learning achievement [1-5, 58]. In comparison with traditional lessons or conventional technology-enhanced learning, game-based learning provides more challenging tasks and engages students in situated and enjoyable learning processes [4-5]. Scholars have further indicated that a well-designed game-based learning system could stimulate students to interact with the game according to different levels of ability [1, 6].

Nowadays, with the popularity and advancement of smart phones and tablet PCs, students are able to play mobile games that enable them to learn without limitations of space or time [7-8]. Moreover, using personal mobile devices allows students to easily interact with peers during the learning process. Therefore, many researchers have tried to develop educational mobile games for different disciplines, especially games which could improve interaction and collaboration during the learning process [9-10]. For example, researchers developed a game-based e-book learning system to improve students' interaction with the learning content, and hence promoted their learning achievement, self-efficacy, and motivation to learn mathematics [11]. Molnar et al. used the EducaMovil tool to help teachers easily create and integrate customized educational content in a mobile learning game [12]. In mathematics education, projects such as MobileMath [13] and UFractions [14] have embedded mobile games in parts of the learning contexts, which have the potential to positively impact knowledge of mathematical concepts. Furthermore, researchers have indicated that the game-based learning model could facilitate students' learning motivation for mathematics and increase their engagement [11, 15]. Some recent studies have also reported that educational mobile games can draw students' attention to the learning materials and facilitate their active learning experiences [16-17, 59]. In the meantime, several researchers have pointed out that using only the gaming approach might not help students improve their learning outcomes; that is, it is necessary to integrate effective learning strategies when developing educational games [18-19].

Among various learning strategies, peer assistance or the peer tutoring strategy has been recognized as an effective strategy for encouraging students to seek help and share knowledge via peer interactions [20]. For example, Hwang, Shi, and Chu pointed out that the strength of mobile devices is that they facilitate peer interactions [21]. Chu et al. investigated students' learning achievements in mathematics using a formative peer tutoring strategy, and found that students could tackle more difficult problems and presented better performance in solving mathematical problems [20]. Similarly, Zeng and Takatsuka also identified the benefits of the computer-mediated peer interactive learning approach [22]. Hwang, Wu, et al. proposed an instant help-seeking context-aware ubiquitous learning platform to give hints to students from the right people [23]. It was found that the experimental group finished the assembly job in nearly 30% less time than

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those in the control group. Therefore, in this study, an interactive mobile math game with a help-seeking mechanism (IMMG-HS) is proposed. It allows students to seek a peer's instant assistance when they encounter learning obstacles in the learning process. The proposed IMMG-HS approach guided third graders to interact online with group members and receive instant help for learning fractions. Moreover, the study attempted to investigate the effectiveness of the proposed learning approach, and a quasi-experimental design was conducted to address the following research questions:

(1). Can IMMG-HS improve students' mathematics learning achievement more than the conventional mobile gaming approach?
(2). Can IMMG-HS promote students' mathematics learning motivation more than the conventional mobile gaming approach?
(3). Can IMMG-HS promote students' flow experience more than the conventional mobile gaming approach?
(4). What are the effects of IMMG-HS on the learning achievements of students with different mathematics self-efficacy in the mathematics course?
(5). What are the differences between the learning behaviors and feedback of the students learning with IMMG-HS in comparison with those learning with the conventional game-based learning approach?

2 Literature Review

2.1 Digital Game-based Learning

Digital game-based learning is considered to be an effective learning method [36] as it enhances students' learning experience and motivation [17]. Several researchers have investigated the influence of digital game-based learning on students' self-efficacy [37] and their collaborative and interactive behavior during game-based learning processes [38]. Many scholars have proposed some different views on the design of game-based learning. For instance, Prensky stated that the characteristics of learning content should be considered in game-based learning design, and appropriate games should be selected to achieve the learning purposes [6]. Zhang et al. adopted a fraction application (app) to help students gain fraction knowledge. The results showed that students performed better on a transfer test, meaning that students in the experimental group understood fractions deeply so they could transfer the knowledge [4]. Lei et al. indicated that certain learning games can enhance learning motivation effectively because their learning content and game context are compatible [24]. Many researchers have indicated that the appropriate design of digital instructional games can help learners achieve the expected learning goals [25-26]. Thus, empirical studies have revealed that essential elements for excellent instructional games should contain a clear set of goals, challenge, potential control, and immediate and appropriate feedback [6]. Students generally hope to use an enjoyable and effective method integrated with challenging games to effectively learn when playing games [27].

An instructional game must be challenging, and a challenging game could increase learners' cognitive knowledge and improve their problem-solving skills [28]. In other words, learners would be able to immerse themselves in game-based learning and focus on learning tasks. By challenging themselves, learners could enhance their self-affirmation, thereby achieving the learning purposes. Therefore, learning goals should be incorporated into games during the design process so that students would have advanced learning outcomes.

With the prevalence of mobile technologies, learning is no longer limited by space and time [7-8] and numerous studies on the application of mobile devices as learning tools have been conducted in diverse fields of education [29], for instance nursing education [30-31], science education [32], English learning [33-34], and so on. Recently, mobile technology has been considered to integrate game-based learning strategies for investigation of students' learning performance and motivation. For example, Chen and Hsu investigated whether a mobile game-based English learning context via virtual reality application could affect university students' learning performance, self-efficacy, and intrinsic motivation. The research findings showed that the proposed learning approach could increase students' game engagement, immersion, and self-efficacy [35]. Consequently, self-regulation and learning performance in English were significantly enhanced as well. Student self-regulation became a moderate factor in the mobile game-based learning. Similarly, Huizenga, Admiraal, Dam, and Voogt tried to guide 181 secondary school students to learn basic accounting with the mobile game-based learning system "NoCredit, GameOver (NCGO)." The research findings showed that the learning system could immerse students in English learning and improve team performance and learning outcomes. Previous studies about using mobile game-based learning enabled learners to enter the state of flow easily and increased their learning motivation [39]. However, it has become a challenge for mobile game-based learning to enhance students' learning achievement without any adequate instructional strategy [7, 33].

Numerous studies have focused on integrating traditional effective instructional strategies into the game-based learning approach, for example, scaffolding [39], concept maps [40], two-tier tests [41], and inquiry-based learning [42]; however, most strategies have primarily focused on learning achievement rather than on social manners. How to employ effective strategies to enhance student social interaction in digital game-based learning is critical, and past research has not addressed this issue properly.

2.2 Help-seeking Mechanism

Researchers have indicated that peer assistance emphasizes the interaction between peers that could help students reduce their anxiety in the learning process and consequently improve their learning performance [43]. Such a learning support, a help-seeking mechanism, developed based on the notation of peer assistance and peer tutoring [44], is a learner-centered and peer-mediated instructional method originating from cognitive psychology, humanistic psychology, social psychology, and motivation theory [45].

In a peer tutoring strategy, students act as academic tutors and tutees. Basically, a higher achieving student who has received complete academic training and has gained a teaching qualification is paired with a lower achieving student. Thus, the tutor possesses the authority to organize the learning content and monitor the learning results [46]. That is, the responsibility of a tutor is to accelerate differences concerning low social interactions between teachers and students, while preventing it from affecting students' learning achievements.

Previous studies on the application of the peer assisted learning (PAL)/ peer tutoring (PT) strategy in learning mathematics have shown that students who adopted the peer assisted learning/ peer tutoring strategy could enhance their learning achievements and increase their positive learning attitudes toward mathematics [20, 44, 47]. During the PAL or PT strategy, students have opportunity to function as a tutor or tutee at different times, and are typically paired with other students who are at the same skill level, without a large discrepancy between abilities. Such a learning context enables students to keep a communicative relationship with each other without any pressure or barrier. Thus, self-efficacy can be raised and can stimulate students to find a way to enhance their cognitive ability [48-49].

In the study, the grouping method referred to the conventional peer tutoring strategy, including the "same-age" and "cross-age" help-seeking mechanisms. The "same-age" help-seeking mechanism involves students who have more advanced ability being paired with less advanced students, while the "cross-age help-seeking mechanism" emphasizes that the older student serves as a tutor and the younger student is the tutee. In this study, students in a class of the same grade were paired. Subsequently, the learning activity with the help-seeking mechanism was conducted through a heterogeneous grouping method which enabled high-achieving students to teach low-achieving students.

In the mobile-learning game environment, students can actively seek peers' help during the game process. Unlike conventional peer tutoring, this study developed an interactive help-seeking interface in the mathematics game, indicating that every pair of students was grouped and played the games together online. The student with lower mathematics grade in the pre-test could request help from his/her peer and pause the game until the problem was solved. The help-seeking mechanism is considered a highly interactive structured online collaborative learning activity that prompts students to learn and improve through online interactions and discussion of the game.

3 Interactive Mobile Math Game with a Help-seeking Mechanism

In this study, the help-seeking mechanism module was developed and embedded into a mathematics app as an interactive interface for the mobile game. The aim of this study was to investigate the effectiveness of the IMMG-HS system. This study developed a mathematics mobile game-based learning system to improve the students' learning performance. The system was implemented according to the client-server model, where client interfaces are designed for students and the server is responsible for game control and message exchange. Installed on a Windows tablet and equipped with a wireless learning environment, this system comprised a help-seeking mechanism network functional module, scoring functional module, help-seeking mechanism grouping module, game-based learning database, help-seeking mechanism interactive-process database, student mathematics score database, and student personal information database. The help-seeking mechanism is shown in Figure 1. The figure shows that when students of the experimental group encounter learning problems in learning fractions, they could ask for a tutor's help by pressing the bottom-right button on the screen. Their help-seeking request would be delivered to the assigned tutor immediately, who would then start to teach the asker basic and important concepts of fractions, shown in the Encouragement and Commendation area. Thus, students of the experimental group were allowed to apply the help-seeking mechanism to seek immediate online assistance from tutors, and to discuss any encountered math problems to clear up their misconceptions.

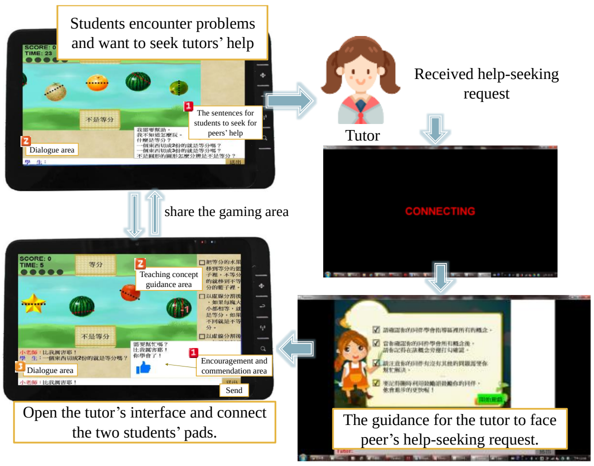

Figure 1. The help-seeking mechanism

This system provided learning content based on the fraction unit for third graders in elementary school, including four topics: "Equal shares," "Fraction measurement," "Unit quantity," and "Comparing simple fractions." In this system, four games were designed for the four units, and each game was timed. The games were equipped with a mechanism in which the number of consecutive errors was calculated, where an incorrect answer led to point deduction. The game ended when the time was up or when five consecutive errors were made (as shown in Figure 2 to Figure 5).

The first unit is "Equal shares." The player must drag the object to the correct basket according to the nature of whether the object is equally divided. If it is dragged incorrectly, points will be deducted (as shown in Figure 2).

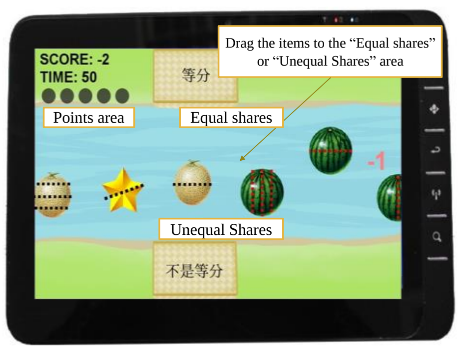

Figure 2. The first unit of the fraction game: "Equal shares"

In the second unit, players must drag the cookies into the correct fraction area, for example, one-half, one-third, one-quarter, etc. The game adopts a timing system. If the dragging error reaches five times in a row, the game is over (as shown in Figure 3).

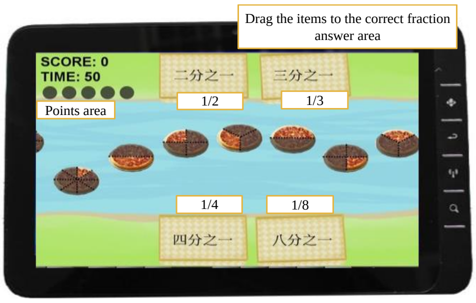

Figure 3. The second unit of the game: "Fraction measurement"

The purpose of the third unit is to let students understand the relationship between the unit quantity of the content. The game adopts a timing system. The premise of the game is that there are 10 eggs in a box. The player must select the eggs in a vertical or horizontal direction to select one-tenth of the box, one-fifth of the box, two-fifths of the box, and three-fifths of the box. At the same time, students must avoid the crossbones that appear randomly at the beginning of the game. The more eggs they pick at a time, the more points they get (as shown in Figure 4).

Figure 4. The third unit of the game: "Unit quantity"

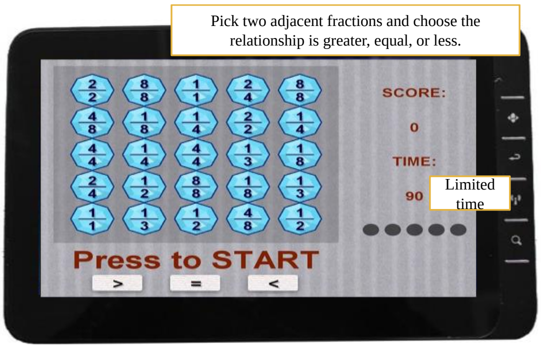

Figure 5. The fourth unit of the game: "Comparing simple fractions"

The game interfaces were based on the help-seeking mechanism strategy (Figure 6). The interfaces for both tutors and tutees had message blocks and dialogue boxes. The tutor part included areas where words of encouragement and commendation are presented, and a list of important instructions are provided. The "teaching concept guidance area" demonstrates the important concepts of this unit that the students need to learn in the unit's learning activity. The tutors could teach their tutees by using the instructions in the teaching concept guidance area; moreover, the tutors were asked to check whether all concepts were taught in the learning activity. The tutee part included a help-seeking area. When a tutee asked for help, the tutor would stop the game and then resume the game when the problem was solved (as shown in Figure 6).

The help-seeking mechanism interface also comprised a chat function and emoticons that enhanced the diversity of the learning activities and communication methods. In addition to face-to-face discussion, the learners could use the online chat function combined with emoticon stickers to enrich the liveliness of the interactive activities (as shown in Figure 7).

Figure 6. Screenshot of a game-based learning scenario for the tutor who can provide help

Figure 7. Screenshot of a game-based learning scenario for the tutee who seeks help

4 Method

In this study, a quasi-experiment design was conducted on the "fraction" unit of the mathematics course in an elementary school. The objective of the course unit was to educate students about concepts such as "equal shares," "fraction measurement," "unit quantity," and "comparing simple fractions." The independent variable was the different modes of game-based learning approach, while the dependent variables included learning achievement, learning motivation, flow experience, and self-efficacy.

4.1 Participants

A total of 59 third graders whose average age was 9 from an elementary school in northern Taiwan participated in this study. This school assigns students to classes by using the normal class grouping method, which ensured that the academic level of students was identical among classes. One class was assigned to be the experimental group and the other was the control group. This study applied a quasi-experimental design, wherein the experimental group comprising 15 tutors and 15 tutees employed the IMMG-HS approach, and the control group consisting of 29 students was taught using the conventional mobile gaming approach.

4.2 Research Instruments

The research instruments of this study were the pre-test and post-test examination papers for assessing learning performance in mathematics, and questionnaires for evaluating students' mathematics learning motivation, flow experience, and self-efficacy in mathematics.

The pre-test and post-test examination papers for assessing learning performance were reviewed by three Grade 3 elementary school teachers with more than 10 years of teaching experience, and therefore exhibited expert validity. The content of the examination papers included four categories: equal share, understanding simple fractions, unit quantity, and words of measurement, and comparing simple fractions. It consisted of three questions of "look at the picture and circle the answer" (15%), 11 questions of "calculate and fill in the answer" (55%), and six questions of "check the formula for which side is bigger" (30%).

In this study, the questionnaire for mathematics learning motivation was adapted from the questionnaire developed by Aiken et al., (2014) [55]. A 5-point Likert scale was adopted and included five questions. The responses to each question were strongly agree, agree, partially agree, disagree, and strongly disagree. The internal consistency reliability estimate for the learning motivation questionnaire (Cronbach's α) was .86.

This study employed the game flow experience questionnaire developed by Wang and Chen [56], which comprised two parts: pre-flow experience and flow experience. A 5-point Likert scale was adopted, with a score ranging from 1 to 5. The lowest and highest total scores were 34 and 170, respectively. The Cronbach's α values for the two dimensions were .92 and .87. The Cronbach's α value for the entire scale was .94.

In this study, the questionnaire for mathematics self-efficacy was adapted from the general self-efficacy questionnaire established by Sherer and Maddux (1982) [57]. This questionnaire comprised three dimensions: proactivity, persistence, and self-confidence. A 5-point Likert scale was adopted for this scale, which included 18 questions. The internal consistency reliability estimates (Cronbach's α) for proactivity, persistence, and self-confidence were .78, .72, and .74, respectively. The Cronbach's α value for the entire scale was .90.

4.3 Experiment Procedure

Figure 8 shows the experimental procedure. To determine how different learning activities influence the students' fraction-learning achievements, the students were divided into two groups: the experimental group, which engaged in the IMMG-HS, and the control group, which adopted the conventional mobile gaming approach. Before the experiment was conducted, an achievement test and the questionnaires for learning motivation and self-efficacy were administered to the two groups. Subsequently, all of the students were taught fractions for 120 min, after which they spent 20 min familiarizing themselves with the game interfaces and operation.

The instructional experiment lasted 120 min. For the experimental group, two students with different learning achievements were paired. The high-achievement student acted as a tutor and led the low-achievement student who acted as the tutee in undertaking a help-seeking mechanism activity. To enhance learning motivation, a competition mechanism was included in the game. For the experimental group, the competition results of each pair of students were accumulated, and the sum of the highest score for the four tests for each group was extracted as the result for announcing rankings during the gaming process. The competition score for each pair of students was the total score for each pair of tutor and tutee. To obtain a high score, a tutor endeavored to teach his or her tutee, thereby establishing an active help-seeking mechanism interaction relationship. For the control group, the ranking of each student's highest competition score among the four game tests was announced to motivate students to learn.

After the learning activity, an achievement post-test, learning motivation and flow experience post-test, and semi-open questionnaire were administered to the two groups of students.

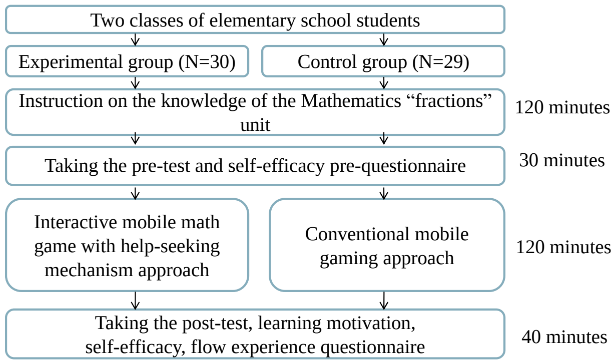

Figure 8. The experimental procedure of the study

5 Results

5.1 Fraction Learning Achievements

Following different types of mobile game-based learning, a one-way ANCOVA was used to compare the two groups' fraction learning achievement. The pre-test and post-test results were considered as the covariate and independent variables. After confirming the assumption of homogeneity of regression with F = 1.433 (p = 1.181 > .0.05), there was no significant interaction between the covariates and independent variable. The ANCOVA was performed, as shown in Table 1. A significant effect was found with F = 15.72 (p < .001), showing that the post-test scores of the experimental group were significantly higher than those of the control group. The research results showed that the fraction learning achievement of the experimental group (M = 96.05, SD = 8.11, Std. error = 2.64) was significantly superior to those of the control group (M = 73.79, SD = 20.99, Std. error = 2.69). Therefore, the learning achievements of the students who adopted the IMMG-HS approach were significantly superior to those of the students who adopted the conventional mobile gaming approach. In other words, the proposed approach enhanced the students' learning achievements. Furthermore, according to

Cohen's (1988) effect size criteria, the ANCOVA results of the proposed approach displayed a large effect size with η^2 = 0.275 (η^2 > 0.138).

Table 1. The ANCOVA results for the students' learning achievement

Group	N	Mean	SD	Adjusted mean	Std. error	F	η^2
Experimental group	30	96.05	8.11	95.07	3.79	15.72***	0.275
Control group	29	73.79	20.99	74.42			

**p* < 0.001

5.2 Learning Motivation for Mathematics

The independent *t*-test was performed to know the students' learning motivation for the two game-based learning approaches. As shown in Table 2, the *t*-test revealed that the motivation of the experimental group to learn mathematics (M = 22.30, SD = 3.54) was significantly superior to that of the control group (M = 20.10, SD = 4.63; t = 2.05, p =0.45 < 0.05, d = 0.54). Therefore, the mathematics learning motivation of the students who adopted the IMMG-HS was significantly superior to that of the students who adopted the conventional mobile gaming approach. In other words, the interactive mobile mathematics game with the help-seeking mechanism enhanced the students' mathematics learning motivation.

Table 2. Independent *t*-test result for students' learning motivation

Group	N	Mean	SD	t	d
Experimental group	30	22.30	3.54	2.05*	0.54
Control group	29	20.10	4.63		

* p < 0.05

5.3 Flow Experience

The independent *t*-test was performed to know the students' flow experience for the two game-based learning approaches. No significant difference in flow experience existed between the two groups of students (t = 1.01, p < .32), indicating that the IMMG-HS exerted no influence on their flow experience. Subsequently, differences in the flow experience of boys and girls were further examined. The results for the control group indicated no significant difference in flow experience (t = 0.36, p < .72) between the boys (N =15, M = 137.07, SD = 22.09) and the girls (N = 14, M = 134.36, SD = 18.28). However, for the experimental group, the flow experience of the boys (N = 15, M = 149.93, SD =15.08) was significantly superior to that of the girls (N = 15, M = 132.27, SD = 21.74; t = 2.59, p < .02), suggesting that the boys in the experimental group more effectively immersed themselves in the interactive mobile game with the help-seeking mechanism approach than did the girls.

5.4 Mathematics Self-efficacy and Fraction-learning Achievement Tests

Both the experimental and control groups were divided into high mathematics self-efficacy and low mathematics self-efficacy groups according to the pre-questionnaire results of self-efficacy. No significant differences were observed between students with high (N = 12, M = 77.50, SD = 18.65) and low (N = 17, M = 71.18, SD = 22.68) mathematics self-efficacy in the control group following the conventional mobile gaming approach (t = .79, p < .43). Therefore, the conventional mobile gaming approach was ineffective in terms of enhancing the learning achievements of students with various mathematics self-efficacy levels.

According to an independent *t* test, for the experimental group, the pre-test mathematics test results of the high mathematics self-efficacy students (N = 18, M = 89.94, SD = 9.19) were significantly superior to those of the low mathematics self-efficacy students (N = 12, M = 75.75, SD = 21.03; t = 2.20, p < .05). However, following the IMMG-HS approach, no significant difference in the achievement test results (t = .95, p < .36) was observed between the high (M = 97.78, SD = 6.00) and low (M = 94.58, SD = 10.54) mathematics self-efficacy students. Therefore, the IMMG-HS approach effectively diminished the difference in the learning achievements of students with high and those with low mathematics self-efficacy.

Figure 9 shows the average pre-test mathematics test scores of the high and low mathematics self-efficacy students in the experimental and control groups. As shown in Figure 9, the difference in average pre-test mathematics test scores between the high and low mathematics self-efficacy students in the experimental groups was larger than that in the control group. Figure 10 presents the average fraction-learning achievement test results of the high and low mathematics self-efficacy students in the two groups, which show that the difference in the average test results for the experimental group was substantially reduced and was smaller than that for the control group.

In summary, the IMMG-HS approach enhanced the learning effectiveness of students who demonstrated low self-efficacy in mathematics.

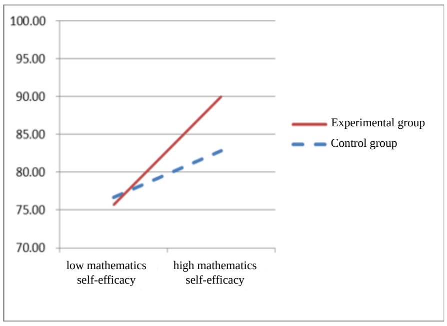

Figure 9. The average pre-test mathematics test scores of high and low mathematics self-efficacy students in the experimental and control groups

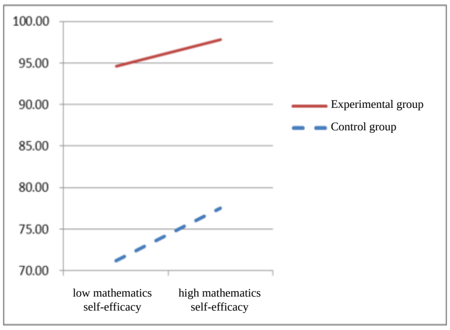

Figure 10. The average fraction-learning achievement test results of high and low mathematics self-efficacy students in the experimental and control groups

5.5 Learning Behavior and Feedback

To examine the interaction between students in the experimental and control groups who adopted different mobile game-based learning methods and the effect of the help-seeking mechanism on learning, the author statistically recorded the frequency with which the learning behavior of the two groups appeared. The following actions were recorded as learning behaviors: two students engaging in discussion with each other (2-people discussion); students teaching one another (teaching behavior); students consulting their textbook or raising their hand to ask questions (textbook-questioning); and students engaging in dialogues or behaviors unrelated to teaching (nonteaching-related dialogue or behavior). During the instructional experiment, observers were requested to use a video recorder to record the interaction between the students in the experimental and control groups. Afterwards, the video-recordings were analyzed by examining the interaction between each pair of students in the experimental group, and the interaction between adjacent students in the control group.

As shown in Figure 11, the students in the experimental group engaged in discussion with another student and in teaching behavior more frequently than did those in the control group. In other words, the students who adopted the IMMG-HS approach demonstrated meaningful learning behavior more frequently compared with those who adopted the general mobile game-based learning method. Therefore, introducing the IMMG-HS approach stimulated the students to discuss and interact with one another, and enhanced their learning achievements and learning motivation.

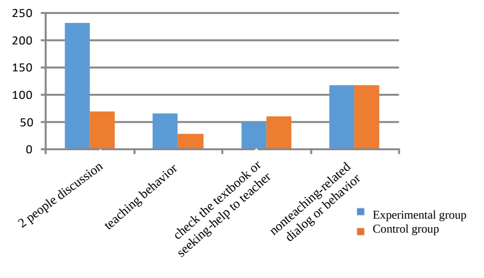

Figure 11. Statistics for the interaction behavior of students in the experimental and control groups during the instructional experiments

To obtain the students' viewpoints on learning, the author asked them to fill in a semi-open questionnaire on whether they had used a tablet, received help from other students, considered game-based learning useful, and enjoyed playing the games. The author then statistically analyzed the collected data (Table 3), determining that both groups of students were familiar with and accepted using tablets (computers).

After experiencing the IMMG-HS mathematics game, the students in the experimental group (83.33%) reported that the help-seeking mechanism was highly effective. In other words, the students in the experimental group reported that they received help from other students or provided help to other students. In addition, the proportion of students in the experimental group who enjoyed the IMMG-HS game was higher than that in the control group who enjoyed the general mobile games. The author inferred that the students enjoyed and did not object to the help-seeking mechanism mobile game-based learning in mathematics. Moreover, they favored this learning approach because of the help-seeking mechanism. The opinions of four students from the experimental group are presented as follows:

No. 4 male student said: At the beginning of the fraction lesson, I felt it was interesting that I could ask for help and discuss with peers online. That is of great help to me.

No. 8 male student said: I asked myself what if I learn without the help-seeking mechanism, I wouldn't know how to do it. Thus, I am looking forward to learning other lessons with this mechanism.

No. 17 female student said: I feel that we learned from these games.

No. 21 female student said: When playing the game, I found that my partner enjoyed the game even more after a 10-minute discussion.

No. 22 female student described the whole process of the learning fraction unit: At the beginning of learning fractions, I couldn't understand the description of fractions shown on the screen of the tablet. Thus, I immediately asked for peers' help to solve my questions by using the help-seeking button. When the tutor received my request, he sent me the prompts and guided me to think how to solve the problems step by step via the Encouragement and Commendation Area. In addition, he kept encouraging me to practice more to enhance my understanding of the concepts of fractions. In sum, I enjoyed the learning process with the assistance of the help-seeking mechanism because other peers can play the role of a tutor guiding the low-achieving math students, like me, to construct basic concepts of math.

In the control group, 93.10% of the students reported that general mobile mathematics games helped them learn the concept of fractions. The viewpoints of two students are presented as follows:

No. 28 female student from the control group: I feel that I learned a lot from the new learning method (i.e., playing with a tablet).

No. 5 male student from the control group: I feel that the fraction lesson was fun because it allowed us to learn a lot about fractions.

Both groups of students provided suggestions for the design of mobile games; they had all hoped to receive more time to play the game during mobile game-based learning. In other words, the students enjoyed the mobile games, asserting that game-based learning was more interesting compared with traditional classroom learning. Students in the experimental group suggested that the Internet connection should be more stable and that more words of encouragement from tutors on the game interface should be provided. Therefore, for the students, interaction stability and diversity made them enjoy learning and enhanced their confidence in learning.

Table 3. The statistical summary table for the results of a semi-open questionnaire survey of the two groups of students

	No.	I have used a tablet before	The tablet was easy to use	I helped other students or received help from others	The game is beneficial for learning	I enjoyed the game	I did not enjoy the game
Experimental group	30	93.33%	83.33%	83.33%	96.33%	90.00%	10.00%
Control group	29	100%	82.76%	0	93.10%	86.21%	13.79%

6 Discussion and Conclusions

The purpose of this study was to design an interactive mobile mathematics game with a help-seeking mechanism approach. The results revealed that the designed learning approach enhanced the students' learning motivation and learning achievements in mathematics and enabled them to experience flow. In addition, the proposed method assisted students with low self-efficacy in improving their learning achievements.

6.1 Discussion

The results of this study revealed that the experimental group outperformed the control group in terms of learning achievement. For the experimental group, we observed a reduced difference in the achievement test results of the high and low mathematics self-efficacy students, whose results were superior to those of high and low mathematics self-efficacy students in the control group. According to the video-recorded observations, students with low mathematics self-efficacy received help and encouragement immediately, thereby demonstrating improved learning achievements. This research finding demonstrates the same result as previous research, revealing that students with low self-efficacy are able to enhance their self-efficacy and learning achievement via peer assistance and peer interaction [50]. The proposed IMMG-HS approach prevented students from being distracted from learning and thus enhanced their learning achievements.

Furthermore, the mathematics learning motivation of the students in the experimental group was significantly superior to that of the control group. This is because, through the help-seeking mechanism, the students with low learning motivation were encouraged and supported by other students during the learning activities, which consequently motivated them to learn. This result is consistent with previous studies [51], indicating that game-based learning activity usually increases students' motivation and naturally results in deep engagement, and consequently enhances learning performance. In addition, peer interaction in small groups embedded in the learning strategy is regarded as an important factor in enhancing students' deep engagement when it comes to the appropriateness of responses to requests for help [52]. AbdulRaheem regarded peer tutoring as an essential instructional strategy because it constitutes one of the strongholds of cooperative learning. Similarly, the study adopted such a peer tutoring method embedded in the Help-seeking mechanism to facilitate those who encountered learning difficulties in math. It can not only increase students' learning motivation, but also enhance their learning achievement [53].

No significant difference was observed in the flow experience of the two groups of students. Both girls and boys in the control group had excellent flow experience. However, for the experimental group, the flow experience of the boys was significantly superior to that of the girls, showing that the boys effectively immersed themselves more in the interactive mobile game than the girls. This finding is consistent with previous studies [54], indicating that male learners could experience more flow than females in game-based learning activities. It can be seen from the feedback records that the boys substantially enjoyed the chat function of the system, which facilitated their immersion in the game, enabling them to enjoy playing due to the help-seeking mechanism.

6.2 Limitations

There are some limitations of the present study that should be noted. First, the research subjects of the study were third graders in Taiwan. Second, the experiment was conducted in a math course. Therefore, the findings might not be unduly extrapolated to other subjects in other regions.

6.3 Conclusions

The main contribution of this study is that it proposes a help-seeking mechanism in game-based learning contexts and showed its effectiveness in terms of improving students' learning performances in mathematics courses. In the future, it is suggested that the mechanisms can be applied to other digital learning contexts for other courses and subjects to further investigate the effectiveness of this approach.

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