

The Effects of Game-Based Learning on Mathematical Confidence and Performance: High Ability vs. Low Ability

Oskar Ku^{1*}, Sherry Y. Chen², Denise H. Wu³, Andrew C. C. Lao² and Tak-Wai Chan²

¹Department of Computer Science & Information Engineering, National Central University, Taiwan // ²Graduate Institute of Network Learning Technology, National Central University, Taiwan // ³Institute of Cognitive Neuroscience, National Central University, Taiwan // oskar@cl.ncu.edu.tw // sherry@cl.ncu.edu.tw // denisewu@cc.ncu.edu.tw // andrew@cl.ncu.edu.tw // chan@cl.ncu.edu.tw

*Corresponding author

(Submitted May 7, 2013; Revised September 12, 2013; Accepted November 7, 2013)

ABSTRACT

Many students possess low confidence toward learning mathematics, which, in turn, may lead them to give up pursuing more mathematics knowledge. Recently, game-based learning (GBL) is regarded as a potential means in improving students' confidence. Thus, this study tried to promote students' confidence toward mathematics by using GBL. In addition, this study also investigated whether GBL is beneficial to all students with various abilities. The results demonstrated that this approach yielded better outcomes than the paper-based setting in both students' confidence and students' performance. The students with high and low levels of ability in the GBL group gained a significant improvement on the confidence toward mathematics. Additionally, low-ability students in the GBL group attained better mathematics performance than those in the paper-based setting.

Keywords

Game-based learning, Confidence, Mathematics, Performance, Ability

Introduction

Mathematics is a fundamental skill in our daily life. Humans have been applying mathematical knowledge for over 4000 years. In addition, Gauss referred mathematics as the queen of sciences (von Waltershausen, 1856), which implied the importance of mathematics. However, students often perceive mathematics as a difficult subject (Stodolsky, Salk, & Glaessner, 1991). Low confidence is one of the critical reasons that makes students feel difficult to learn mathematics. Such a negative feeling may consequently make a student give up learning mathematics (Brown, Brown, & Bibby, 2008).

In other words, self-confidence plays an important role in learning (MacLellan, 2014) because it is a predictor of a learner's learning behavior, such as the degree of effort made and the expectation of outcomes (Schunk, 1990). Students with high self-confidence may attain better performance in tasks (Kleitman, Stankov, Allwood, Young, & Mak, 2013) and engage in target tasks more actively (Gushue, Scanlan, Pantzer, & Clarke, 2006) than those who are less confident about the tasks. In addition, students with high self-confidence usually regard difficult tasks as meaningful tests (Bandura, 1994) while those with low self-confidence tend to avoid calling for help (Ryan, Patrick, & Shim, 2005). Thus, there is a need to give additional support to students with low confidence toward mathematics.

Past studies found that digital games had potentials to enhance students' confidence (Cunningham, 1994; Radford, 2000). Furthermore, digital games can also enhance students' learning motivation (Klawe, 1998; Nussbaum, 2007) and their learning performance (Ke & Grabowski, 2007). Therefore, embedding math learning into digital games may be a possible solution to enhance students' self-confidence, learning motivation and learning performance.

To this end, this study investigates whether digital games can be adopted to enhance students' confidence toward mathematics and meanwhile to improve students' learning performance, especially for those with a low level of self-confidence toward mathematics. In addition, although past studies found the positive effects of GBL, the effects were usually reported holistically. However, it is not clear whether every student could benefit from GBL. Since the issue of individual difference is more and more important in the design of learning environments, this study further investigates how students with different levels of academic ability react to GBL. More specifically, the research questions of this study can be summarized as follows:

- Whether GBL enhances students' confidence and learning performance toward mathematics?
- Whether students with different levels of academic ability react similarly to GBL?

Theoretical background

Confidence is a critical element in learning; past studies indicated that confidence correlates positively with performance (Al-Hebaish, 2012). This strong and positive correlation was also reported in the area of mathematics education (Stankov, Lee, Luo, & Hogan, 2012). Confidence affects an individual's learning in various aspects. For example, there is a correlation between confidence and the elective enrollment of mathematics courses (Kleanthous & Williams, 2011; Metie, Frank, & Croft, 2007). Confidence also affects an individual's effort; a learner with low confidence might not pay full effort to complete the task (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998).

Recently, the results of the Trends in International Mathematics and Science Study (TIMSS) showed that Asian students tended to have low confidence toward mathematics (Mullis, Martin, & Foy, 2008). Comparing the confidence level from the eighth grade and the fourth grade, students at the eighth grade had lower confidence than students at the fourth grade. This result implies students are losing their confidence toward learning mathematics by the increase of their age. This is a warning message because low confidence may also lead students to have negative reactions to mathematics (Brown, Brown, & Bibby, 2008), which, in turn, may make them give up learning mathematics. Thus, there is a need to help students build up their confidence about learning mathematics.

Digital games may be a possible solution to address this issue. Although not all GBL studies consistently reported positive results (e.g., Chen, 2012; Ke, 2009; Kebritchi, Hirumi, & Bai, 2010; Sitzmann, 2011), the majority of the studies revealed positive effects brought by applying digital games to support learning environments. For example, GBL engages students in learning activities (Huizenga, Admiraal, Akkerman, & ten Dam, 2009; Shute, Ventura, Bauer, & Zapata-Rivera, 2009) and stimulates students' learning motivation (Dickey, 2007; Nussbaum, 2007; Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009). In particular, GBL was found to have the potential to enhance students' confidence (Cunningham, 1994). For example, Radford (2000) argued that, through successfully manipulating three-dimensional objects in simulation game environments, his architecture students gained opportunities to build up confidence toward related architectural tasks. Such research implies that embedding math learning into digital games may be a possible solution to enhance students' self-confidence toward learning mathematics.

However, previous studies mainly focused on two dependent variables: achievement and motivation (Table 1). Paucity of them investigated the effect of digital games on learners' confidence. As mentioned earlier, confidence is also an important element, which influences the learning outcome of a learner. Thus, this study aims at investigating the effects of GBL on learners' confidence.

Table 1. Dependent variables of recent studies on game-based learning

Study	Dependent variable(s)	Result(s)
Ke & Grabowski (2007)	Achievement	Students who played games had a better math performance than those who received paper-based drills.
Ke (2008)	Achievement Attitude	Students had more positive attitude on computer math gaming, but there was no significant outcome for the performance and metacognitive awareness development.
Owston, Wideman, Ronda, & Brown (2009)	Achievement	Students who learned by a game development shell had a better performance than those who did not play games.
Papastergiou (2009)	Achievement Motivation	Students who played games had better performance and were more motivated than the non-gaming students.
Suh, Kim & Kim (2010)	Achievement	Students who used online role-playing games for English learning had better performance than those who received face-to-face instruction.
Kebritchi, Hirumi, & Bai (2010)	Achievement Motivation	Students' achievement was improved as a result of applying GBL; however GBL did not produce significant improvement on motivation.

Dickey (2011)	Motivation	The game-like environment supported students' learning motivation, including students' curiosity and plausibility.
Vos, van der Meijden, & Denessen (2011)	Motivation Strategy	Higher motivation and deeper strategy use were found in constructing a new game, rather than playing an existing game.
Tsai, Yu & Hsiao (2012)	Achievement Motivation	Students' motivation, capability on learning, and the skill of playing games had impacts on the level of their knowledge acquisition.
Chen (2012)	Achievement	Students' achievement was not improved as a result of applying GBL. However, students developed a deep relationship with the game agent.

In addition, past studies reported the positive effects of GBL in a general way; however, the positive results may be contributed by a specific group of learners, instead of all learners. Because different pedagogies may be favored by different learners with different learning styles (Clewley, Chen, & Liu, 2011), GBL may not also be beneficial to all learners. For example, the multimedia elements of game-based-learning may also increase students' cognitive load (Huang, 2011) because they have to play and learn at the same time; it might go against learners with low ability. Researchers should put more emphasis on individual differences when designing new pedagogies. On the other hand, past studies indicated that students with different academic abilities performed differently (Colquitt, LePine, & Noe, 2000). More specifically, students with a high level of academic abilities usually perform well on tasks, and vice versa. For example, MacCann, Fogarty, Zeidner, and Roberts (2011) found that students with high academic ability have higher emotional intelligence and have better problem coping performance. Thus, students' academic ability is an important variable that may correlate with students' task performance and should be taken into consideration when researchers analyze the effects of pedagogy. To this end, this study not only examines the effect of GBL on learners' confidence and achievement, but also attempts to further verify the effect on students with different levels of academic ability.

Methods

Experimental design

An experiment was designed to examine the effects of GBL, with a focus on confidence toward mathematics and learning performance. To this end, an experiment group (EG) learned in digital game-based environment was arranged to examine the effect of GBL while a control group (CG) learned in a paper-based condition was set to provide a comparison. Table 2 describes the distribution of participants in each group. All the participants were fourth-grade elementary school students between 10 to 11 years old. Because of the limitation of school administration and the students' normally distribution to each class based on their academic performance, the participants were recruited via convenience sampling (i.e., two classes of students were randomly selected from all classes in the fourth grade). One of the two classes was randomly considered as the EG while the other was regarded as the CG. The experiment was conducted twice a week for five weeks; each session lasted for 20 minutes.

A computational test and a confidence scale were administered before and after the experiment. In addition, students in both groups were further divided into two subgroups: high-ability and low-ability, according to their general math performance—to investigate whether GBL is beneficial for both high and low-ability students. Thus, the experiment forms a 2 (between-subject variable: EG vs. CG) by 2 (between-subject variable: high-ability vs. low-ability) by 2 (within-subject variable: before- vs. after-learning) mixed design.

Table 2. The numbers of the participants in the EG and CG

	Male	Female	Total
EG	12	14	26
CG	10	15	25

Instruments

Materials

This study chose mental calculation methods as the subject content of the learning material. The result of students' previous mathematics midterm exam ($Mean = 83.78$, $SD = 14.111$, Full score = 100) demonstrated that students had prior knowledge of basic multiplication and division, irrespective of the EG or CG. In other words, all of the students had the prerequisite concepts of the learning material used in this study. To avoid the interference of standard courses, this subject matter was not taught in regular math courses. In order to prevent students from applying computation strategies mechanically, 20~30% questions that require students to refer to simple number facts were included in the learning material. The mixed patterns of arithmetic problems require students to think carefully, not just repeatedly applying the same strategy.

Mini-games

As suggested by Kafai (2001), the design of GBL can be categorized into tight coupling and loose coupling, in terms of the relationship of learning content and gameplay in GBL. The loose coupling makes the learning content interchangeable and requires few resources to implement a game, but designers may lose their attention on the specific parts of the learning content. Conversely, tight coupling puts more emphases on the essence of the learning content, which could rich learning experience, but there is a need to use more resources to implement a game which is not reusable with different leaning content. In other words, both methods have their own strengths and weaknesses and have been applied in different contexts. For example, Anderson & Barnett (2013) applied the tight coupling approach to develop a digital game, Supercharged, to deliver basic electromagnetic concepts. The result of that study demonstrated that the game helped students obtain more learning gain and the insight of electromagnetic concepts than those learned in a traditional setting. On the other hand, Papastergiou (2009) developed a loose coupling game to teach computer memory concepts. The result indicated that students with the game-based environment gained more improvement on computer knowledge and learning motivation than those with a non-game approach. In brief, both tight coupling and loose coupling have positive effects on student learning.

However, loose coupling was selected for this study. This is due to the fact that mental calculation requires a high level of concentration for students to produce an answer, so there is a need to reduce students' cognitive load by using the loose coupling approach. More specifically, two additional mini-games were designed in this study. One named as Battleship (Figure 1) is similar to a board game and is a turn-based strategy game in competition with a virtual competitor. A student must answer each question within a limited time; a correct answer yields an opportunity to place a bomb on the opponent's board. However, an incorrect answer makes the student lose the chance to attack the opponent, and the virtual competitor can take its turn. The other named as Math Kicker is a soccer game, with which the participants are very good at playing (Figure 2). In this game, a student plays as a soccer player who is ready to shoot a goal. A correct answer of a question yields a successful shoot and the score is increased.

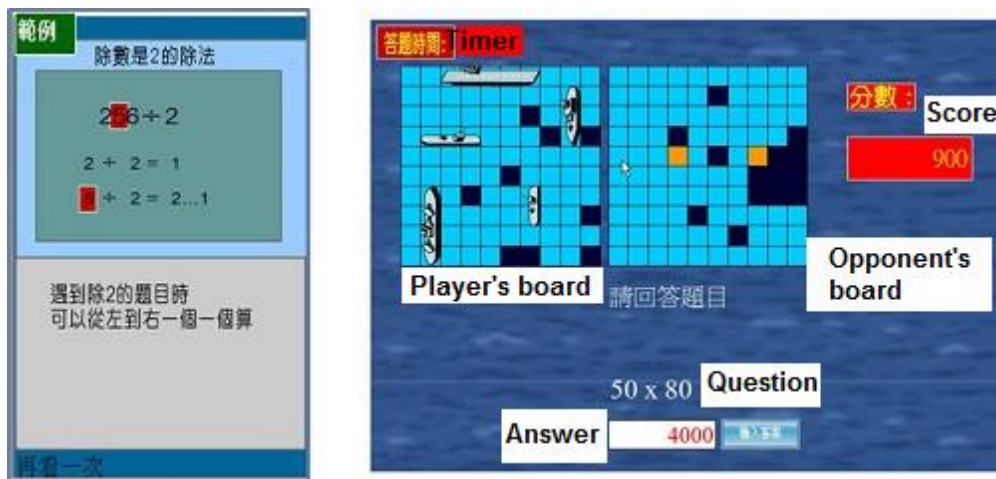


Figure 1. A screenshot of Battleship



Figure 2. A screenshot of the sports game: Math Kicker

Due to the fact that the learning material used in this experiment was mental calculation, speed is a primary factor. Therefore, the two games were designed as time-constraint games. Although students in this experiment learned individually, virtual competition was added into the mini-games to engage students in the learning activity. On the one hand, playing against opponents creates a socio-competitive situation that can promote active engagement and can provide immediate feedback to players (Vorderer, Hartmann, & Kimmt, 2003). On the other hand, the virtual opponents simulated students' abilities. More specifically, the virtual opponents are often tied with students or a bit behind/beyond students during the process of playing the games. Thus, all students received adequate challenge meeting their abilities and could have a big chance to win unless they kept making errors. By doing so, students can immerse in the flow state (Csíkszentmihályi, 1990).

Measurement

Confidence

In order to determine changes in confidence toward mathematics as a result of GBL intervention, this study employed a questionnaire modified from the confidence sub-scale of the Fennema-Sherman mathematics attitudes scales (Fennema, & Sherman, 1976), which has widely been adopted to investigate students' opinions toward mathematics (e.g., Rattan, Good, & Dweck, 2012).

Mathematical performance

Mathematical proficiency (Kilpatrick, Swafford, & Findell, 2001) includes five components, of which the "procedural fluency" is highly related to the mental calculation. On the one hand, procedural fluency is the basis of math learning, which helps students understand that mathematics is well structured knowledge (Kilpatrick, Swafford, & Findell, 2001). On the other hand, procedural fluency emphasizes the flexibility, accuracy, and efficiency of computational skills, which is the goal of mental calculation, i.e., the subject matter of this study. Therefore, students' computational skill was measured to examine the effect of the intervention. Two test papers for the pretest and the posttest were created to measure students' computational skill. The test papers comprise a set of computational questions, which require students to calculate and write down their answers (e.g., $23 \times 20 =$). To avoid a ceiling effect, 250 questions were included in the test papers, so that no students could complete the test during 20 minutes. Both of the test papers for the pretest and posttest were created by two elementary school teachers; the tests had also been reviewed by the other two experienced teachers to adjust the difficulty of questions. In order to make it possible to compare students' performance between the pretest and posttest, the level of difficulty of the pretest and posttest was maintained: the questions used in the posttest were the same as those in the pretest, except for the order of the questions. In addition, because the subjects were recruited via convenient sampling and the learning material was related to mathematics, a general mathematics test was administered before the intervention to identify whether the subjects in the CG and the EG possessed similar level of prior mathematical knowledge.

Procedures

As shown in Figure 3, the pretest and the posttest were administered a week before and after the experimental intervention. During the experiment, nine learning sessions were conducted for five consecutive weeks. Students could access the learning content via a digital document (EG) or via a paper-based handout (CG). The learning materials presented to both groups were completely the same in each session, except for the presentation medium and error feedback. The contents of the error feedback, which are the same in both conditions, include the place where an error was made and a message asking the students who committed the error to re-answer the question until the correct answer was made. Students in the EG received immediate feedback while students in the CG received the same message after their teacher marked their worksheets. The teacher also highlighted the place where an error was made on students' worksheets and asked students to revise their wrong answers until they got the correct answer. The only difference is the timing of feedback of which immediate feedback is the innate characteristic of digital games.

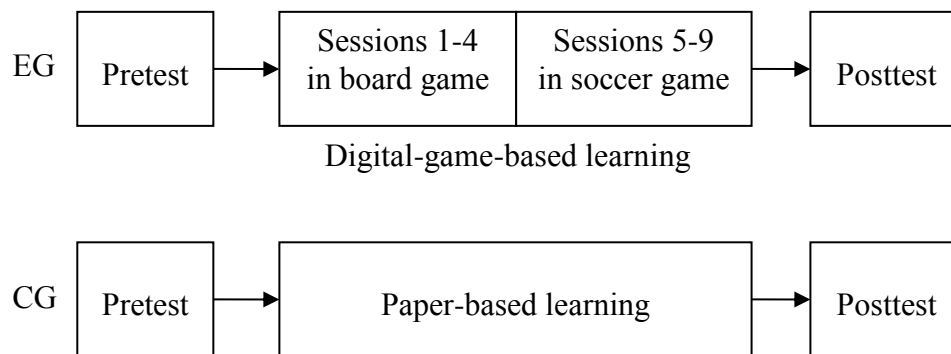


Figure 3. The procedure of this study

Results and discussion

Due to the small sample size, the Mann–Whitney U test, and the Wilcoxon's matched-pairs signed-ranks test were employed to conduct data analyses. The results from the Mann-Whitney test shows no significant difference between the EG and the CG ($U = 312.500, p = .813$). In other words, the EG and CG had a similar level of prior mathematical knowledge (Fig. 4).

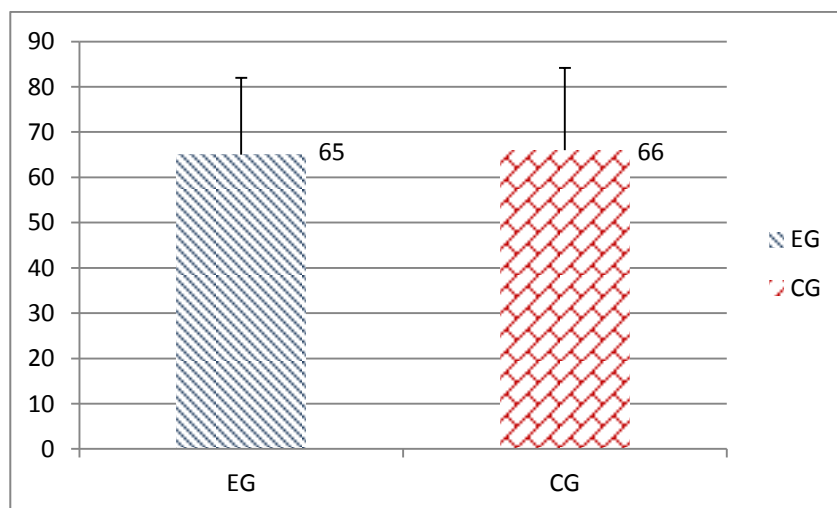


Figure 4. Students' mean scores of the general mathematics test

Comparison between the EG and the CG

To answer the first research question, students' confidence and computational performance were analyzed and reported in the following subsections.

Confidence

Students' confidence toward mathematics is shown in Figure 5. The result of the Mann-Whitney test revealed a significant difference of the gain score of confidence between the EG and the CG ($U = 175.000, p = .005$). In addition, the Wilcoxon's matched-pairs signed-ranks tests revealed a significant increase of the confidence between the pretest and the posttest for EG students ($Z = 3.051, p = .002$), while the difference was not found on CG students ($Z = 1.107, p = .268$). These results indicate that the EG students' confidence gained more improvement than the CG students'.

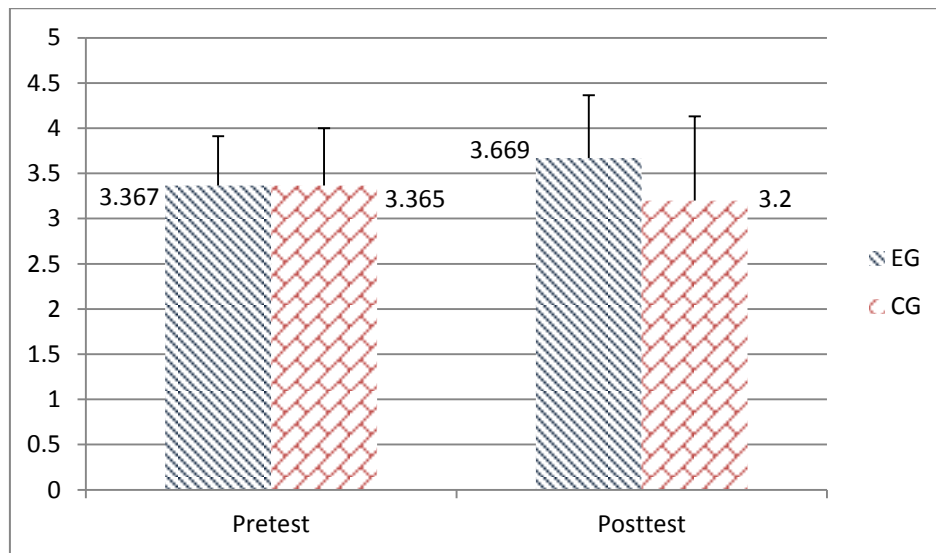


Figure 5. The mean scores of students' confidence toward mathematics

A possible reason for such results is that games have specific goals, which provide the opportunity of attaining a winning state for students in the EG and then provide the EG students with a sense of success. Successfully completing a task enhanced students' confidence toward the future mathematics learning tasks. This finding echoes the theory of *mastery experience* (Bandura, 1997), which argues that people who repeatedly gain the successful experience due to their effort can become confident when performing related tasks.

In contrast with the EG, the CG students could not realize their performance and progress immediately. In other words, the gradually increased success experience may be the key to help the EG students gain the improvement of confidence toward mathematics. However, other factors (e.g., different timing of feedback) that resulted in such a result are possible and need to be verified in our further works.

Computational performance

In this study, students' mathematical achievement was determined by their computational abilities. More specifically, students' mathematical achievement was defined as the amount of correct answers they produced during the assessment time. Figure 6 presents the result of students' computational performance in the pretest and posttest. Students in both groups answered more questions correctly in the posttest than in the pretest. Both of the learning approaches seemed helpful to students. Importantly, the Mann-Whitney test indicated that the gain score in the EG was significantly greater than that in the CG ($U = 193.000, p = .013$). This result suggests that the game-based approach may help EG students produce more correct answers.

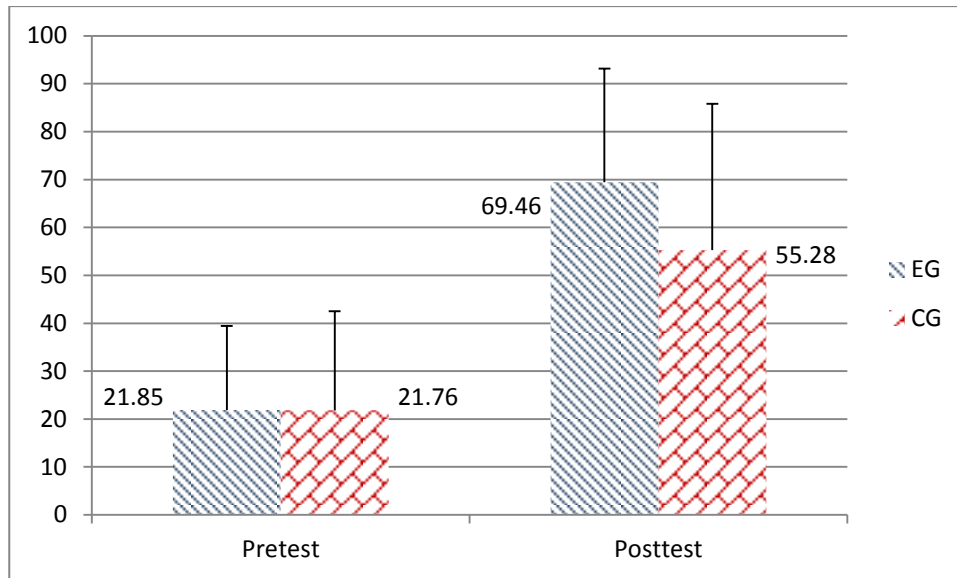


Figure 6. The mean scores of computational tests

Comparison between EG and CG in terms of students' mathematical ability

The previous sections demonstrated that the game-based approach may help students gain improvement on their confidence toward mathematics and mathematical performance. To answer the second research question, participants were further divided into four sub-groups in terms of their academic abilities. The results were reported in the following sections.

Students in the EG and CG were divided into high and low-ability groups according to their math performance of the general math test. The distribution of students is shown in Table 3. Students whose score is higher than the average score of their class were assigned to the high-ability group while students who performed lower than the average score were assigned to the low-ability group.

Table 3. The numbers of students grouped by their math ability

	EG	CG
High ability	14	12
Low ability	12	13

Confidence

Students' confidence toward mathematics is illustrated in Figure 7. Low-ability students in the CG, in contrast to the other three sub-groups, demonstrated a different trend of their confidence change. More specifically, those low-ability CG students' confidence decreased after the intervention.

Regarding the paper-based (CG) condition, the result of the Mann-Whitney test revealed a significant difference of the gain score of confidence between the high-ability and the low-ability students ($U = 40.500, p = .041$). The Wilcoxon's matched-pairs signed-ranks tests revealed significant decrease of confidence between the pretest and the posttest for low-ability students ($Z = 2.398, p = .016$), while the difference was not found in the high-ability students ($Z = .817, p = .414$). This may be due to the fact that low-ability students usually have fewer chances to receive academic achievement than their high-ability peers. In addition, low-ability students have greater tendency to attribute their success to external reasons (e.g., luck), instead of internal reasons (e.g., effort), than high-ability students (Vlahović-Štetić, Vizek Vidović, & Arambašić, 1999; Weiner, 1980). Low-ability students may need more positive feedback on their performance to build their confidence than high-ability students because such feedback helps students grasp their progress and enhances students' confidence toward the task that they are carrying out

(Earley, Northcraft, Lee, & Lituchy, 1990; Schunk and Swartz, 1993). Students in the CG did not receive any immediate feedback about how well they had done. Thus, it may be the key issue that students did not gain significant improvement of confidence.

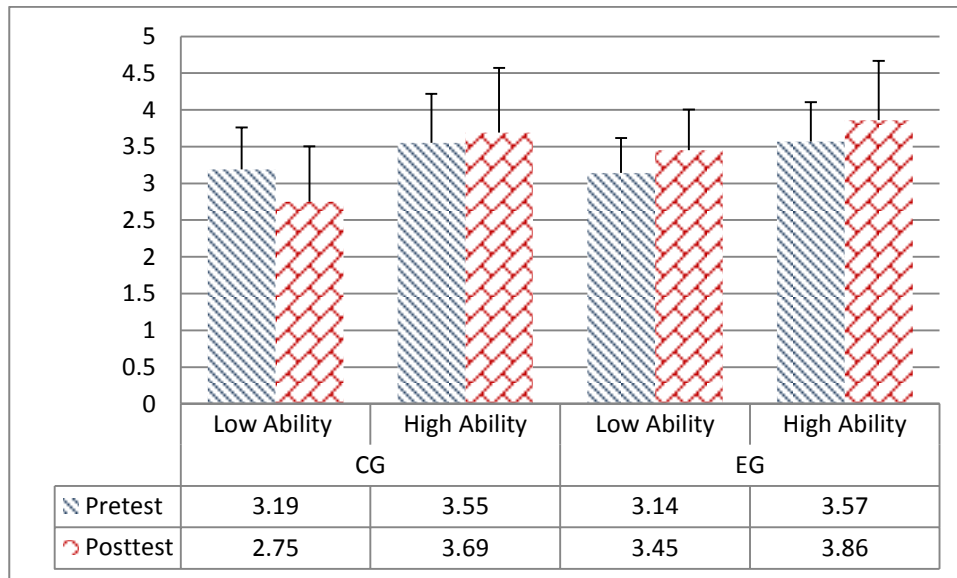


Figure 7. The mean scores of confidence toward mathematics grouped by ability

Regarding the digital game-based (EG) condition, both high and low-ability students demonstrated a similar trend of confidence change. The result of the Mann-Whitney test indicated no significant difference of the gain score of confidence between the two groups of students ($U = 81.000, p = .876$). At the same time, the Wilcoxon's matched-pairs signed-ranks tests revealed significant differences of the confidence between the pretest and the posttest for high-ability ($Z = 2.165, p = .030$) and low-ability ($Z = 2.156, p = .031$) students. This may be due to the fact that the GBL environment provided more chances to receive positive feedback, which is useful for low-ability students. Students could rectify their errors by themselves with the feedback provided by the games. Frequently receiving the message of successfully completing learning tasks motivated low-ability EG students so that their confidence toward mathematics could be improved. This is coherent with past studies, which indicated that the feedback of successfully completing a learning task increases students' confidence toward learning (Schunk, 1991, Pajares, 2006). On the other hand, the improvement of high-ability students' confidence may result from completing challenging tasks since they may tend to expect challenging tasks (Li & Pan, 2009). Completing challenging tasks brings the sense of achievement to students (Dickey, 2007), which in turn raises students' confidence (Hammond, 2004). Virtual opponents in the games simulated students' ability to provide different levels of challenge for students with different levels of ability. Therefore, the games were still challenging for high-ability students, and this may be why the high-ability students' confidence was improved.

In this study, both high-ability and low-ability students benefited from the positive effect of embedding learning materials into digital games, which provided students with adequate challenge, immediate feedback of their performance and opportunities so that they could gain the sense of achievement. This result indicates that GBL may help students with different levels of ability to improve confidence toward mathematics. On the one hand, concrete feedback about whether they were correct and where they made mistakes would help low-ability students consolidate their knowledge and strengthen their confidence (Kelley & McLaughlin, 2012). In this study, the immediate feedback of performance provided by the game-based environment may be the key element that supports low-ability students in learning mathematics.

On the other hand, those high-ability students in the GBL environment gained more improvement of confidence toward mathematics than their high-ability peers who gained confidence in the paper-based condition, though a significant degree is not reached. These results imply that GBL may not only be beneficial to low-ability students, but also be helpful to high-ability students, in terms of improving confidence, because digital games maintain keep providing appropriate challenge to students.

To sum up, the experience of successfully completing a task acts as a source for building low-ability students' confidence and completing challenging tasks resulted in the improvement of high-ability students' confidence. In addition, the findings reported in this section further indicates that the decrease of confidence toward mathematics in CG is contributed by low-ability students, whose confidence is significantly reduced in the posttest.

Computational performance

Students' computational performance grouped by different levels of ability is shown in Figure 8. For the paper-based (CG) condition, the Wilcoxon's matched-pairs signed-ranks tests indicated that both the high-ability ($Z = 3.061, p = .002$) and the low-ability ($Z = 2.971, p = .003$) students gained significant improvement on their computational performance. As expected, the course delivered in this study brought different levels of improvement depending on students' abilities. The result of the Mann-Whitney test demonstrated a significant difference of the gain score of computational performance between the high-ability and the low-ability students ($U = 40.000, p = .039$). This implied that the high-ability students in the CG gained more improvement than their low-ability peers in the same setting. This result is consistent with that of previous studies which indicated that high-ability students possessed greater learning capacity to learn new skills, such as various learning strategies (Yip, 2007) and better reasoning ability (Means & Voss, 1996). Thus, the high-ability students obtained more learning gain than low-ability students in this traditional setting.

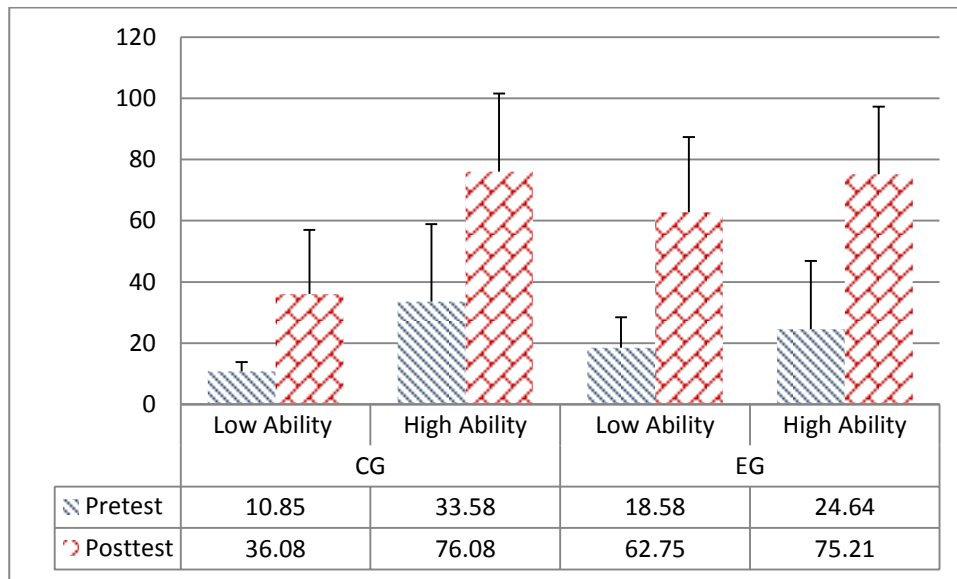


Figure 8. The mean scores of computational performance grouped by ability

Importantly, although the students in the EG performed slightly worse than the CG students in the pretest, the high-ability students in both groups attained a comparable level of performance in the posttest. For a direct comparison of the effect between the EG and CG on low-ability students, the result of the Mann-Whitney tests demonstrated a significant difference of the gain score of math performance between the EG low-ability and the CG low-ability students ($U = 38.500, p = .032$) while the difference of pretest between the EG low-ability and the CG low-ability students was not found ($U = 46.500, p = .085$). This result indicated that the low-ability students in the EG gained more improvement than those in the CG.

The results reported in this section indicated that GBL may be a better approach for low-ability students, in terms of the learning gain. Although all students gained significant improvement, the improvement of the low-ability students in CG is most limited. Although the high-ability students in the EG performed a bit worse than their high-ability peers in the CG in the pretest, they achieved a comparable level of computational performance in the posttest. For low-ability students, students in the EG gained more improvement than their peers in the CG. The immediate feedback for error correction provided in the digital games may be the element that makes students reach a higher improvement. This is consistent with the results of previous studies (Brosvic, Epstein, Dihoff, & Cook, 2006;

McDaniel, Roediger, & McDermott, 2007), which indicated that immediate feedback helped learner obtain more learning gain and better retention of knowledge.

The aforementioned results suggest that the GBL approach seems to be a better approach than the paper-based approach, regardless of for low or high-ability learners. In contrast with the paper-based approach which weakened low-ability students' confidence, GBL helps low-ability learners build their confidence toward mathematics in this study. In addition, the GBL approach also helped low-ability students gain more boost for their math skills than their low-ability peers who received paper-based intervention. As to the high-ability students, although students in both groups attained a comparable level of achievement, GBL also helped students gain significant improvement of confidence toward mathematics while those high-ability students learned with the paper-based setting did not gain significant improvement of confidence.

Conclusions

This study investigates whether GBL can enhance students' confidence toward mathematics. The results indicate that both high-ability and low-ability students with the GBL approach gained significant improvement on their confidence toward mathematics. In contrast, students with the paper-based setting did not show a significant improvement on their confidence toward mathematics due to a significant decrease of confidence toward mathematics from low-ability students. Regarding performance, students in both conditions gained significant improvements in their performance; however, the students with the digital game-based setting gained more improvement than their peers with the paper-based setting. Furthermore, the results showed that high-ability students in both groups attained a comparable level of performance while the low-ability students in the game-based condition gained more improvement in their performance than those in the paper-based condition.

The contribution of this study can be summarized from three aspects. First, the power of mini-games: the simple mini-games used in this study helped students improve both their confidence and performance toward learning mathematics, especially for low-ability students. Second, through the bridging of the mini-games, students' confidence toward mathematics and their calculation performance formed a bidirectional relationship and hence mutually enhanced with each other. Third, several characteristics of the mini-games which enhanced students' confidence and performance were identified; these elements are specific goals, immediate feedback, and various levels of challenge. Specific goals provide students with a chance to obtain the sense of success which then enhance student's confidence. Immediate feedback of students' performance plays a supporting role, which lets students grasp their progress and directs them to move forward, especially for low-ability students. Various levels of challenge let students with diverse levels of ability enter the flow state.

This study has figured out the advantages of incorporating digital games into math learning. However, it has some limitations. First, this study was a small-scale study; a further study with a larger sample needs to be done to provide additional evidence. Second, this study used two mini-games as the learning environments; there is a need to identify the effects of the two mini-games in future study. In addition, there is also a need to conduct further research to examine how other human factors, such as cognitive styles and gender differences, affect learners' reactions to digital games.

Acknowledgements

The authors would like to thank the National Science Council of the Republic of China, Taiwan, for financially supporting this study under contract numbers NSC 100-2511-S-008-014 and NSC 100-2511-S-008-013.

References

- Al-Hebaish, S. M. (2012). The Correlation between general self-confidence and academic achievement in the oral presentation course. *Theory and Practice in Language Studies*, 2(1), 60-65.
- Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of*

Science Education and Technology, 22(6), 914-926. doi: 10.1007/s10956-013-9438-8

Bandura, A. (1994). Self-efficacy. In V. S. Ramachandran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York, NY: Academic Press.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Brosvic, G. M., Epstein, M. L., Dihoff, R. E., & Cook, M. J. (2006). Acquisition and retention of Esperanto: The case for error correction and immediate feedback. *The Psychological Record*, 56(2), 205-218.

Brown, M., Brown, P., & Bibby, T. (2008). 'I would rather die': Reasons given by 16-year-olds for not continuing their study of mathematics. *Research in Mathematics Education*, 10(1), 3-18.

Chen, Z. H. (2012). We care about you: Incorporating pet characteristics with educational agents through reciprocal caring approach. *Computers and Education*, 59(4), 1081-1088.

Clewley, N., Chen, S. Y., & Liu, X. (2011). Mining learning preferences in web-based instruction: Holists vs. serialists. *Educational Technology & Society*, 14(4), 266-277.

Colquitt, J. A., LePine, J. A., & Noe, R. A. (2000). Toward an integrative theory of training motivation: A meta-analytic path analysis of 20 years of research. *Journal of Applied Psychology*, 85(5), 678-707.

Csikszentmihályi, M. (1990). *Flow: The psychology of optimal experience*. New York, NY: Harper and Row.

Cunningham, H. (1994). Gender and computer games. *Media Education Journal*, 17, 13-15.

Dickey, M. D. (2007). Game design and learning: A conjectural analysis of how massively multiple online role-playing games (MMORPGs) foster intrinsic motivation. *Educational Technology Research and Development*, 55(3), 253-273.

Dickey, M. D. (2011). Murder on Grimm Isle: The impact of game narrative design in an educational game-based learning environment. *British Journal of Educational Technology*, 42(3), 456-469.

Earley, P. C., Northcraft, G. B., Lee, C., & Lituchy, T. R. (1990). Impact of process and outcome feedback on the relation of goal setting to task performance. *Academy of Management Journal*, 33(1), 87-105.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education*, 7(5), 324-326.

Gushue, G. V., Scanlan, K. R., Pantzer, K. M., & Clarke, C. P. (2006). The relationship of career decision-making self-efficacy, vocational identity, and career exploration behavior in African American high school students. *Journal of Career Development*, 33(1), 19-28.

Hammond, C. (2004). Impacts of lifelong learning upon emotional resilience, psychological and mental health: Fieldwork evidence. *Oxford Review of Education*, 30(4), 551-568.

Huang, W. H. (2011). Evaluating learners' motivational and cognitive processing in an online game-based learning environment. *Computers in Human Behavior*, 27(2), 694-704.

Huizenga, J., Admiraal, W., Akkerman, S., & ten Dam, G. (2009). Mobile game-based learning in secondary education: Engagement, motivation and learning in a mobile city game. *Journal of Computer Assisted Learning*, 25(4), 332-344.

Kafai, Y. B. (2001). *The educational potential of electronic games: From games-to-teach to games-to-learn*. Retrieved 31 August 2013, from <http://culturalpolicy.uchicago.edu/conf2001/papers/kafai.html>

Ke, F. (2008). A case study of computer gaming for math: Engaged learning from gameplay? *Computers & Education*, 51(4), 1609-1620.

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. In R. E. Ferdig, (Ed.), *Handbook of Research on Effective Electronic Gaming in Education* (pp. 1-32). Hershey, PA: Information Science Reference.

Ke, F., & Grabowski, B. (2007). Game playing for mathematics learning: Cooperative or not? *British Journal of Educational Technology*, 38(2), 249-259.

Kebritchi, M., Hirumi, A., & Bai, H. (2010). The effects of modern mathematics computer games on mathematics achievement and class motivation. *Computers & Education*, 55(2), 427-443.

Kelley, C., & McLaughlin, A. (2012). Individual differences in the benefits of feedback for learning. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 54(1), 26-35.

- Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Academies Press.
- Klawe, M. (1998, June). *When does the use of computer games and other interactive multimedia software help students learn mathematics?* Paper presented at the NCTM Standards 2000 Technology Conference, Arlington, VA. Retrieved from: <http://mathforum.org/technology/papers/papers/klawe.html>
- Kleanthous, I., & Williams, J. (2011). Students' dispositions to study further mathematics in higher education: The effect of students' mathematics self-efficacy. In M. Pytlak, T. Rowland, & E. Swoboda (Eds.), *Proceedings of the seventh Congress of the European Society for Research in Mathematics Education* (pp. 1229-1238). Rzeszów, Poland: University of Rzeszów.
- Kleitman, S., Stankov, L., Allwood, C. M., Young, S., & Mak, K. K. L. (2013). Metacognitive self-confidence in school-aged children. In M. M. C. Mok (Ed.), *Self-directed learning oriented assessment in the Asia-Pacific* (pp. 139-153). New York, NY: Springer.
- Li, P., & Pan, G. (2009). The Relationship between motivation and achievement—A survey of the study motivation of English majors in Qingdao Agricultural University. *English Language Teaching*, 2(1), 123-128.
- MacCann, C., Fogarty, G. J., Zeidner, M., & Roberts, R. D. (2011). Coping mediates the relationship between emotional intelligence (EI) and academic achievement. *Contemporary Educational Psychology*, 36(1), 60-70.
- Maclellan, E. (2014). How might teachers enable learner self-confidence? A review study. *Educational Review*, 66(1), 59-74. doi: 10.1080/00131911.2013.768601
- McDaniel, M. A., Roediger, H. L., & McDermott, K. B. (2007). Generalizing test-enhanced learning from the laboratory to the classroom. *Psychonomic Bulletin & Review*, 14(2), 200-206.
- Means, M. L., & Voss, J. F. (1996). Who reasons well? Two studies of informal reasoning among children of different grade, ability, and knowledge levels. *Cognition and Instruction*, 14(2), 139-178.
- Metie, N., Frank, H. L., & Croft, P. (2007). Can't do maths—Understanding students' math anxiety. *Teaching Mathematics and its Applications*, 26(2), 79-81.
- Mullis, I. V. S., Martin, M. O., & Foy, P. (2008). *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the fourth and eighth grades*. Boston, MA: International Association for the Evaluation of Education Achievement, Boston College.
- Nussbaum, M. (2007). *Games, learning, collaboration and cognitive divide*. OECD. Retrieved May, 20, 2010 from <http://www.oecd.org/dataoecd/43/39/39414787.pdf>
- Owston, R., Wideman, H., Ronda, N. S., & Brown, C. (2009). Computer game development as a literacy activity. *Computers & Education*, 53(3), 977-989.
- Pajares, F. (2006). Self-efficacy during childhood and adolescence. In F. Pajares & T. Urdan (Eds.), *Self-efficacy beliefs of adolescents* (pp. 339-367). Greenwich, CT: Information Age Publishing.
- Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, 52(1), 1-12.
- Radford, A. (2000). Games and learning about form in architecture. *Automation in Construction*, 9(4), 379-385.
- Rattan, A., Good, C., & Dweck, C. S. (2012). "It's ok—Not everyone can be good at math": Instructors with an entity theory comfort (and demotivate) students. *Journal of Experimental Social Psychology*, 48(3), 731-737.
- Ryan, A. M., Patrick, H., & Shim, S. O. (2005). Differential profiles of students identified by their teacher as having avoidant, appropriate, or dependent help-seeking tendencies in the classroom. *Journal of Educational Psychology*, 97(2), 275-285.
- Schunk, D. H. (1990). Goal setting and self-efficacy during self-regulated learning. *Educational Psychologist*, 25(1), 71-86.
- Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist*, 26, 207-231.
- Schunk, D. H., & Swartz, C. W. (1993). Goals and progress feedback: Effects on self-efficacy and writing achievement. *Contemporary Educational Psychology*, 18, 337-354.
- Shute, V. J., Ventura, M., Bauer, M. I., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning: Flow and grow. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious Games: Mechanisms and Effects* (pp. 295-321). Mahwah, NJ: Routledge.
- Sitzmann, T. (2011) A meta-analytic examination of the instructional effectiveness of computer-based simulation games.

Personnel Psychology, 64(2), 489–528.

Stankov, L., Lee, J., Luo, W., & Hogan, D. J. (2012). Confidence: A better predictor of academic achievement than self-efficacy, self-concept and anxiety? *Learning and Individual Differences*, 22(6), 747-758.

Stodolsky, S., Salk, S., & Glaessner, B. (1991). Student views about learning math and social studies. *American Educational Research Journal*, 28(1), 89-116.

Suh, S., Kim, S. W., & Kim, S. W. (2010). Effectiveness of MMORPG-based instruction in elementary English education in Korea. *Journal of Computer Assisted Learning*, 26(5), 370-378.

Tsai, F.-H., Yu, K.-C., & Hsiao, H.-S. (2012). Exploring the factors influencing learning effectiveness in digital game-based learning. *Educational Technology & Society*, 15(3), 240-250.

Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, 68(2), 202-248.

Tüzün, H., Yılmaz-Soylu, M., Karakuş, T., İnal, Y., & Kızılkaya, G. (2009). The effects of computer games on primary school students' achievement and motivation in geography learning. *Computers & Education*, 52(1), 68-77.

Vlahović-Štetić, V., Vizek Vidović, V., & Arambašić, L. (1999). Motivational characteristics in mathematical achievement: A study of gifted high-achieving, gifted underachieving and non-gifted pupils. *High Ability Studies*, 10(1), 37-49.

von Waltershausen, W. S. (1856). *Gauss zum Gedächtnis* [Gauss: A memorial]. Leipzig, Germany: von S. Hirzel.

Vorderer, P., Hartmann, T., & Klimmt, C. (2003, May). *Explaining the enjoyment of playing video games: The role of competition*. Paper presented at the Second International Conference on Entertainment Computing, Pittsburgh, PA. Retrieved from: <http://dl.acm.org/citation.cfm?id=958735>

Vos, N., van der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education*, 56(1), 127-137.

Weiner, B. (1980). *Human motivation*. New York, NY: Holt, Rinehart & Winston.

Yip, M. C. W. (2007). Differences in learning and study strategies between high and low achieving university students: A Hong Kong study. *Educational Psychology*, 27(5), 597-606.