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Alternative goal structures for computer game-based learning

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Abstract This field study investigated the application of cooperative, competitive, and individualistic goal structures in classroom use of computer math games and its impact on students' math performance and math learning attitudes. One hundred and sixty 5th-grade students were recruited and randomly assigned to Teams–Games–Tournament cooperative gaming, interpersonal competitive gaming, individualistic gaming, and the control group. A state-standards-based math exam and an inventory on attitudes toward mathematics were used in pretest and posttest. Students' gender and socioeconomic status were examined as the moderating variables. Results indicated that even though there was not a significant effect of classroom goal structure in reinforcing computer gaming for math test performance, game-based learning in cooperative goal structure was most effective in promoting positive math attitudes. It was also found that students with different socioeconomic statuses were influenced differently by gaming within alternative goal structures.

Keywords Cooperative learning · Instructional gaming · Teams–Games–Tournament

Introduction

Over the past two decades there has been a move in mathematics education away from abstract calculations and toward *mathematics in context* (NCTM 1989). Educational researchers have proposed computer games as a math learning tool with considerable potential in teaching mathematics in context and boosting affect and motivation (Van Eck and Dempsey 2002). Empirical evidence also supports that games can be effective tools for engaging math learners and supplementing the instruction of arithmetical concepts understanding and problem solving (Ota and DuPaul 2002).

However, not all computer games produce the same effects; the findings on the effectiveness of computer games on learning are often contradictory and the evaluations

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anecdotal or judgmental (Vogel et al. 2006). Major reviews of educational games (Dempsey et al. 1996; Hays 2005; Randel et al. 1992; Vogel et al. 2006) report there is no evidence to indicate that games are the preferred instructional method in all situations; rather, the instructional effectiveness of a computer game depends on its characteristics and how it is used.

All too often computer games are promoted as being solitary educational solutions in their own right, without qualification about the kinds of instructional activities that should structure the way students use and interact with computer games (Kaptelinin and Cole 2002). Miller et al. (1999) argued that the investigation of computer games for learning should focus on how games can be carefully aligned with sound classroom pedagogies to be beneficial. Greater focus should be placed on the interconnection between technological tools and instructional activities that comprise a planned learning *environment* (Winn 2000). Consistent with this proposition, this study investigates whether and how classroom use of educational games within alternative external goal structures—*cooperative, competitive*, and *individualistic* (Johnson and Johnson 1996)—reinforce or weaken the cognitive and motivational effects of computer games on math learning, hence to determine an effective classroom situation for implementing computer games in school classrooms.

Literature review

Games for math education

McFarlane et al. (2002) distinguished three potential uses of computer games in a school environment: general cognitive abilities and skills, affective and motivational aspects, and knowledge- and content-related learning. The strongest empirical support is for the claim that games improve affective and motivational aspects, whereas the claim that games enhance content-related learning has mixed support (Vogel et al. 2006).

A review of the literature lends support to the claim that some knowledge domains are particularly suited to computer gaming, such as math (Randel et al. 1992; Hays 2005). Particularly, porting math drill and skill exercises to electronic gaming formats is deemed as easier to be integrated sinto a traditional curriculum (Squire 2003). Evidence exists that suggests a strong preference among school teachers for simpler computer games in the classroom since simpler edutainment software requires less computing power and can run on older, more widely available computers in schools (Kirriemuir and McFarlane 2003). Empirically, math drill-and-practice games have also been found successful in educational environments (Lee et al. 2004; Rice 2007). However, there are also studies (Ota and DuPaul 2002; Van Eck 2006) reporting insignificant or negative effects of computer games versus paper drills on math learning achievement. Therefore, more empirical studies should be conducted to evaluate the use of math drill games, and more importantly, explore the underlying conditions for a successful math gaming practice.

Individual differences in game-based learning

Even though the alignment of gaming with learner differences is a strong proposition throughout the past decades of educational gaming research, a recent meta-analysis of computer instructional games indicated that only 10 out of 88 game studies examined the variable of learner profile (Ke 2008). As Dempsey et al. (1996) noted, research on the interaction of learner profile and instructional game usage is still limited.

Among the gaming studies reviewed, gender differences in game use and derived benefits were frequently mentioned. Gaming researchers argue that the differences are due to the gender prejudices in games that have weak female protagonists that can turn away girls (Inkpen 1998). Some also believe girls are less likely to enjoy game-play situations that emphasize violence and competition because "they gained a lesser sense of control than they did in other play activities" (Lucas and Sherry 2004). However, findings on gender-specific motivation or performance in computer gaming environment are still inconclusive. For instance, De Jean et al. (1999) reported that more boys were engaged by cooperative game-playing whereas girls had trouble recognizing embedded math elements in the game. Differently, Inkpen et al. (1994) reported that girls not only preferred playing in pairs or small groups (over competition or solo) but also solved significantly more math puzzles embedded in computer games than girls who worked alone, while the opposite was true for the boys in the study. Yet Haynes' study (2000) did not indicate gender difference in terms of game-based learning performance and game design preference.

Another potential individual characteristic variable that moderates the effect of gaming on learning is the socio-economic status (SES). Paperny and Starn (1989) evaluated the effects of computer action games on health education with 718 high school students. They reported that games (as opposed to traditional instruction) produced significant knowledge gain and attitude change among students with low SES (as opposed to other students). Prominent variables related to SES are prior computer experience and prior topic knowledge (Bozionelos 2003; McLoyd 1998). Moreno (2002) reported that students with low computer experience and low prior knowledge were helped most by the visual representations in the gaming situation. As such, it is speculated that game-based learning (as opposed to traditional instruction) may help solve the digital divide issue by supporting students of low SES. This speculation, however, needs to be corroborated in more recent empirical gaming studies.

Classroom goal structures for use of computer games

A current movement within the education research field is toward the cultivation of interactive learning environments integrating computers and social interactions (Winn 2000). A good example of integrating social interactions into a computer-supported classroom is using *goal structure*—"the ways in which students will interact with each other and the teacher to achieve the goal" (Johnson et al. 1985, p. 669). There are three choices in goal structure: cooperative, competitive, and individualistic. In a *cooperative* goal structure learners perceive that they are working together with other students to gain rewards. In a *competitive* goal structure learners perceive that they will be rewarded based on comparisons with other learners. In an *individualistic* goal structure learners perceive themselves as working for their own rewards. According to social interdependence theory, the way in which the goals in a situation are structured determines the interaction patterns among participants, which, in turn, determines the situational outcomes (Johnson and Johnson 1996).

A host of research conducted on the relative effects of alternative classroom goal structures generally indicates that cooperation is considerably more effective than interpersonal competition and individualistic efforts in promoting achievement and retention (Johnson and Johnson 1996). However, the interdependence between the use of technology-supported instruction and classroom goal structure is relatively unexplored. A lot more research is needed to assess and document "the ways in which technology may enhance or interfere with cooperative learning" (Johnson and Johnson 1996, p. 804).

From a cognitive elaboration perspective, cooperative learning is assumed to be advantageous because it requires participants to elaborate their cognitive structures in a social context (Slavin 1995). Computing technology, as claimed by Järvelä et al. (1999), can enhance cooperative learning by further motivating students in a group to "turn toward" a joint task and facilitating them to elaborate meanings concerning different abstract phenomena and achieve a reciprocal understanding of the situation (p. 363).

A theoretical framework that fosters a more explicit speculation on the interaction between classroom goal structures and game-based learning is cognitive evaluation theory (Deci et al. 1999; Ryan and Deci 2000). Cognitive evaluation theory (CET) predicts that when the interpersonal context of administering performance-contingent rewards is relatively pressuring, the rewards tend to be experienced as more controlling,[1] thereby diminishing intrinsic motivation; whereas when the interpersonal context of performance-contingent rewards is relatively noncontrolling,[2] the rewards tend to be experienced as more informational, thereby leading to possible enhancement of intrinsic motivation. CET also predicts that the effect of a sense of relatedness (connectedness with others) has a strong, positive impact on intrinsic motivation (Ryan and Deci 2000; Furrer and Skinner 2003). Following this theoretical perspective, the speculation is that the effects of a computer game as *an intrinsic motivation tool* (Rieber 1996) will be mediated by classroom goal structures that define the interpersonal context of extrinsic rewards. Within a cooperative goal structure, the perceived interpersonal context of extrinsic reward is relatively noncontrolling (as opposed to competition) and encouraging a sense of relatedness (as opposed to individualistic structure), hence may sustain, if not enhance, the intrinsic motivation effect of computer games. Within a competitive goal structure, the interpersonal context of extrinsic reward is perceived as relatively pressuring and therefore may diminish the intrinsic motivation effect of computer games. An individualistic goal structure will not construct extrinsic reward for task performance, thus not influencing the motivation effect of computer games. As such, a cooperative goal structure may reinforce the affective outcome of game-based learning most.

Despite the large number of studies about the use of classroom goal structure alone and computer games alone, few empirical studies examine the interaction between the two variables (Cavalier and Klein 1998; Tanner and Lindquist 1998). Closely related to the current study is Bahr and Rieth's (1989) investigation of a computer-based arithmetic drill-and-practice game designed to increase single-digit computation fluency. Forty-six mildly handicapped junior high school students practiced with their partners, recorded and graphed daily computer scores, and received points for backup reinforces based on pair's scores (cooperative condition), or comparing an individual with his/her partner (competitive condition), or the individual's self-progress (individualistic condition). Dyads worked 10 min per day, 3 days per week, over a 4-week period. The study findings indicated that students gained test-based math learning achievement during the game-based drill-and-practice, but there was no significant effect of goal conditions.

Individual differences

Although cooperative learning theory suggests individuals, regardless of gender and ability, should experience enhancements in learning and attitudes toward a subject, there is

[1] Learners perceive that they will be rewarded based on comparisons with other individual learners and their sense of self-determination decreases.

[2] Learners perceive that they are working together with other students to gain rewards or perceive themselves as working for their own rewards; their sense of self-determination increases.

evidence that the level of enhancement may vary across moderating factors (Johnson and Johnson 1996). For example, it was found that girls were more affected by the nature of the classroom climate than are boys in the studies of the relationship between school students' academic task values and classroom goal structures (Townsend and Hicks 1995). Other studies on computer-based collaborative learning also evidenced students' difference in the amount and type of participation related to their gender, preknowledge, and social-cultural background (Prinsen et al. 2007; Terwel et al. 2001; Stahl et al. 2006).

Summary

The literature review reveals that empirical, substantive studies concerning ways that computer games can be used in a classroom environment are still limited. Although the effects of alternative classroom goal structures have a well-formulated theory validated by hundreds of research studies in a face-to-face environment, the ways in which alternative classroom goal structures may enhance or diminish the learning effects of computer-based games have not been extensively investigated and conceptualized. In addition, more empirical research on how individual differences moderate the computer game-based learning outcomes within alternative classroom goal structures is warranted.

Research purpose and questions

Employing a pretest-posttest control group design, this study examined the effects of game-based learning with alternative classroom goal structures in comparison to the control condition on 5th graders' cognitive and affective learning outcomes (standards-based math exam performance and attitudes toward math learning). Students' gender and socio-economic status were considered as moderating variables. Specifically, the researcher's expectations were that:

1. Cooperative game-based learning would result in significantly greater math test achievement and more positive math attitudes than competitive and individualistic game-based learning conditions, and all gaming groups would perform significantly better than the no-gaming group, and
2. The effects of game-based learning within alternative goal structures on both cognitive and affective learning outcomes would be different for boys than for girls, and for economic-disadvantaged students than for economic-normal students. These unspecified hypotheses were formulated due to: (1) mixed reports in the literature on the effect of gender on game-based learning, and (2) empirical studies that examined the role of socio-economic status in the use of computer games were too limited to inform a directional hypothesis.

Method

Participants

One hundred sixty participants were recruited from eight 5th-grade public school classes in central Pennsylvania in the USA. Participants varied in gender (48% female) and socioeconomic status (42% economically disadvantaged). Socioeconomic status was measured by students' "free lunch" status. All participants knew basic computer skills and had hands-on game-playing experiences in or out of class before the experiment. Participation was voluntary. Participants were randomly assigned by intact classes to one of four groups: Teams–Games–Tournament cooperative game-based learning (n=43), competitive game-based learning (n=41), individualistic game-based learning (n=40), and control group (n=36). All participants participated in the pre- and posttest. Because the experiment treatments took place during regular math classes, absenteeism was rare, hence all 160 students' data were included in the analysis.

Materials

ASTRA EAGLE was a series of Web-based games designed as drill-and-practice programs to reinforce academic standards for mathematics required by "Pennsylvania System of School Assessment (PSSA)," which is a standards-based criterion-referenced assessment required by all public schools in the Commonwealth of Pennsylvania. The games were developed as single-player games using Macromedia's Flash, run on various major Internet browsers, and can be used in a normal classroom. Game players' gaming performance, time online, and gaming scores were archived in the system database, hence making it easily adapted for competitive (comparison across individuals), individualistic (self-comparison through the experiment period), and cooperative task structure (congregate individual members' performance into team score).

In this study, four mathematics games within the ASTRA EAGLE set that target 5th grade students were used. Each game contained one background story with a series of problems concentrating on one math concept comprehension or skill application. An example was the task of locating X and Y coordinates in a game called "Treasure Hunt," where game players could follow a hint "Go to X15, Y3 on the map" to dig for treasure. The games used only corrective feedback. As observed, students knew how to play games instantly after reading the instruction, which is clear and brief. The games had a simple interface that helped children focus on interacting with the game content and math tasks rather than learning game playing rules (Fig. 1).

Fig. 1 Screen-shots of one math game "Treasure Hunt"

Instruments

A Web-based, 30-item multiple-choice "Game Skills Arithmetic Test (GSAT)" was researcher-developed. It measured math skills that the games reinforced, including "solving word problems involving addition, subtraction, multiplication and division of whole numbers," "adding and subtracting measurements," "comparing quantities and magnitudes of numbers," and "locating and identifying points on a coordinate plane" (Pennsylvania Department of Education 2004). A panel of 5th grade math teachers from the sampled school district vetted its content validity. The GSAT was piloted with 548 fifth grade students during the previous academic semester with a Cronbach's alpha reliability of 0.80.

Tapia's "Attitudes Towards Math Inventory" was modified for a 5th grade audience (ATMI, Tapia and Marsh 2004). This Web-based, five-point Likert-scaled inventory contained 40-items investigating students' self-confidence, value, enjoyment, and motivation toward mathematics. This inventory reliably measured math attitudes with a Cronbach's alpha of 0.97.

Procedure

Data on gender and socioeconomic status was collected prior to the treatment. Socioeconomic status was measured by students' "free lunch" status. The teachers administered the GSAT and ATMI as a pretest. Participants took two orientation sessions (40 min each) during which they read the guidelines and tried each of the four math games. They were then required to play one math game during two 40-min sessions each week for four weeks. Participants were seated in their own classrooms, each with an Internet-connected laptop. The teachers administered the treatments by setting up in-class game-playing sessions and monitoring participants' activities. Before that, the teachers had received a 1-h training session and were given administration job-aids. The researcher observed most game-playing sessions. At the end of the 4-week experiment, all participants took the post GSAT and ATMI.

Teams–Games–Tournament cooperative game-based learning situation The application of cooperative learning in this study was anchored in a structural approach known as Teams–Games–Tournament (TGT; Slavin 1995). Empirical research indicates that TGT enhances students' motivation and academic achievement (Ben-Ari 2001).

Particularly, TGT is a cooperative goal structure using group rewards with inter-group competition (Slavin 1995). Researchers (Johnson and Johnson 1996; Slavin 1995) stated that cooperative learning has its greatest effects on student learning when group rewards exist. Slavin (1995) reviewed 64 studies on cooperative learning methods that provided group rewards based on the sum of group members' individual learning, found 50 indicating significantly positive effects on achievement and none indicating negative effects. According to Kohn (1992) and (Bossert 1989), inter-group competition heightens or induces cohesiveness and interdependency within the groups by posing an external threat to the groups and is capable of maximizing performance without sacrificing social benefits of cooperation.

Specifically, in the TGT cooperative group, students were first stratified by math ability levels and gender and then randomly assigned to four-member teams. At the beginning of each game session, students collaborated for 10 min in group as a whole, practicing with the game, discussing questions and solutions, and correcting each other's misconceptions. For the remainder of the 30 min, class teams then competed against one another; each team member held a laptop and was assigned to a tournament table to play against representatives of the other teams. At any tournament table there were four or five students who were roughly comparable in achievement level. Students at each table played individually. Teachers, as designed, kept encouraging students to consult a teammate sitting at the neighboring tournament table when they were stuck with difficult items in the math games. Therefore, cooperation activities for the TGT cooperative group were in two formats: whole-group cooperation at the beginning and peer help or consultation during the remained time. At the end of every two gaming sessions students' gaming scores were compared at each table to determine their rank order which was then converted into points. The points were added to compute a team score. The team scores were ranked and listed in a newsletter, and distributed to the class at the beginning of every treatment week.

Competitive game-based learning situation Students were seated at their own desks and played games against the computer. At the end of every two gaming sessions, individual scores were compared against others in the class. Their individual percentile ranks, identified by their own names (so everyone could compare him/herself with the other individuals), were announced in a newsletter every week.

Individualistic game-base learning situation Students in the individualistic game-based learning group were seated at their own desks and played games individually. However, there were neither interpersonal performance comparisons nor individual gaming performance ranks announced. They would measure their own learning improvement based on the gaming score record and the number of game levels (episodes) they completed within each gaming session.

Control/no-gaming situation Participants took two 40-min math drill sessions each week for 4 weeks. During the math drill session, participants individually completed paper-and-pencil math drills that targeted the math concepts and skills taught in ASTRA EAGLE games. The instructors provided corrective feedback to students on correct/incorrect items in the drill sheets completed at the end of each session. There were no planned cooperative or competitive activities going on during the math drill sessions.

Results

A three-way multivariate analysis of covariance (MANCOVA) was conducted on the post GSAT and ATMI scores using treatment group, gender (boy versus girl) and socio-economic status (economic-disadvantaged versus economic-normal) as fixed factors, and using pretest GSAT and ATMI scores as covariates. Pre- and post-test scores were transformed into percentages. A covariance analysis was preferred over a gain-score (repeated measure) analysis because in a study where the treatment assignment was random ANCOVA yields unbiased treatment estimates and typically has superior power to gain-score methods (Laird 1983; Oakes and Feldman 2001). Three prerequisites—homogeneity of variance,[3] homogeneity of regression slopes,[4] and the correlations between the two dependent variables—had been met before the MANCOVA was used. Additionally,

[3] Levene's test is non-significant ($p>0.05$), indicating the assumption of homogeneity of variance not been violated.

[4] The test of the significance value of the covariates by independent variables interaction is non-significant ($p>0.05$), hence the assumption of homogeneity of regression slopes (ANCOVA prerequisite) has not been violated.

analyses of variance between groups on the pretest scores indicated that there was no significant group difference at the pretest comparison.

The MANCOVA test showed an overall significant effect of the treatment variable on participants' math performance and math attitudes, $F(3, 142)=3.4$, $p<.01$. Descriptive statistics are presented in Table 1.

Hypothesis 1 *TGT cooperative game-based learning would result in significantly greater math performance and more positive math attitudes than the other two game-based learning conditions, and all gaming groups would perform significantly better than the no-gaming group.*

This hypothesis was partially supported. A significant main effect for the treatment was obtained on both GSAT scores, $F(3, 142)=2.8$, $p<0.05$ (partial eta squared=0.06) and ATMI scores, $F(3, 142)=4.9$, $p<0.01$ (partial eta squared=0.10). However, both effect sizes were relatively weak.

The Bonferroni corrected post-hoc comparisons on the adjusted posttest GSAT means showed that all gaming groups ($M_{coop}=61.1$, $M_{comp}=60.4$, $M_{indi}=61.0$) performed significantly better than the control group ($M_{cont}=55.3$, $p_{coop}<0.05$, $p_{comp}<0.05$, $p_{indi}<0.05$). Yet there was no significant superiority of TGT cooperative game-based learning over the other two game-based learning conditions on GSAT test achievement.

The Bonferroni corrected post-hoc comparisons on the ATMI attitudes measure indicated that game-based learning with cooperative goal structure ($M_{coop}=79.7$) promoted positive math attitudes significantly more than the other two game-based learning conditions ($M_{comp}=75.2$, $p_{comp}<0.05$; $M_{indi}=75.9$, $p_{indi}<0.05$) and the control group ($M_{cont}=72.8$, $p<0.0001$). However there was no evidence suggesting that the competitive or the individualistic game-based learning group was more advantaged than the control group in terms of ATMI attitudes outcome.

Hypothesis 2 *The effects of the treatment on both cognitive and affective learning outcomes would be different for boys than for girls, and for economic-disadvantaged students than for economic-normal students.*

This hypothesis was partially supported. The original MANCOVA test did not indicate a significant interaction effect between the treatment and gender on either math performance

Table 1 Descriptive statistics for math performance and math attitudes

	Control		Individualistic		Competitive		Cooperative	
	$n=36$		$n=40$		$n=41$		$n=43$	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pre test performance	61.2	14.4	57.8	14.5	56.0	13.7	56.7	14.3
Attitudes	77.5	9.38	77.7	13.2	74.7	12.4	74.1	12.6
Post test performance	58.2	15.2	63.2	15.1	57.7	13.7	59.5	14.6
Attitudes	74.2	12.0	77.3	15.6	75.0	13.5	78.5	12.4
Adjusted posttest means[a] performance	55.3	–	61.0	–	60.4	–	61.1	–
Attitudes	72.8	–	75.9	–	75.2	–	79.7	–

[a] Adjusted means using pretests as covariates.

or math learning attitudes. Additionally, there was not a significant main effect of gender on outcome variables.

However, the original MANCOVA test indicated a significant interaction effect between the treatment and socioeconomic status on students' math test performance and learning attitudes, $F(3, 142)=3.1$, $p<0.01$, even though the effect size is weak (partial eta squared=0.06).

To interpret the interaction between the treatment and socioeconomic status, another one-way MANCOVA was run[5] to compare means at eight levels (treatment = control, individualistic, competitive, or cooperative; SES=0 or 1[6]). The test again indicated a significant difference among the eight levels in both GSAT math test, $F(7, 150)=3.2$, $p<0.01$ (partial eta squared=0.13) and ATMI attitudes, $F(7, 150)=3.7$, $p<0.01$ (partial eta squared=0.15).

The Bonferroni corrected post-hoc comparisons on the GSAT math test revealed that economic-disadvantaged students at the cooperative and the competitive game-based learning groups scored significantly higher in math test than those at the control group ($p<0.05$). The economic-disadvantaged students at the cooperative and the competitive game-based learning groups also scored higher than those at the individualistic game-based learning group, but the difference was not statistically significant. On the contrary, economic-normal students under the individualistic game-based learning condition gained significantly higher math test scores than those under other learning conditions ($p_{cont}<0.001$, $p_{comp}<0.01$, $p_{coop}<0.05$).

The Bonferroni corrected post-hoc comparisons on math attitudes outcome indicated that economic-disadvantaged students in the cooperative game-based learning situation developed positive math attitudes significantly more than other learning situations ($p_{cont}<0.01$, $p_{indi}<0.05$, $p_{comp}<0.01$). In addition, the competitive game-based learning situation seemed to be least effective in promoting positive math attitudes among economic-disadvantaged students. However, for economic-normal students there was no significant difference among the three game-based learning conditions in promoting positive math attitudes (Fig. 2).

Conclusion

The findings indicated that computer game-based learning within all of the three classroom goal structures promoted cognitive math test performance significantly more than the paper-and-pencil drill situation, but the effect size was small. The partial eta squared was just 0.06, which means that the factor game-based learning by itself accounted for only 6% of the overall variance in the dependent variable.

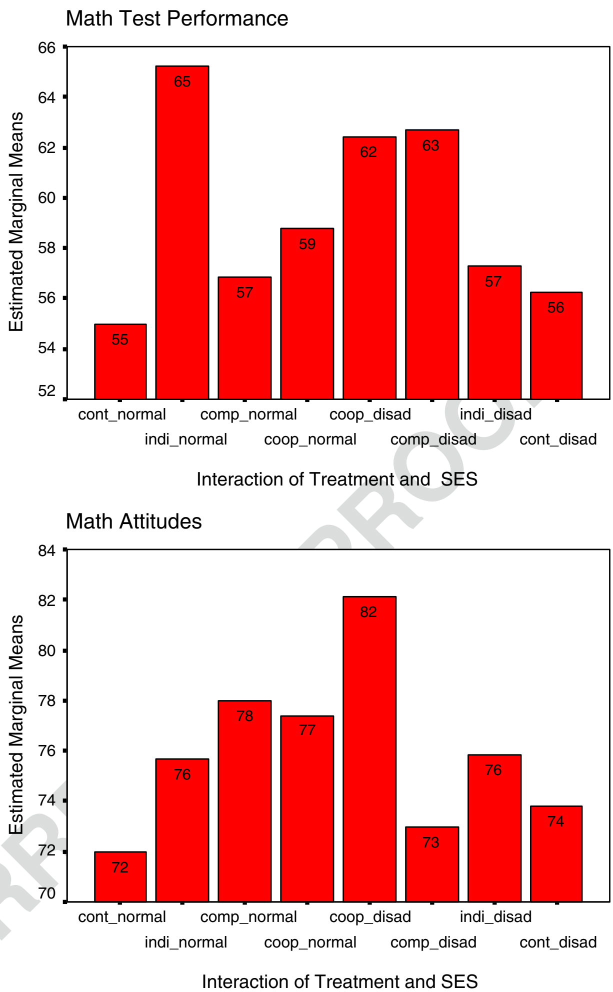
The findings also indicated that there was no significant difference among the three gaming groups in terms of math test performance. There was no evidence suggesting a significant effect of classroom goal structure on game-based learning in terms of test-based cognitive outcome.

However, there was evidence suggesting that classroom goal structure played a significant role in moderating the effect of computer games on affective learning outcome, even though the effect size of the moderating influence was small (partial eta squared=0.10). Among the three game-based learning situations, TGT cooperative game-based learning was significantly more effective than the other two; it was also the only gaming group that outperformed the control group in facilitating positive math learning attitudes.

[5] The adopted procedure of post-hoc analysis for a significant interaction was based on the work by Morgan et al. (2001).

[6] 0 means socio-disadvantaged and 1 means socio-normal.

Fig. 2 Post-hoc analysis of the interaction between treatment and SES on math test performance and attitudes toward math



Surprisingly, no evidence was found in this study for either the interaction between gender and the gaming treatment or the main effect of gender on learning outcomes. Instead, there was a significant interaction effect between SES variable and the treatment. It was found that in terms of math test performance, economic-disadvantaged students benefited from cooperative and competitive game-based learning while economic-normal ones gained more under the individualistic game-based learning condition. In terms of math learning attitudes, economic-disadvantaged students thrived in cooperative game-based learning while suffered in competitive situation; economic-normal students felt the same under the three game-based learning conditions.

Discussion

McFarlane et al. (2002) noted that education gaming yields best results when coupled with suitable off-computer activities. The current study attempted to find out effective classroom situations for implementing computer games in school, by examining how alternative game-based learning situations influenced math learning.

The effect of alternative game-based learning situations on math test performance

The study finding of a significant but small effect of the classroom use of computer games on cognitive math test performance is in accordance with the discovery of Vogel et al. (2006) in their recent meta-analysis of 32 gaming studies—even though significantly higher cognitive gains were observed in subjects utilizing computer games versus traditional teaching methods, there is low reliability for the effects.

The games used in this study are more concerned with having children drill and practice their prior knowledge than teaching them new knowledge. As indicated by this study and other empirical studies on using drill-and-practice games for math learning (Lee et al. 2004; Koran and McLaughlin 1990), game-based drilling on the computer can be an equally, if not more, effective and engaging alternative to paper-and-pencil-based drilling without gaming.

However, a better design of gaming feedback may help to increase the effects of drill-and-practice games. As opposed to paper-and-pencil drilling where feedback was delayed, the games in the study provided instant feedback that should be constructive to students' learning activities (Prensky 2001). Yet the feedback provided was *summative* rather than *informative*. Students were only credited for a correct answer, regardless of how they worked it out or whether they understood the method, which contrasts against a prevalent math learning proposition that the process is important as well as the outcome (Schoenfeld 1992). As such, a speculation is that educationalists may be able to enhance the games' effects by either embedding adaptive, informative feedback within the games or creating an external context for informative feedback, such as a cooperative learning situation for elaborations exchanged between peers.

The proposition on using a cooperative situation to cultivate informative feedback between peers and to enhance the effect of computer gaming, however, was not compliant with the finding of this study and Bahr and Rieth (1989): cooperative was not superior to competitive or individual structure in promoting test-based academic achievement. A potential reason of this disparity may be that the time (10 min) for the whole-group cooperation activity at a cooperative gaming session was too short to unfold the benefit of cooperation. The field observation revealed that even though students were encouraged to consult individual teammates during the remaining 30-minute game playing phase, they usually consulted for a correct answer rather than understanding how to work it out since game-based teamwork was rewarded based on correct answers. According to Webb (1992), giving or receiving answers without explanation generally reduces achievement. A major infield observation on cooperative gaming sessions was that communications among teammates were often characterized by questioning and explanation limited in level of cognitive demand, coupled with infrequent correction of errors and the giving of judgmental feedback when not appropriate. Students were rarely observed being skilled at requesting or initiating elaborated explanations. This observation corroborates the claim by Person and Graesser (1999) that spontaneous (untrained) peer tutoring behaviors tend to be primitive. It indicates that the major assumption of group learning that all students are able to perform cognitive elaboration is not valid (Webb 1992). In conclusion, it is suggested that future cooperative game-based learning situations should adopt a longer phase for whole-group peer tutoring, a reward mechanism that credits students' elaboration behaviors during cooperation, and a planned training that prepares young participants for content-related peer tutoring and elaboration.

The effect of alternative game-based learning situations on attitudes toward math

Although Vogel et al. (2006) reported a high and reliable effect size for subjects' attitudes toward learning when using the computer games versus traditional teaching methods, there is no evidence in this study suggesting that the classroom use of educational computer games by itself would certainly reinforce attitudes toward math learning. Rather, the motivational effect of the games depends on the game-based classroom situations.

Consistent with the investigation by Tanner and Lindquist (1998), this study indicates that computer-based gaming within Teams–Games–Tournament cooperative goal structure facilitated students' attitudes toward learning. This finding confirms Johnson and Johnson's (1996) and Slavin's (1995) claim that cooperative experiences promoted higher self-esteem than competitive or individualistic experiences did. It has also supported the speculation rooted in cognitive evaluation theory (Ryan and Deci 2000): a competitive goal structure, with performance-contingent rewards discouraging interpersonal association, weakens positive effects of computer game on affective learning outcome; cooperative goal structure, with performance-contingent rewards encouraging interpersonal association and sense of relatedness, reinforces positive effects of computer games on affective learning outcomes.

The study finding on the superiority of cooperative gaming over individualistic gaming in facilitating affective learning outcome sustains the motivation theory of computer gaming. According to Csikszentmihalyi (1990), computer games need to have optimized challenge (matching challenge with skill or ability) to be fun. In the math games used in this study some tasks targeted skilled math learners. It is possible that certain students, especially those academic-disadvantaged ones, could not fully enjoy the games where they found tasks too difficult. As such, group support may have helped to maintain game-based learning as attainable hence enjoyable for all teammates. The group support, in comparison, is missing in the individualistic game-based learning setting.

However, in this study the effect size on the superiority of cooperative goal structure against the other two goal structures is small. The cooperative goal structure in this study—Teams–Games–Tournament—involves group rewards and inter-group competition. Even though cooperative learning research generally evidences that group rewards and intergroup competition are valuable for cooperative learning in achievement gains in applications of several weeks or months (Slavin 1995), there is empirical research reporting that cooperation without inter-group competition may engender better attitudes toward the subject matter studies and tend to promote better cognitive test performance than cooperation with inter-group competition (Yu 2001). Cognitive evaluation theory (Ryan and Deci 2000) also implies that inter-group competition may negatively impact the effects of cooperative learning by decreasing intrinsic motivation with competition's controlling nature. Therefore, the affective effects of cooperative gaming may be enhanced by adopting a cooperation structure without inter-group competition.

Individual difference in game-based learning

In their meta-analysis on the effects of interactive simulation and computer games, Vogel et al. (2006) reported that studies comparing males and females yielded no significant differences between the two, suggesting that they perform similar to each other. This conclusion is sustained by the current study. It should be noted that most extant literature discussion on gender and gaming has focused on how the representations of girls in game content or in game interaction style influence gender-specific motivation (Littleton et al. 1998). Yet in this study, all of the four computer games feature a mixture of male and female persona and abstract gender-neutral character. These games do not require stereotypically masculine actions or violence such as fighting, shooting, or other target-directed motor skills, and involve the themes less likely to be associated with gender. Therefore it is less possible for the games to educe gender difference in the outcomes.

De Jean et al. (1999) claimed that boys benefited more from cooperative gaming while Inkpen et al. (1994) reported the contrast. This study does not indicate enough statistical evidence to support either side. It may be that the cooperative structure adopted in this study—Teams–Games–Tournament—integrates both peer collaboration and individual accountability, resulting in well-adjusted reactions from children of both genders.

Against the report of Paperny and Starn (1989), the study does not indicate significant difference between students of different economic status in enjoying or learning from computer games. However, the study generates a finding that has not been well addressed in previous research—students of differing socioeconomic status respond to game-based learning within alternative goal structures differently. Economic-normal students learned most from individualistic game-based learning situation whereas economic-disadvantaged students enjoyed and learned from a cooperative game-based learning situation most. This finding may be because low SES tends to be associated with lower school achievement and reduced access to computer technology resources (McLoyd 1998). Hence a justification is that economic-disadvantaged students, with lower prior topic knowledge and prior computer skills, benefit from peer support and experience less anxiety in a cooperative situation. The finding is in accordance with the argument of CSCL researchers that collaborative learning scenarios rely heavily on learners' prerequisites (Shapiro 2004; Ertl and Mandl 2006). As Felder and Brent (1994) claimed, the greatest cooperative learning success story comes from the literature on at-risk students.

Implications

The most important implication of this work is to inform educational practitioners to be cognizant of the need to select appropriate classroom management strategies when integrating educational games into school education. As this study indicates, classroom goal structures for game-based learning, beyond the computer game itself, yield significant effects on attitudes toward math learning. Consistent with McDonald and Hannafin (2003), this paper recommends that educational practitioners use gaming within meaningful learning environments or strategies to promote learning.

This study also provides an argument for combining the two teaching techniques, computer games and cooperative learning, to improve math education. The findings suggest that cooperative game-based learning is especially effective in facilitating positive math learning attitudes. However, to enhance the effects of game-based cooperative learning on cognitive learning achievement, training of cognitive elaboration skills and a better design of cooperative structure that credits peer tutoring and elaboration will be warranted.

Additionally, this study provides helpful findings on using Teams–Games–Tournament technique in a computer-assisted instructional setting. TGT cooperation is more effective than competition or individualistic structure in facilitating positive math attitudes, but not in promoting math test performance. Future research should continue to explore and determine other effective techniques to implement cooperative learning structures with classroom use of computer games.

Finally, in this study there is evidence suggesting that effects of goal structures on game-based learning outcomes are different for economic-disadvantaged students than for economic-normal students. This implicates that during classroom application of computer games, educationalists should take special efforts to construct the best combination of classroom structure and learning tasks that caters to the needs of diverse student groups in technology access and learning preference.

Limitations

It should be emphasized that this is a study of one specific set of games, one specific formulation of classroom goal structures, and one specific structure for cooperative learning. The cooperative learning strategy adopted in this study involved inter-group competition that might compromise the advantage of cooperative structure. In addition, the games used in this study were originally designed as single-player games. The game characteristics of a single-player game may influence its supremacy in serving cooperative learning format. Therefore, cautions should be exercised when generalizing the study findings to interpret the interdependence between other types of games (e.g. multiplayer games), other sets of classroom structures, and other cooperative learning structures (e.g. Jigsaw or Reciprocal Teaching, Slavin 1995).

In this study, the author followed the tradition of social research in considering socio-economic status as one measured variable. In future research, researchers should also collect and analyze potential indicator variables of socio-economic status, such as computer experience, prior ability, and computer anxiety in examining their interactions with game-based learning situations. The current study did not indicate gender difference in game-based learning situations as expected. A post-hoc explanation is that the games' content and task design were unlikely to educe gender difference. Future research should continue to test empirically and purposefully whether a neutral-character design in games will help reduce gender difference at game-based learning setting. Finally, the control situation in the current study implements a natural individualistic goal structure in the non-gaming setting. Future research on the interaction between classroom goal structures and educational gaming can extend the current research design by embedding alternative goal structures in both gaming and non-gaming settings.

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