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Teaching mathematics in game learning environment

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Abstract: The primary focus of this study was to investigate the impact of games activities in mathematics classes. The study incorporated a pre-post approach that involved surveys to assess students' perceptions of psychosocial features of the learning environment, academic efficacy and students' enjoyment of mathematics lessons. A sample of 90 students from three colleges in the United Arab Emirates participated in the study. After the initial collection of quantitative data, *Jeopardy!*-type games were introduced to 90 students over a six-week period. The findings suggest that, during exposure to games, students experienced an improvement in the three psychosocial features of the learning environment (teacher support, involvement and personal relevance) and also academic efficacy and enjoyment of mathematics lessons. The results of this study offer potential opportunities for mathematics educators to incorporate the use of mathematical games in the curriculum as a practical way to improve classroom environments and students' attitudes.

Keywords: Attitudes, learning environment, what Is Happening In this Class? (WIHIC), jeopardy-type games, United Arab Emirates.

Introduction

There is a significant body of research supporting the use of non-traditional interventions, such as games as a valuable teaching method (Glynn, Price & Owens, 2005; Kumar & Lightner, 2007). Past research indicates that games have the potential to draw students into the learning process and to encourage them to participate through a more interactive environment (Gosen & Washbush, 2004; Proserpio & Gioia, 2007; Zantow, Knowlton & Sharp, 2005). The use of games in class encourages active learning, as well as collaboration and interactivity (Reuben, 1999). Games can also provide educators with an interactive means of delivering knowledge that is particularly useful for teaching cause and effect (Gosen & Washbush, 2004; Thompson & Dass, 2000). Finally, as an educational tool, games have the capacity to engage and motivate students (Paraskeva, Mysirlaki & Papagianni, 2010; Prensky, 2001) and the learning from games is more likely to be retained (Annetta, Cheng & Holmes, 2010).

According to Paraskeva et al. (2010, p. 499), the use of games is a "fun, engaging, motivating, interesting and encouraging way" of teaching. They also state that games have potential for teaching complex new information to students and, in their opinion, both academic performance and interpersonal relationships are likely to be enhanced through the use of games. Although active learning with plenty of student involvement is the norm, and games are fun, some college instructors feel that if learners are laughing and having fun, they could not be learning very much (Gaudart, 1999).

Although mathematics games are popular with teachers as alternatives to more traditional forms of repetitive practice, they are more commonly employed in school classrooms as rewards for early finishers or to enhance students' attitudes towards mathematics (Bragg 2007). Past research supports the idea that games can stimulate students' interest and motivation (Gough, 1999; Owens, 2005), but only a handful of studies have been carried out to investigate the impact of mathematics games at the college level in the United Arab Emirates.

As a mathematics educator, I have struggled to know what I can do to increase the motivation level of my students with respect to learning mathematics. I feel strongly that an important aspect of my job, as a mathematics educator, is to incorporate different pedagogies in my lessons to improve my students' perception of the learning environment and their attitudes towards mathematics. The purpose of my study,

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then, was to determine the extent to which the use of games in mathematics classes might influence the classroom environment and students' attitudes towards mathematics.

Learning Environments

Students' observations of and reactions to, their experiences in school—specifically their learning environments—are of significance, since they spend up to 20,000 hours at educational institutions by the time they finish university. The term learning environment refers to the social, physical, psychological and pedagogical context in which learning occurs and which affects student achievement and attitudes. Results of studies conducted over the past 40 years have provided convincing evidence that the quality of classroom environment in schools is a significant determinant of student learning (Fraser, 2007, 2012). This implies that students learn better when they perceive the classroom environment more positively (Dorman & Fraser, 2009).

Researchers have developed numerous questionnaires designed to measure perceptions of a range of dimensions pertinent to the learning environment (Fraser, 1998), including the What Is Happening In This Class? (WIHIC; Aldridge, Fraser & Huang, 1999) and the Constructivist Learning Environment Survey (CLES; Taylor, Fraser & Fisher, 1997). In my study, I used five of the seven What Is Happening In This Class? (WIHIC) scales, namely, Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity, and one scale, from the Constructivist Learning Environment Survey (CLES), namely, Personal Relevance. This study draws on past evaluations of educational innovations (Maor & Fraser, 1996; Wolf & Fraser, 2008; Nix, Fraser & Ledbetter, 2005; Martin-Dunlop & Fraser, 2008) from the field of learning environments to investigate the impact of games in the mathematics classroom learning environments.

Jeopardy! Games

Jeopardy! game is an American quiz show that features topics such as history, literature, the arts, pop culture, science and sports. The show has a unique question-and-answer format in which contestants are presented with clues in the form of answers, and must phrase their responses in question form. Six categories are announced, each with a column of five trivia clues, each one incrementally valued more than the previous. Figure 1 provides an example of the *Jeopardy!* game board.

Figure 1 *Jeopardy!* Game Board

The clues are read by a host and the contestants 'ring in' using a hand-held signalling device. The first contestant to ring in successfully responds and, if correct, earns the dollar value of the clue and the opportunity to select the next clue from the board. An incorrect response or failure to respond within the five-second time limit leads to a deduction of the dollar value from the contestant's score.

Based on the television quiz show, Story (2007) developed *Jeopardy!*-type games, that I modified for use in the United Arab Emirates. The game involves a board upon which four different mathematical concepts are posted (see Figure 2), with a series of point values under each. For example, in Figure 2, the first row, display the names of the different mathematics concepts, such as fractions as percentages, decimals as percentages, percentages as decimals and percent of a number. The first row provides problems each worth 100 points. In this case, the students selected a problem from the first row and first column. The answer that they provided to the problem was incorrect and therefore the word ‘wrong’ is displayed. The point values increase from top to bottom. Each point value has an associate problem or question. Figure 3 provides a problem selected by the students from the third column and second row with a point value of 200. Generally the higher the point value, the tougher the problem. The teacher reads the problem, and the contestants take turns to answer the questions.

In mathematics classes, when playing the *Jeopardy!*-type game, students are placed into teams and take turns to select a mathematics concept and a corresponding question from the board. When the teacher clicks on the cell selected by the student, the question is exposed. The members of the team are then expected to work together to solve the problem. If they get the answer correct, they earn the point value of that question and, if the answer is incorrect, the point value is subtracted from the total. A member of the group that gets the correct answer is then asked to present the correct solution to the class. After all of the questions have been answered, the team with the most points is declared the winner.

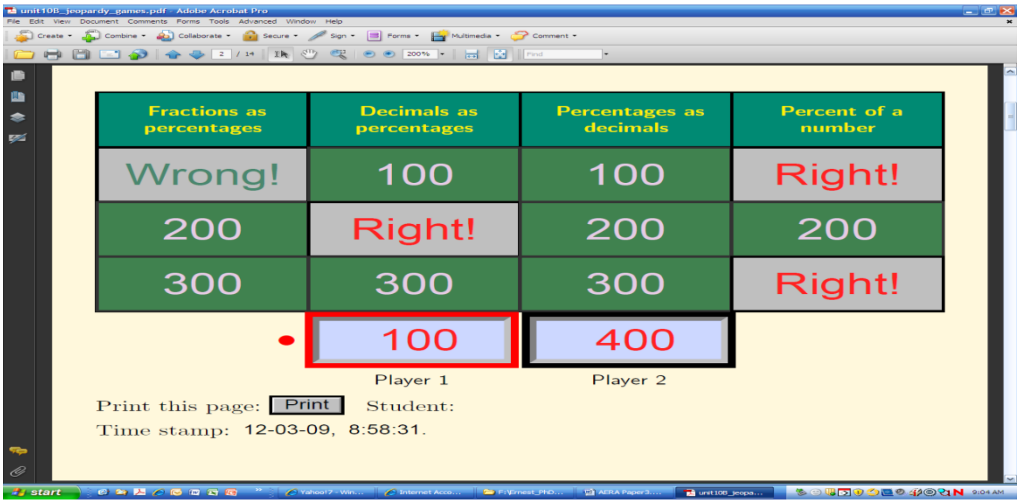

Figure 2 Game Board Page

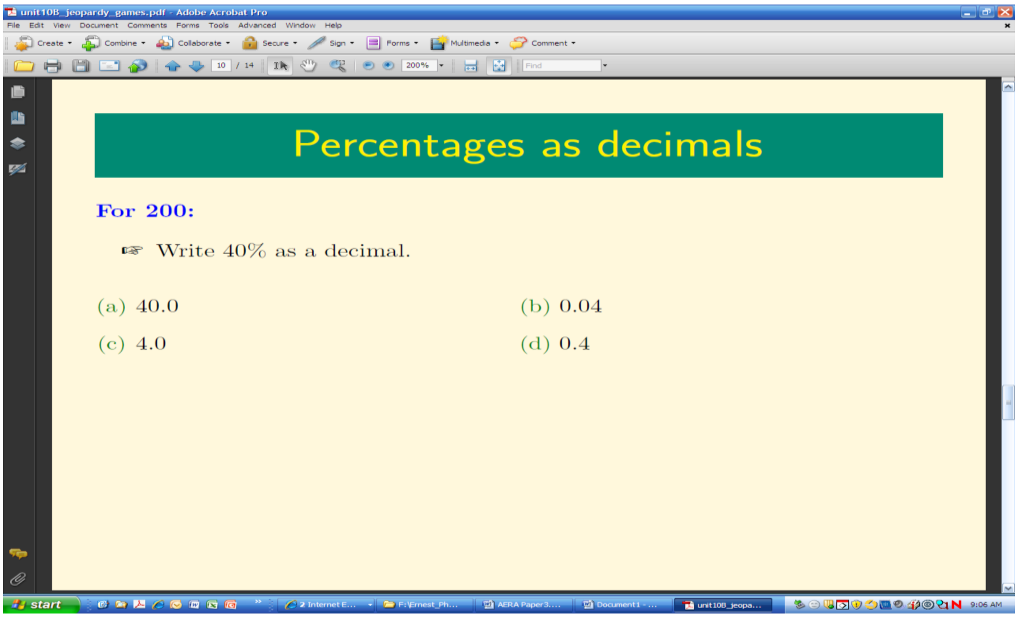

Figure 3 Question Page

According to Rotter (2004), *Jeopardy!*-type games have the potential for teachers to assess the current level of student knowledge, clarify problem areas and to reinforce critical information. Past research has indicated that computer game-based learning is effective in promoting positive mathematics attitudes (Ke, 2008). A study by Woolfolk and Margetts (2007) indicated that students' interest, enjoyment and excitement about what they were learning was one of the most important factors in education, and that when students' motivation levels were increased, they were more likely to find academic tasks meaningful. My study explored the effectiveness of *Jeopardy!*-type games in terms of students' perceptions of the learning environment and attitudes toward mathematics classes in the United Arab Emirates.

Gender Differences

A review of the literature indicates that a number of studies have found that males perform better than females in mathematics (Hedges & Nowell, 1995; Peterson & Fennema, 1985; Randhawa, 1994). Other studies, however, have found no difference (Bronholt, Goodnow & Cooney, 1994). Speering and Rennie (1996) found that some secondary school subjects, particularly the sciences, are perceived negatively by students, especially girls. A study by Papastergiou (2009), which assessed the learning effectiveness and motivational appeal of a computer game for learning computer memory concepts, reported that, despite boys greater involvement with and experience in, computer gaming, and their greater initial computer memory knowledge, the learning gains that boys and girls achieved through the use of the game did not differ significantly. In addition, the game was found to be equally motivating for boys and girls.

Studies in the United States have suggested that boys have more positive attitudes towards mathematics than girls (Kurth, 2007). Also, Hoang (2008) found that males have slightly more positive perceptions of their classroom environment and attitudes towards mathematics than females. My study builds on and extends these past studies by investigating whether the use of mathematics games is differentially effective for male and female students in terms of student perceptions of the learning environment and attitudes towards mathematics.

Methods

Participants

The United Arab Emirates is a federation of seven emirates located in the northeast corner of the Arabian Peninsula. Since the development of significant oil reserves in the 1980s and 90s, the country has seen rapid development to become a modernized, multicultural society with a population of almost 4 million people. Emiratis make up only around 17% of the population. While the official language of the United Arab Emirates is Arabic, English is the medium of instruction of public institutes of higher education.

My study involved a pre-post design in which the initial collection of the data was carried out before *Jeopardy!*-type games were introduced. 90 students (52 males and 38 females), from 8 classes enrolled in their foundation year in three English medium colleges in the United Arab Emirates (UAE) were randomly selected to participate in the study. The participants' ages ranged from 18 to 35 years. After the initial collection of the data, jeopardy-type games were introduced to the 90 students over a six-week period. At the end of the six weeks, the same questionnaires were re-administered to students in the eight classes to assess whether there were changes in students' perceptions of the learning environment and their attitudes towards mathematics.

About 90% of the students who participated in the study were United Arab Emirates nationals and the rest were from the neighbouring Arab countries. The questionnaire was administered at the middle of the semester. Participants completed the questionnaires in their classrooms during normal school hours. I distributed the questionnaire, explained the procedure, and answered students' clarifications. The students took approximately 20 minutes to complete the questionnaires and participation was voluntary.

Aims

The aims of my study were:

1. To investigate the effectiveness of games activities in mathematics class.
2. To examine the effectiveness of the use of mathematics games in class for males or females.

Instruments

Two questionnaires were used to gather data for this study. A 48-item questionnaire was used to assess student perceptions of the learning environment. The questionnaire involved six scales of Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity, and Personal Relevance. The second questionnaire involved two scales of an Enjoyment of Mathematics Lessons scale and an academic efficacy scale consisting of 16-items was used to assess students' attitudes towards their mathematics class. A description of each scale used in the learning environment questionnaire and the Enjoyment of Mathematics Lessons scale and an Academic Efficacy scale are provided in Table 1 along with a sample item for each scale.

The What Is Happening In this Class? (WIHIC; Aldridge et al., 1999) questionnaire was used to assess students' perceptions of the learning environment. The WIHIC incorporates the best features of existing instruments, adapting their salient scales and combining them with particular aspects of constructivism and other relevant factors operating in contemporary classrooms to bring parsimony to the field of learning environments research (Aldridge et al., 1999; Dorman, 2008). For my study, the WIHIC was modified by omitting two of the original scales (Investigation and Task Orientation), as these were not considered to be pertinent to the context of the study, and adding one scale (Personal Relevance) as this aspect was considered to be important. The reliability and validity of the WIHIC have been supported for samples in Taiwan and Australia (Aldridge et al., 1999), the US (Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008), Indonesia and Australia (Fraser, Aldridge & Adolphe, 2010), Singapore (Chionh & Fraser, 2009; Khoo & Fraser, 2008), Korea (Kim, Fisher & Fraser, 2000), Uganda (Opolot-Okurut, 2010) and UAE (Afari, Aldridge, Fraser & Khine, in press). The Enjoyment of Mathematics Lessons scale, consisting of eight items, was adapted from one scale in the Test of Science-Related Attitudes (TOSRA; Fraser 1981) by Spinner and Fraser (2005). The second eight-item Academic Efficacy scale was based on Jinks and Morgan's (1999) Student Efficacy Scale (MJSES).

Translation

All the questionnaires were originally developed in English. Because all of the participants involved in my study spoke English as a second language, an Arabic translation was created to ensure that they were able to understand the items. The questionnaires were translated into the Arabic language using a standard research methodology of translation, back-translation, verification and modification as recommended by

Ercikan (1998) and Warwick and Osherson (1973). Each item was translated into Arabic by a professional translator from the United Arab Emirates. The next step involved an independent back-translation of the Arabic version into English by a different professional translator, who was not involved in the original translation. Items of the original English version and the back-translated version were then compared by me to ensure that the Arabic version maintained the meanings and concepts in the original version.

Table 1: Scale description and sample item for each scale in the learning environment and attitudes questionnaires

Scale	Description	Sample Item
Learning Environment	*The extent to which …*	
Student Cohesiveness	Students are friendly and supportive of each other.	I make friends among students in this class.
Teacher Support	the teacher helps, befriends, and is interested in students.	The teacher helps me when I have trouble with the work.
Involvement	students have attentive interest, participate in discussions, and enjoy the class.	I explain my ideas to other students.
Cooperation	students cooperate with each other during activities.	When I work in groups in this class, there is teamwork.
Equity	the teacher treats students equally, including distributing praise, questions and opportunities to be included in discussions.	The teacher gives as much attention to my questions as to other students' questions.
Personal Relevance	there is a link between what is taught and students' out of school experiences.	This class is relevant to my life outside of college.
Attitudes		
Enjoyment of Mathematics Lessons	students enjoy their mathematics lessons.	Lessons in mathematics are fun.
Academic Efficacy	Students' belief about their academic competence	I find it easy to get good grades in mathematics.

All items used the response alternatives of Almost Always, Often, Sometimes, Seldom and Almost Never

Results

Effectiveness of Mathematics Games

The *Jeopardy!*-type games were introduced to 90 students in eight classes over a six-week period. Before the introduction of the games and at the end of the six weeks, the WIHIC and attitude (Enjoyment of Mathematics Lessons and academic efficacy) scales were administered to the students. To provide a measure of the effectiveness of the mathematics games, differences between students' pre-test and post-test scores on the WIHIC, Enjoyment of Mathematics Lessons and Academic Efficacy scales were used. Pre-post differences were explored using a one-way multivariate analysis of variance (MANOVA) with repeated measures (using the student as the unit of analysis). The set of six learning environment scales and the two attitude scales of Enjoyment of Mathematics Lessons and Academic Efficacy scales constituted the dependent variables and the testing occasion (pre-test/post-test) constituted the independent variable. Table 2 reports the average item mean, average item standard deviation, effect size, and MANOVA results for pre-post differences for each of the WIHIC and attitude scales. The average item means indicate that, for all six WIHIC scales, students' scores increased somewhat during the use of games.

Because the multivariate test (Wilks' lambda) revealed significant pre-test - post-test differences overall, the ANOVA with repeated measures was interpreted for each individual modified WIHIC and attitude scale (see Table 2). Statistically significant pre-post differences (p<0.05) emerged for three of the six

WIHIC scales (namely, Teacher Support, Involvement and Personal Relevance) and for both the Enjoyment of Mathematics Lessons scale ($p<0.01$) and the Academic Efficacy scale ($p<0.01$).

Table 2 Average item mean, average item standard deviation and difference (effect size and MANOVA with repeated measures) between pre-test and post-test scores on each WIHIC and Attitude scale

Scale	Average Mean Item		Average Item Standard Deviation		Difference	
	Pre-test	Post-test	Pre-test	Post-test	Effect Size	*F*
Learning Environment						
Student Cohesiveness	4.20	4.23	0.66	0.68	0.02	0.46
Teacher Support	4.00	4.19	0.78	0.73	0.12	2.51*
Involvement	3.73	3.93	0.67	0.66	0.15	2.88**
Cooperation	3.97	4.04	0.78	0.75	0.05	0.82
Equity	4.28	4.35	0.62	0.66	0.05	1.07
Personal Relevance	3.59	3.86	0.78	0.70	0.18	2.68**
Attitudes						
Enjoyment of Mathematics Lessons	3.60	3.86	0.99	1.00	0.13	2.87**
Academic Efficacy	3.74	3.97	0.89	0.88	0.13	2.81**

N=90 student in 8 classes present for both the pre-test and post-test
*$p<0.05$ **$p<0.01$

To examine the magnitudes of these pre-test – post-test differences, as well as their statistical significance, effect sizes were calculated in terms of the differences in means divided by the pooled standard deviation (as recommended by Thompson, 1998, 2001). The effect sizes, for those scales with statistically significant differences, range between 0.12 to 0.18 standard deviations, which are considered to be ‘small’ according to Cohen’s (1992) criteria. According to the data, the use of games in the mathematics classroom facilitated a more positive learning environment (in terms of more Teacher Support, Involvement and Personal Relevance) and also greater Enjoyment of Mathematics Lessons and Academic Efficacy.

Differential Effectiveness of Mathematics Games for Different Sexes

The differential effectiveness of the use of mathematics games in class for males and females was examined for the sample of 90 students (38 females and 52 males) in 8 classes. I report the use of a two-way MANOVA with repeated measures to identify the differential effectiveness of using games activities in mathematics instructions for males and females. The criterion for identifying the differential effectiveness of using mathematics games was an occasion (pre-test-post-test) × sex (male-female) interaction. For the two-way MANOVA, the independent variables were the testing occasion (pre-test and post-test) and sex, and the dependent variables were the six learning environment scales and attitudes scales. Testing occasion was the repeated measure factor. Because the multivariate test using Wilks’ lambda criterion yielded significant differences for the two main effects and for the interaction, the univariate ANOVA was interpreted for each scale (see Table 3).

As anticipated, the results in Table 3 for testing occasion from the two-way ANOVAs (with control for sexes) match the results of the MANOVA for pre-post differences for each of the WIHIC and attitude scales when sex was regarded. In both cases, statistically significant ($p<0.05$) differences were found between pre-test and post-test for Teacher Support, Involvement, Personal Relevance, Enjoyment of Mathematics Lessons, and Academic Efficacy.

The eta² statistics was calculated to provide an estimate of the strength of association between each effect (Testing Occasion, sex and the interaction) for each WIHIC and the Attitude scale. For example, Table 3 shows that the amount of variance in scores accounted for by Testing Occasion (i.e. eta²) ranged from 0.00 to 0.06 for the WIHIC scales and 0.07 for both attitude scales. The results in Table 3 indicate that a statistically significant interaction between testing occasion and sex emerged only for Student Cohesiveness. Therefore the independent interpretations of testing occasion differences and sex differences are valid for all scales except Student Cohesiveness.

For the sample of 90 students, a two-way ANOVA focuses on whether differences exist between females and males regardless of testing occasion. As shown in Table 3, statistically significant ($p<0.05$) differences exist between females and males for Teacher Support, Involvement, Cooperation, Equity, and Personal Relevance, with male students perceiving all of these scales more favourably than their female counterparts. The proportions of variance for these significant differences (eta²) ranged from 0.04 to 0.11 and were positive.

For the only statistically significant interaction, Student Cohesiveness, the amount of variance accounted for was 0.06. Figure 4 illustrates the interpretation of the statistically significant testing occasion-by-sex interaction for the Student Cohesiveness scale. Whereas the Student Cohesiveness scores of males and females were similar for the pre-test, males' perceived greater Cohesiveness than did females for the post-test. Figure 4 suggests that males' perception of Student Cohesiveness improved, while female scores deteriorated, during the use of games.

Table 3 Two-way ANOVA results (F ratio and eta^2 statistic) for testing occasion and sex differences for each WIHIC and attitude scale

Scale	Testing Occasion		Sex		Occasion × Sex	
	F	eta²	*F*	eta²	*F*	eta²
Learning Environment						
Student Cohesiveness	0.01	0.00	1.49	0.02	5.09*	0.06
Teacher Support	5.77*	0.06	10.07**	0.10	0.17	0.00
Involvement	4.20*	0.05	4.16*	0.05	3.58	0.04
Cooperation	0.81	0.01	5.17*	0.06	0.30	0.00
Equity	0.78	0.01	3.88*	0.04	0.98	0.01
Personal Relevance	6.26*	0.04	10.54**	0.11	0.86	0.01
Attitudes						
Enjoyment of Mathematics Lessons	6.49*	0.07	2.24	0.03	3.66	0.04
Academic Efficacy	6.42*	0.07	0.47	0.01	2.40	0.03

N=90 student in 8 classes present for both the pre-test and post-test
*$p<0.05$ **$p<0.01$

Although there is a statistically significant interaction, the amount of variance accounted for is only 0.06. These might be because of the competitive nature of the male students when playing *Jeopardy!*-type games. The male students spent longer negotiating and justifying their answers before agreeing on an answer, as opposed to the female students who did not do much negotiation or justification of their answers.

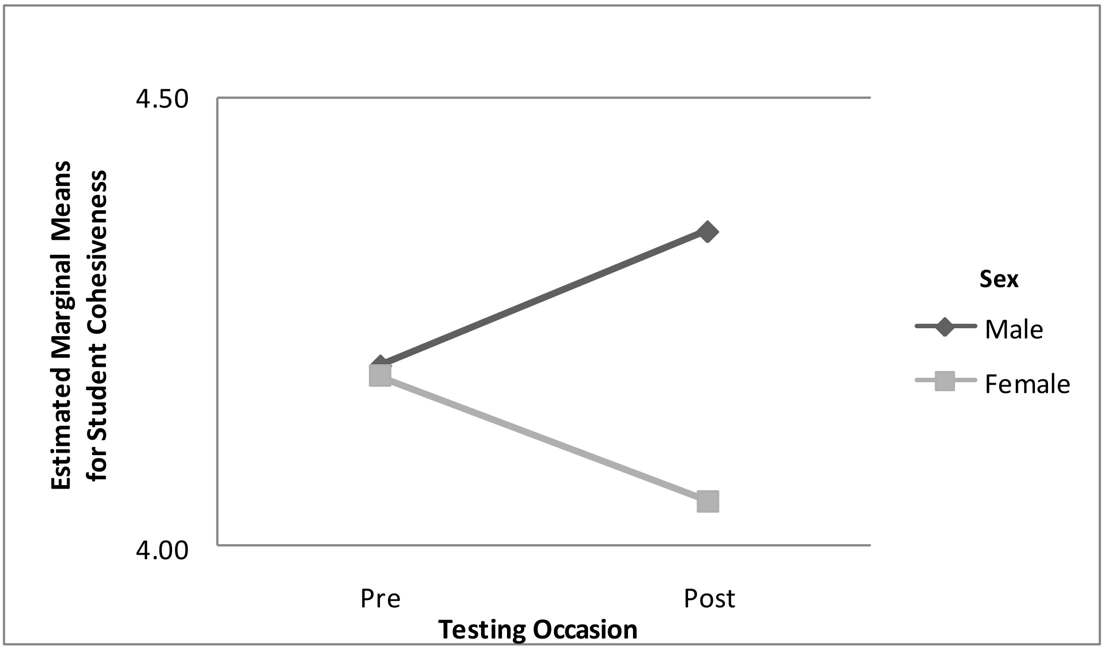

Figure 4 Interaction between Testing Occasion and Sex for Student Cohesiveness

Discussion

Games provide experience in experimentation, exploration, trial and error, imagination, role play, and simulation (Khine & Saleh, 2009). There are studies that draw attention to the potential of games to support the learning of competencies, collaboration and participation (Kirriemuir & McFarlane, 2004). According to Khine and Saleh (2009), the challenges that lie ahead for educators are to draw on teaching strategies to transform traditional approaches to a new learning model that infuses the use of educational games and simulations in the formal curriculum. They also suggest that teachers can harness the motivational power of games to make learning more enjoyable.

This research represents one of the few studies of mathematics classroom environment conducted in the United Arab Emirates that focuses on the effect of mathematical games on the classroom environment perceived by students. A sample of 90 college-level students in Abu Dhabi was used to investigate whether differences exist between students' pre-test and post-test scores on the WIHIC, Enjoyment of Mathematics Lessons and Academic Efficacy scales. *Jeopardy!*-type games were introduced to students in eight classes after the initial collection of data. Four teachers from three Colleges in Abu Dhabi volunteered to trial the use of *Jeopardy!*-type games for six weeks. This provided a sample of 90 students from 8 classes who were attending the classes that were exposed to the use of games. At the end of the six-week period, the same questionnaires (learning environment and attitude) used in the initial administration were re-administered to the eight classes to determine whether there were changes in students' scores on the questionnaires.

Differences between students' pre-test and post-test scores on the WIHIC, Enjoyment of Mathematics Lessons and Academic Efficacy scales were explored using a one-way multivariate analysis of variance (MANOVA) with repeated measures (using the student as the unit of analysis). The set of 6 learning environment scales and the two attitude scales of Enjoyment of Mathematics Lessons and Academic Efficacy scales constituted the dependent variables. The independent variable was testing occasion (pre-test/post-test). The average item mean, average item standard deviation, effect size, and MANOVA results for pre-post differences for each of the modified WIHIC and attitude scale were reported. The average item means indicate that, for all six WIHIC scales and attitude scales, students' scores increased after the games had been introduced, suggesting improved perceptions of the learning environment.

Because the multivariate test (Wilks' lambda) revealed significant pre-test-post-test differences overall, the ANOVA with repeated measures was interpreted for each modified WIHIC and attitude scale. The results indicated that there were statistically significant pre-post differences ($p<0.05$) in learning environment scores for three of the six WIHIC scales, namely, Teacher Support, Involvement and Personal relevance. The results also indicated statistically significant differences between the pre-test and post-test scores for both the Enjoyment of Mathematics class scale ($p<0.01$) and the Academic Efficacy scale ($p<0.01$). The effect sizes, for those scales with statistically significant differences, range between 0.12 and 0.18 standard deviations.

The results of the study suggested that the games impacted positively on students' attitudes towards the learning of mathematics and their perceptions of some important aspects of classroom environment. My findings suggest that, during exposure to games, students experienced improved Teacher Support, Involvement and Personal Relevance, Enjoyment and Academic Efficacy.

The differential effectiveness of the use of mathematics games in class for males and females was explored for the sample of 90 students (38 females and 52 males) in 8 classes. A two-way MANOVA with repeated measures was used to identify the differential effectiveness of using games activities in mathematics instructions for males and females. The criterion for identifying the differential effectiveness of using mathematics games was an occasion (pre-test-post-test) × sex (male-female) interaction. For the two-way MANOVA, the independent variables were the testing occasion (pre-test and post-test) and sex (male and female), and the dependent variables were the six learning environment scales and two attitudes scales. Testing occasion was the repeated measure factor. Because the multivariate test using Wilks' lambda criterion yielded significant differences for the two main effects and for the interaction, the univariate ANOVA was interpreted for each scale. The results for testing occasion from the two-way ANOVAs (with control for sexes) match the results of the MANOVA for pre-post differences in each of the modified WIHIC and attitude scales ignoring sex. In both cases, statistically significant ($p<0.05$) differences were found between pre-test and post-test for Teacher Support, Involvement, Personal Relevance, Enjoyment of Mathematics Lessons, and Academic Efficacy.

The eta^2 statistics was calculated to provide an estimate of the strength of association between each effect (Testing Occasion, sex and the interaction) for each WIHIC and the Attitude scale. The amount of variance in scores accounted for by Testing Occasion (i.e. eta^2) ranged from 0.00 to 0.06 for the WIHIC scales and 0.07 for both attitude scales.

The results indicate that, whereas the Student Cohesiveness scores were similar for males and females before the introduction of games, there was a pre-post increase in Student Cohesiveness for males and a pre-post decrease for females. The introduction of games in the mathematics class appears to have benefited male students in terms of developing stronger support systems within the class, allowing the male students to work together more closely than the female students when playing the *Jeopardy!*-type games. It would appear that cultivating students' supportive relationships with their peers (both male and female) could be a way to increase students' motivation in their mathematics learning. If students are provided with opportunities to interact and work together so that they can get to know each other well and build positive social bonds during mathematics lessons, they also are likely to experience increased enjoyment of their mathematics lessons.

The WIHIC questionnaire used in this study has 48 items that assess six dimensions that are important in mathematics classrooms, namely, Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity and Personal Relevance. The study reports the positive class-level link between attitudes and Teacher Support, Involvement and Personal Relevance. Classes of students who perceived stronger teacher support and are actively involved in learning activities, are more likely to perceive learning as relevant, and hence more positive attitudes. Increased support by teachers might help students to feel more comfortable in the classroom and this could lead to higher attitude scores. This questionnaire has the potential to provide information to teachers about how they can improve their classroom learning environments to better accommodate the needs of their students.

The generalisation of the results to other populations should be made with caution since this study involved a relatively small number of teachers and students (8 classes from three colleges in Abu Dhabi). The United Arab Emirates is a country with seven emirates (states) with at least five colleges in each emirate and no sample was drawn from any of the other six emirates. It is therefore unclear whether my findings would apply to other college-level institutions in the United Arab Emirates.

The limited sample size also limited the power of statistical analyses. A larger sample would have permitted pre-post differences in perceptions of learning environment and attitudes to be identified more clearly. To try and overcome this, however, rich, in-depth, qualitative data could have been gathered to complement findings from the quantitative data. Because students were exposed to the mathematics games for only six weeks, a longer period of exposure could have provided more insights into the effect of games activities on students' attitudes and the learning environment. A further limitation of my study is the limited scope in terms of student outcomes, which included only students' academic efficacy and their enjoyment of mathematics lessons. In particular, the absence of any achievement outcomes might be considered as a limitation and the inclusion of which may have enhanced my study.

Given that a student's attitude, shaped by school experiences, is likely to impact on his or her achievement (Lumsden, 1994; Reynolds & Walberg, 1992), it is important to consider the types of learning environments and teaching approaches that are used. In my study, the introduction of *Jeopardy!*-type games, led to improved students' perceptions of the learning environment and attitudes, suggesting that policy makers and curriculum developers wishing to improve students' attitudes should consider incorporating the use of mathematical games into the curriculum.

The findings of my study also suggest a strong and positive association between the learning environment and the student enjoyment of their mathematics lessons and their academic efficacy. The findings of this study in the United Arab Emirates replicate those of Aldridge and Fraser (2008), Chionh and Fraser (2009), Ogbuehi and Fraser (2007) and Opolot-Okurut (2010) who reported associations between the learning environment and students' outcomes for most scales. These positive associations suggest practical ways in which the learning environment might be changed to enhance student attitudes. Opolot-Okurut (2010) suggested that teachers wishing to improve students' motivation to mathematics should consider emphasising student involvement and task organisation. With more positive attitudes towards mathematics classes, it is possible that more students might choose to pursue mathematics-oriented classes in high school and college and mathematics-related careers.

These findings provide a starting point from which practical attempts, involving the use of mathematics games, can be used to enhance students' attitudes towards mathematics. In many classrooms, the teacher's willingness to incorporate games or different pedagogies in their lessons could be a key to success in improving the classroom environment and students' attitudes towards mathematics.

In the United Arab Emirates, there is a push for teachers to shift in their focus from more traditional education and delivery methods to contemporary approaches (Nicks-McCaleb, 2005). The results of my study suggest that it could be useful for mathematics teachers to use more creative pedagogical practices such as games in order to improve the classroom environment and students' attitudes towards mathematics.

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