Science and Mathematics Education Centre

Investigating the Effectiveness of Mathematics Games on Students' Attitudes and the Learning Environment

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made.

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ABSTRACT

The primary focus of the present study was an evaluation of the effectiveness of games when used in college-level mathematics classes in the United Arab Emirates (UAE). A mixed-method approach involved surveys, interviews, observations of classes and narrative stories.

As a first step, a sample of 352 students in 33 classes from three colleges in Abu Dhabi (the largest emirate in the UAE) responded to two surveys. The first, a modified version of the What Is Happening In this Class? (WIHIC) questionnaire, was used to assess students' perceptions of the learning environment. Five of the seven WIHIC scales were selected for use in my study, namely, Student Cohesiveness, Teacher Support, Involvement, Cooperation and Equity. One scale, from the Constructivist Learning Environment Survey (CLES), Personal Relevance, was also added. The second survey, used to assess students' attitudes, involved two scales: one to assess students enjoyment of mathematics classes (from the Test of Science-Related Attitudes (Fraser, 1981); and one to assess students' academic efficacy (modified from the Jinks and Morgan's (1999) Student Efficacy Scale). Both the WIHIC and attitude scales were modified to improve their suitability for use in the UAE and relevance to the present study, and then they were translated into Arabic.

The data were analysed for the modified WIHIC and attitude scales to check their factor structure, reliability, discriminant validity, and the ability to distinguish between different classes and groups. In terms of the validity of modified WIHIC and attitude scales when used with college-level students in the UAE, the factor analysis results attested to the sound factor structure of each questionnaire. The results for each modified WIHIC and attitude scale for alpha reliability and discriminant validity for two units of analysis (individual and class mean) compared favourably with the results for well-established classroom environment instruments.

A one-way analysis of variance (ANOVA) for each modified WIHIC scale was used to investigate its ability to differentiate between the perceptions of students in different classrooms. The ANOVA results suggested that students perceived the learning environments of different mathematics classrooms differently on the modified WIHIC scales. In general, the results provided evidence of the validity of the modified WIHIC in describing psychosocial factors in the learning environments of college-level students' mathematics classrooms in the UAE.

The sample of 352 students was also used to examine the strength and direction of associations between the six learning environment scales and the two attitudes scales using simple correlation and multiple regression analyses. There was a statistically significant simple correlation between each attitude scale (Enjoyment of Mathematics Lessons and Academic Efficacy) and each of the six WIHIC scales with the individual as the unit of analysis, but not with the class mean as the unit of analysis. Multiple regression analysis suggested that students' enjoyment of their mathematics lessons was more positive in classrooms with greater Teacher Support, Cooperation and Personal Relevance, and that Academic Efficacy was higher in classes with more Personal Relevance.

Eight of the 33 classes (n=90 students) were exposed to mathematics games. For these students, the effectiveness of the mathematics games was evaluated in terms of classroom environment and attitudes, as well as achievement. Pre-test–post-test differences were explored using a one-way multivariate analysis of variance (MANOVA) with repeated measures (using the student as the unit of analysis). The results suggest that there were statistically significant pre–post differences for three of the six WIHIC scales (namely, Teacher Support, Involvement and Personal Relevance), for both attitude scales, and achievement.

In-depth qualitative data (from observations and interviews) provided information about the introduction and use of games in mathematics. The data were analysed to shed light on students' interactions during the games and to triangulate and to clarify and explain students' responses to the learning environment and attitude questionnaires. Analysis of the interviews suggested that the students generally enjoyed mathematics more when games were included in their lessons, and that the use of mathematics games had improved their feelings about how well they were performing in mathematics.

A narrative, based on the classroom observations, was written to provide the reader with insights into the classrooms that were exposed to the mathematics games. The narrative describing students playing mathematics games suggested that, with the introduction of games in the classroom, students were given the opportunity to interact with each other and to explain and compare their solutions with those of their team-mates. Therefore, qualitative data obtained from students who experienced the use of mathematics games supported the quantitative findings concerning the effectiveness of games in mathematics classes.

Finally, a two-way MANOVA with repeated measures on one factor was used to identify the differential effectiveness of using games activities in mathematics instructions for male and female students. The results suggested that, whereas Student Cohesiveness scores were similar for the pre-test, males' perceived greater cohesiveness than did females for the post-test. Males' perceptions of Student Cohesiveness improved, while female score deteriorated, during the use of games.

The results of my study provide information about the effectiveness of *Jeopardy!*-type games in terms of the classroom learning environment and students' outcomes (attitudes and achievement). Because teachers are often reluctant to use computer-based games in their mathematics classrooms, my study is significant as the results have the potential to encourage mathematics teachers to incorporate the use of computer-based games in their classrooms as a viable alternative pedagogical approach. In particular, this study provides valuable information that could help teachers in the UAE to improve their pedagogical practices. The results of this study have the potential to encourage educators, researchers and curriculum developers in the UAE to incorporate the use of computer-based games in the curriculum as a practical way to improve classroom environments and students' attitudes and achievement.

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LIST OF ACRONYMS USED IN THE THESIS

Acronym	Meaning
UAE	United Arab Emirates
WIHIC	What Is Happening In this Class
CLES	Constructivist Learning Environment Survey
TOSRA	Test of Science-Related Attitudes
LER	Learning Environments Research
LEI	Learning Environments Inventory
CES	Classroom Environment Scale
ICEQ	Individualised Classroom Environment Questionnaire
MCI	My Class Inventory
CUCEI	College and University Classroom Environment Inventory
QTI	Questionnaire on Teacher Interaction
SLEI	Science Laboratory Environment Inventory
CLES	Constructivist Learning Environment Survey
CLCEI	Chinese Language Classroom Environment Inventory
OBLEQ	Outcomes-Based Learning Environment Questionnaire
HCCW	How Chemistry Class is Working
MJSES	Morgan Jinks Student Efficacy Scale
ANOVA	Analysis of Variance
MANOVA	Multivariate Analysis of Variance
SPSS	Statistical Package for Social Scientists

CHAPTER 1

INTRODUCTION AND OVERVIEW

1.1 Introduction

In over 25 years of teaching mathematics in schools and colleges, including 15 years of teaching in the United Arab Emirates (UAE) and Qatar, I have noticed that, when students are motivated, they tend to learn mathematics more successfully. 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 that will improve my students' perception of the learning environment, their attitudes towards mathematics and their achievement. Over the years, I have incorporated games to enhance students' learning of mathematics. I have maintained that, through games, students are more motivated. It was with this in mind that my study was formulated to determine whether or not the introduction of *Jeopardy!*-type games into UAE college-level mathematics classes can help to improve students' perceptions of the learning environment, their belief in themselves as learners of mathematics and their attitudes towards mathematics and achievement.

Students often lack motivation when it comes to learning mathematics and this, in turn, can affect their achievement. The results of past studies have suggested that the introduction of games in mathematics can improve students' attitudes (Bragg, 2007; Massey, Brown & Johnston, 2005), but this has not been systematically verified in the UAE at all school levels. Past research has indicated that teachers who design, develop and implement innovative teaching methods in their classrooms are more likely to capture students' interests and to optimise their learning outcomes than those who do not (Chandra & Fisher, 2009).

When students are motivated and engaged in a task, learning is more likely to occur than when they are not. According to Bragg (2006), introducing and practising mathematical concepts through active involvement, such as game-playing, could contribute to developing the learning process. The use of games, according to Massey et al. (2005), is beneficial, both in terms of examination performance and student perceptions of the learning experience. Game playing not only stimulates students' interest in mathematics, but also can promote creativity and students' knowledge (Papastergiou, 2009; Story, 2001).

This chapter introduces my thesis under the following headings:

- Context of the Study (Section 1.2);
- Theoretical Framework (Section 1.3) ;
- Research Questions (Section 1.4);
- Significance of the Study (Section 1.5);
- Overview of the Thesis (Section 1.6).

1.2 Context of the study

This section provides a background and context to the setting to facilitate understanding of the importance of the study. Section 1.2.1 provides a brief history and background of the UAE. Section 1.2.2 discusses the education system in the UAE and Section 1.2.3 provides information related to the history and purpose of *Jeopardy!*-type games.

1.2.1 History and Background of the United Arab Emirates

The UAE is located at the southern tip of the Arabian Gulf with a total area of 83,600 square kilometres. The country forms a border with Saudi Arabia, Qatar and the Sultanate of Oman. The UAE is a federation of seven independent states, namely, Abu Dhabi, Dubai, Sharjah, Ajman, Umm al-Quwain, Ras al-Khaimah and Fujairah. Before the discovery of oil in the 1950s, the UAE was a group of low-income emirates under the protection of the British. Oil brought rapid growth and modernization to the area and, on December 2, 1971, these small states became independent and known as the UAE. Abu Dhabi city is the capital of the UAE. Appendix A provides a map of the UAE.

In less than four decades, the UAE have experienced a huge shift in income and development. In 40 years, the UAE has developed a public national educational system similar to that developed for Western countries in over 100 years. Arabic is the official language of the UAE. English is also widely spoken, as are Hindi, Urdu and Persian. Islam is the official religion of the country and all Emiratis and a majority of the expatriates are Muslims. The constitution guarantees religious freedom and so there are some Christian churches in the country. The most conservative arenas of life in the UAE concern women and male–female interaction. For most Emirati women, the home remains the basic sphere of activity. Younger women, benefiting from their access to modern education, are playing a wider role in society but, with only 14 per cent of the overall Emirati labour force being female, their numbers are few (Gaad, Arif & Scott, 2006).

1.2.2 The Education System in the United Arab Emirates

After the founding of the UAE in 1971, there was a tremendous expansion of public education facilities. The UAE constitution declares that education is fundamental to the progress of society and is to be compulsory at the primary level and free at all levels. In the early years of the UAE's existence, education was second only to defence in the federal budget, a pattern that continues today.

A basic feature of the UAE educational system is its astounding growth since 1964. During the 2006–2007 academic year, 650,000 students were in UAE schools, which numbered 710 institutions with 27,493 teachers and administrators. The existing educational structure, which was established in the early 1970s, is a four-tier system covering 14 years of education. The tiers include kindergarten (4–5 years of age), primary (6–11 years of age), intermediate (12–14 years of age) and secondary (15–17 years of age) levels (Gaad et al., 2006). It has been noted with concern that, within the UAE educational system, poor-quality instruction exists in some tertiary-level institutions and that, on the whole, teaching methods are based on rote memorisation (Gaad et al., 2006; Shaw, Badri & Hukul, 1995). Innovation on the part of teachers is often viewed as difficult because of the demands of complying with a centralised curriculum and evaluation system enforced by administrators and school inspectors (Gaad et al., 2006). Explanation and discussion are the most common methods reported, with little use of small-group, individualised, lecturing, experimental, laboratory or role-playing methods.

To overcome this, the Ministry of Education in the UAE has adopted Education 2020, a series of five-year plans, up to the year 2020, designed to introduce advanced education techniques, improve the innovative skills of teachers and enhance the self-learning ability of students. It is within this backdrop that the challenge of introducing mathematics games at the college-level for the purpose of this study was undertaken.

1.2.3 **College-*Level Education in the United Arab Emirates***

Although the UAE has achieved much in the field of education, the government continues to update policy and to invest in infrastructure to ensure that graduates are properly equipped to enter the workforce and to assist in the country's development (Gaad et al., 2006). The UAE aims to develop an educational system that will be recognised as being amongst the best in the world.

The education system of the UAE is divided into two sectors, public and private. The government funds the public sector schools; which have a strong Islamic influence and are conducted in single gender classes. All UAE nationals have access to this mainstream public education and no expatriates are admitted. In response, expatriates have opened private schools to meet their religious, cultural and educational needs (Gaad, 2001; Gaad et al., 2006).

After completing high school, UAE citizens have access to higher education at a variety of public (government) and private colleges. The colleges include vocational and technical institutions, teaching and research institutions, business and technology colleges and medical colleges. The UAE University (a teaching and research institution) was the first national university to be established in 1976 in Al-Ain. Today, the UAE University is a leading institution in the Gulf Region with 700 faculty and approximately 15,000 students (Hassane, McClam & Woodside, 2009). The Higher Colleges of Technology, which offer a more technically oriented education, were established in 1988 and together they are the largest higher educational institution in the UAE with an enrolment of more than 18,000 students, all of whom are UAE nationals. The sixteen Higher Colleges of Technology men's and women's campuses offer a range of programs in such areas as business administration, accounting, banking, information systems, computers, health science, engineering and aviation technology.

The Abu Dhabi government is facilitating leading international universities (such as La Sorbonne University, Paris and New York University, USA) in their efforts to establish and provide exemplary educational opportunities for the Abu Dhabi emirate and the UAE. The Abu Dhabi government, through the Abu Dhabi Educational Council, is also providing vocational education and training institutes, as well as teacher education delivered through the newly-established Emirates College of Advanced Education.

In addition to the higher level institutions outlined above, the UAE has a number of vocational and technical educational centres for students seeking practical training in their chosen careers. These include the Emirates Institute for Banking and Finance, the Abu Dhabi National Oil Company Career Development Centre, the Dubai School of Government, and The Emirates Aviation College for Aerospace and Academic Studies. In all of these colleges, students are required to undergo a compulsory one-year foundation program (that includes mathematics) designed to bridge the gap between secondary and college-level education. At the school level, the language of instruction is Arabic but at the college level, English is the primary language of instruction. Therefore, the acquisition of English language skills, at all levels of education is a government priority. My study took place in the UAE in three of these technical education centres. All of the students involved in my sample were studying at the compulsory first year foundation level.

1.3 History and Purpose of *Jeopardy!*-type Games

McFarlane, Sparrowhawk and Heald (2002) found that games provide a forum in which learning arises as a result of tasks stimulated by the content of the games. They also concluded that games promote thinking and problem-solving skills, which might be transferable to other activities. Facer (2003) notes that the key features that contribute to motivation to play games are challenge, fantasy and curiosity. All games are designed to engage the players and, for the most part, consist of rules, goals and objectives, outcomes and feedback, conflict, competition, challenge, opposition and interaction (Prensky, 2007).

From the students' perspective, there are many advantages of using games in the classroom. Rather than passive regurgitation of concepts, games allow students to engage in an interesting deviation from the classroom norm (Grabowski & Price, 2003). Story (2007), a mathematics professor at Akron University, USA, recognised the potential of using games in the classroom, and developed a mathematics game that is based on the popular American television game show *Jeopardy!*

Jeopardy! 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. Five categories are announced, each with a column of five trivia clues, each one incrementally valued more than the previous. Figure 1.1 provides an example of the *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 has 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.

Figure 1.1 *Jeopardy!* Game Board

Based on the television quiz show, Story (2001) developed *Jeopardy!*-type games, that I modified for use in the UAE. The game involves a board upon which four different mathematical concepts are posted (see Figure 1.2), with a series of point values under each. For example, in Figure 1.2, the first row displays the names of four different mathematics concepts, in this case fractions as percentages, decimals as percentages, percentages as decimals and per cent of a number. Each row provides problems worth different amounts of 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 associated problem or question. Figure 1.3 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 more difficult the problem is. The teacher reads the problem and the contestants take turns to answer the questions.

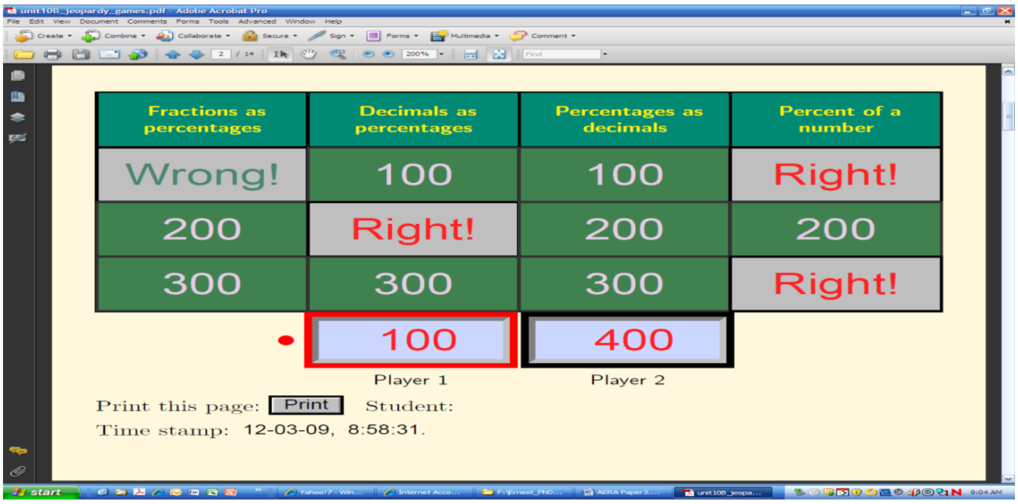

Figure 1.2 Example Game Board Page for the *Jeopardy!*-type Game

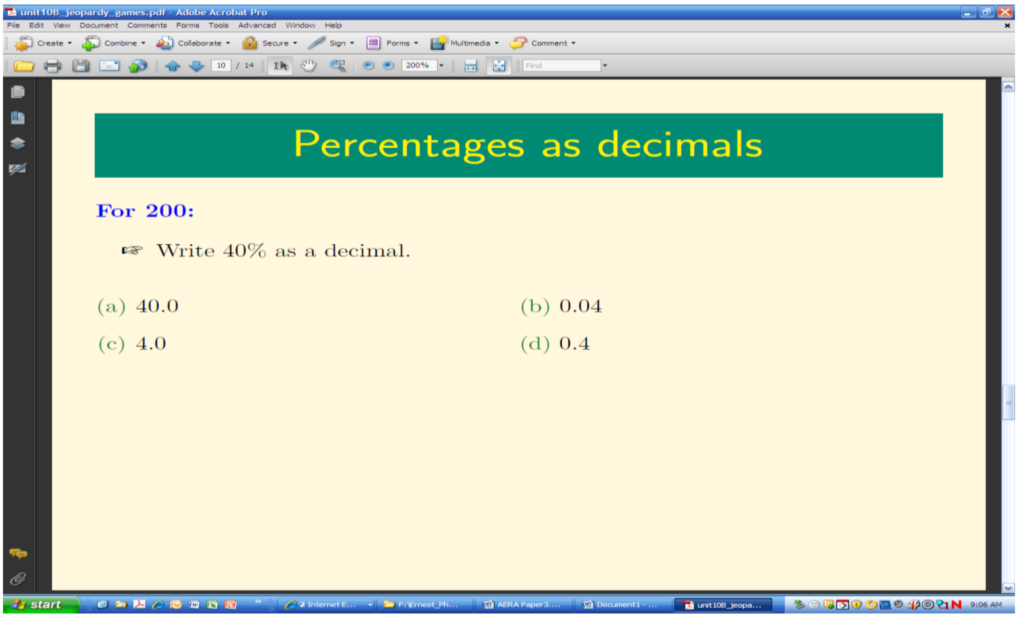

Figure 1.3 Example Question Page for the *Jeopardy!*-type Game

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 their 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. 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.

1.4 Theoretical Framework

A paradigm can be defined as a 'worldview', which involves a set of beliefs or assumptions that guide a researcher's inquiry (Creswell, 2009). Researchers generally bring to a study a worldview, which favours the qualitative or quantitative ontological (the nature of reality), epistemological (the nature of the relationship between the knower and what can be known) and methodological (the means by which the knower came to know) assumptions (Creswell, 2009).

My study was undertaken in two distinct stages. In the first stage, questionnaires were administered to collect quantitative data. This stage of the study employed a more positivistic framework, favouring an objectivist view. The second stage of the study involved the collection of qualitative data and employed an interpretative framework, drawing on elements of the interpretativist paradigm (Schwandt, 2000; Tobin, 1993; von Glasersfeld, 1989). Such a shift meant that, as a researcher, I no longer favoured one method, but rather became multi-method in focus to help to make sense of the classroom environments that were created as the games were in use.

Postpositive assumptions have traditionally been governed by claims about what warrants knowledge. This position is sometimes called quantitative research, positivist/postpositivist research, scientific method or postpositivism (Creswell, 2009). The term 'postpositivism', which refers to the thinking after positivism, challenges the traditional notion of absolute truth of knowledge (Phillips & Burbules, 2000) and recognises that one cannot be 'positive' about the claims of knowledge when studying the behaviour and actions of humans (Creswell, 2009). The knowledge that postpositivists develop is based on careful observation and measurement of the objective reality that exists 'out there' in the world. Hence, developing numeric measures of observations and studying the behaviour of individuals become very important for a postpositivist (Creswell, 2009).

The interpretive perspective, drawn on for the present study, works from a realist ontology, and assumes that individuals seek understanding of the world in which they live and work, and that they develop subjective meanings of their experiences that are directed towards certain objects or things (Lincoln & Guba, 2000; Neuman, 2000; Schwandt, 2000). Interpretive researchers often address the processes of interaction among individuals, and on the specific contexts in which people live and work in order to understand the historical and cultural settings of the participants (Creswell, 2009).

My study was also influenced by the pragmatist position which involves using the philosophical and/or methodological approach that is most likely to address the particular research problem under study (Patton, 2002; Tashakkori & Teddlie, 2010). According to Patton (2002), research design and implementation decisions are made according to the methods which best meet the practical demands of a particular inquiry. The knowledge claims provided by pragmatism are that the researcher is not committed to any one system of philosophy and reality. This applies to mixed-methods research during which the researcher draws from both quantitative and qualitative assumptions (Cherryholmes, 1992; Creswell, 2009; Creswell & Plano Clarke, 2010). For the mixed-methods researcher, pragmatism opens the door to multiple methods, different worldviews and different assumptions, as well as to different forms of data collection and analysis (Creswell, 2009; Creswell & Plano Clarke, 2010). According to Creswell and Garrett (2008), when researchers bring together both quantitative and qualitative research, it is likely to lead to a better understanding of research problems than either approach alone.

My study embraced a mixed-method approach that included both qualitative and quantitative research methods. The epistemological status of the present study can best be described in the light of Denzin and Lincoln's (2000) analogy of the researcher as *bricoleur*. The research questions formed the basis for the methodology by which data were collected from these multiple methodologies and pieced together to form a 'bricolage' to answer the research questions that evolved.

My study examined and explored the learning environments in mathematics classes in the UAE. The notion that a distinct classroom environment exists began as early as 1936, when Lewin (1936) recognised that the environment and its interactions with personal characteristics of the individual were determinants of human behaviour. Following Lewin's work, Murray (1938) proposed a Needs-Press Model in which situational variables, found in the environment, account for a degree of behavioural variance. Stern's (1970) Person-Environment Congruence Theory, based on Murray's Needs-Press Model, proposed that more congruence between personal needs and environmental press leads to enhanced outcomes.

The works of Lewin and Murray have provided a strong theoretical base which has influenced classroom environments research. The assessment of perceptions has reflected the work of these pioneers and, more recently, Murray's needs-press model of interaction has been used to identify the situational variables recognised in his model (Anderson & Walberg, 1974; Moos, 1974; Rentoul & Fraser, 1979). In the late 1960s, two instruments were developed which pioneered the use of perceptions to measure the classroom environment. The Learning Environment Inventory (LEI), developed by Herbert Walberg (Anderson & Walberg, 1968), and the Classroom Environment Scale (CES), developed by Rudolf Moos (Trickett & Moos, 1973), paved the way for the development of subsequent instruments. Chapter 2 provides a more extensive review of learning environment research.

1.5 Research Questions

My study involved a mixed-method approach, a research design which involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in the research process (Creswell & Plano Clark, 2010). This approach was used to investigate the effectiveness of *Jeopardy!*-type games when used in college-level mathematics classes in the UAE. Quantitative data were collected using two instruments, namely, a modified version of the What Is Happening In this Class? (to assess students' perceptions of the learning environment) and enjoyment of their mathematics lessons and their academic efficacy scales (to assess students' attitudes towards mathematics). In addition, achievement data were collected using mid-semester and final examination grades. Qualitative data were gathered using interviews with the participants (teachers and students) and observations of classes that were exposed to the *Jeopardy!*-type games.

This section outlines the research questions raised in my investigation of the impact of J*eopardy!*-type games when used in college-level mathematics classes in the UAE.

The first research question was developed to examine whether the instruments used in the present study were valid and reliable, and was:

Research Question #1:

> Are the learning environment questionnaire and attitude questionnaire valid and reliable when used with a sample of 18 to 35 year-old college-level mathematics students in the UAE?

To examine the usefulness of the modified instruments, I investigated whether associations exist between students' perceptions of the classroom learning environment and their attitudes towards mathematics class. To this end, the second research question was:

Research Question #2:

> Is there a relationship between the nature of the classroom learning environment and student attitudes to mathematics?

A central focus of the study involved an investigation of the effectiveness of games activities in mathematics instruction in terms of changes in students' learning environment and student outcomes (attitudes and achievement). To this end, the third question developed was:

Research Question #3:

Is using mathematical games effective in improving:

i. the classroom learning environment?

ii. students' attitudes to mathematics?

iii. students' mathematics achievement

To investigate whether the effectiveness of mathematical games was different for male and female students, the fourth question delineated was:

Research Question #4:

Is the use of games activities in mathematics instruction differentially effective for males and females in terms of:

i. classroom learning environment?

ii. students' attitudes to mathematics?

iii. Students' mathematics achievement?

1.6 Significance of the Study

This study is significant because it is one of the first studies of learning environment to be conducted in the UAE. It also represents one of the few learning environment studies anywhere in the world that focused on the effect of mathematical games on the classroom environment of students. Specifically, the study provided information about the effect of *Jeopardy!*-type games on students' perception of their classroom learning environment and also their attitudes towards the learning of mathematics and mathematics achievement.

The study was significant as its results have the potential to encourage mathematics teachers to incorporate the use of games in their classrooms as a viable alternative pedagogical approach. In particular, this study provided valuable information that could help teachers and researchers in the UAE to improve their pedagogical practices. The results of the present study have the potential to influence educators, researchers and curriculum developers to incorporate the use of mathematical games in the curriculum as a practical way to improve classroom environments, students' attitudes towards mathematics and mathematics achievement.

1.7 Overview of the Thesis

My study investigated the effectiveness of introducing games into college-level mathematics classes. The conceptualisation, implementation, findings of the study, discussion and conclusions are presented in five chapters. Chapter 1 has introduced and provided a rationale for the study.

A review of the literature related to the current study is presented in Chapter 2. This chapter reviews literature relevant to college-level mathematics in the UAE, the field of learning environments and the assessment of students' attitudes. The benefits of mathematics games and sex issues in mathematics education are also included.

Chapter 3 provides details related to the research methods and the sampling procedure used in the current study. The research questions are restated and the samples selected for the initial collection of the data and those who were introduced to the *Jeopardy!*-type games are described in detail. In this chapter, the two instruments that were used to assess students' perceptions of the learning environment and attitudes towards mathematics are introduced, as well as ethical issues related to the study and how these were addressed. Finally, the analysis of the data, narrative and interviews conducted with students and teachers are described.

Chapter 4 gives a detailed report of the results of the study. The chapter begins by examining analyses of quantitative data, including the reliability and validity of the Arabic version of the learning environment and attitude questionnaires when used in the UAE context. Qualitative results derived from observations and interviews are presented as narrative to provide insights into the classroom life of students as they played *Jeopardy!*-type games. The differential effectiveness of mathematical games among different sexes and the effectiveness of using mathematical games is reported in terms of pre-test–post-test differences in perceptions of the learning environment and students' outcome (attitudes and achievement).

Chapter 5, the concluding chapter of the thesis, presents a detailed discussion of the study's results, educational implications and limitations. As well, conclusions and future lines of research are suggested.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

My study involved investigation of the effectiveness of games activities in mathematics instruction at college-level institutions in the UAE in terms of changes in students' learning environment and outcomes (attitudes and achievement). Therefore, this chapter reviews literatures pertinent to my study under the following headings:

- Using Games in Mathematics Classes (Section 2.2);
- Learning Environment Research (Section 2.3);
- Students' Attitudes towards Mathematics (Section 2.4);
- Students' Academic Efficacy (Section 2.5);
- Sex Differences (Section 2.6), and
- Chapter Summary (Section 2.7).

2.2 Using Games in Mathematics Classes

My study involved the impact of mathematics games at the college setting. There is a significant body of research to support the potential of using games as an educational tool (Annetta, Cheng & Holmes, 2010; Paraskeva, Mysirlaki & Papagianni, 2010) and to complement traditional lectures for enhancing students' learning (Kiili, 2005; Tan, 2007; Tan, Tse & Chung, 2010). 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 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 et al., 2010; Prensky, 2007) and, according to Annetta et al. (2010), the learning from games is more likely to be retained.
Kim (1995) argued that it is a common misperception that all learning should be serious in nature and that, if one is having fun, then it is not really learning. He purports that it is possible to learn mathematics while enjoying oneself and that one of the best ways of doing this is through games. 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 the potential to teach complex new information to students and that, in their opinion, both academic performance and interpersonal relationships are likely to be enhanced through the use of games.

A number of researchers have reported the advantages of using games in the classroom (Malone & Lepper, 1987; Papert, 1980; Prensky, 2007). According to Khine and Saleh (2009), games can provide experience in experimentation, exploration, trial and error, imagination, role play and simulation and that the challenge that lies ahead for educators is to draw on strategies to transform traditional approaches to a new learning model that infuses the use of educational games in the formal curriculum.

Past studies have drawn attention to the potential of games to support learning of competencies, collaboration and participation in practice (Kirriemuir & McFarlane, 2004). A study in Chile by Rosas et al. (2003) evaluated the effects of using educational video games on students' learning, motivation, and classroom dynamics, using 1274 first and second elementary grade students. The findings of this study revealed that the use of games on portable devices led to improved motivation and learning outcomes compared to traditional teaching within primary school mathematics and reading.

Rather than passive regurgitation of concepts, games can engage students in an interesting deviation from the class norm (Grabowski & Price, 2003). However, it is advocated by Bragg (2006) that, when using games as a tool for learning, teachers and curriculum developers should clearly specify the learning outcomes that are related to a game and to reinforce the relevance of the game in an explicit way to the students. Bragg (2006) also suggested that students be encouraged to reflect on their learning during and after the game-playing experiences. My study explored whether it might be useful for mathematics teachers to use more creative pedagogical practices, such as games, in improving the classroom environment and students' attitudes towards mathematics at the college level.

In the UAE, two studies have examined the use of games. The first, conducted by Al Neyadi (2007), examined the effectiveness of using games to reinforce vocabulary learning with 29 grade six primary school girls. The second, an action research by Al Zaabi (2007), investigated the use of memory and guessing games in teaching vocabulary to young learners in a boys' primary school. These studies both revealed that using games can enhance students' motivation to learn vocabulary and encourage interaction among students.

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). Although research supports the idea that games can stimulate students' interest and motivation (Gough 1999; Owens 2005), only a handful of studies have been carried out to investigate the effectiveness of mathematics games at the college level and none of these in the UAE. As such, my study of the effectiveness of mathematics games at the college-level in the UAE has built on and extended these past studies.

2.3 Learning Environments Research

Students spend up to 20,000 hours at educational institutions by the time they finish university (Fraser, 2001). Therefore, students' observations of and reactions to, their experiences in school – specifically their learning environments – are of significance. The term learning environment refers to the social, physical, psychological and pedagogical context in which learning occurs and which affects student achievement and attitudes (Fraser, 2007, 2012). This section reviews literature related to the theories that have influenced the field of learning environments and how this has led educational researchers to study the learning environment as an alterable educational variable which can directly influence students' cognitive and affective outcomes.

2.3.1 History of the Field of Learning Environments

As discussed in Chapter 1, the notion of a learning environment existed as early as 1936 when Lewin proposed that both the environment and its interaction with personal characteristics of the individual are potent determinants of human behaviour. To this end, he developed the formula $B = f(P, E)$ in which behaviour (B) is a result of the interaction between the person (P) and environmental factors (E). Murray (1938) identified that Lewin's formula did not take into account the personal needs of an individual. To address this shortcoming he proposed a needs–press model in which an individual's behaviour is affected internally by characteristics of personality (needs) and externally by the environment itself (press). Personal needs refer to motivational personality characteristics representing tendencies to move in the direction of certain goals, while environmental press provides an external situational counterpart which supports or frustrates the expression of internalised personality needs.

Stern, Stein and Bloom (1956) further proposed that the same environment can be perceived differently by different entities, namely, individuals, groups and external observers of the environment. They also pointed to measurements of educational environments as decisive components for prediction and successful learning manipulation. Hunt (1975), Stern (1970) and Fraser and Fisher (1983) proposed the notion of person-environment fit in which an individual whose perceived environment is more closely matched to the environment that they would prefer is likely to perform better on a range of outcomes.

In 1981, Walberg proposed a nine-factor model of educational productivity in which student outcomes are co-determined by such variables as the quantity and quality of instruction, the psychosocial environments of the school/class, the home, the peer group and the mass media (Fraser, Walberg, Welch & Hattie, 1987; Walberg, 1981).

In their research, carried out to examine whether associations exist between student outcomes and the various factors proposed in the nine factor model, Fraser et al. (1987) found that the psychosocial environment was a strong predictor of both achievement and attitudes even when a comprehensive set of other factors were held constant.

Moos (1991) proposed that the different characteristics of all human environments can be classified into the three broad dimensions of Relationship Dimension, Personal Development Dimension and the System Maintenance and System Change Dimension. The Relationship Dimension assesses “the extent to which people are involved in the setting, the extent to which they support and help each other and the extent to which they express themselves freely and openly” (Moos, 1979, p. 14). The Personal Development Dimension assesses “the basic directions along which personal growth and self enhancement tend to occur in the particular environment” (Moos, 1976, p. 331). Finally, the System Maintenance and System Change Dimension assesses the “extent to which the environment is orderly and clear in its expectations, maintains control and responds to change” (Moos, 1979, p. 16). These dimensions co-exist in all human environments and have been used extensively by researchers in the construction of learning environment instruments (Fraser, 1998, 2007, 2012) and the classification of individual scales.

Over 40 years ago, the first two psychosocial learning environment instruments were developed independently of each other: the Learning Environment Inventory (Walberg & Anderson, 1968); and the Classroom Environment Scale (Moos & Trickett, 1974). Since then, much work has been done to conceptualise the learning environment and to assess students’ perceptions of their educational environments (Fraser, 2007, 2012). The development of Kluwer/Springer’s *Learning Environments Research: An International Journal* (Fraser, 1998), as well as books such as *Studies in Educational Learning Environments* (Goh & Khine, 2002), *Contemporary Approaches to Research on Learning Environments* (Fisher & Khine, 2006) and *Outcomes-Focused Learning Environments* (Aldridge & Fraser, 2008), among others, have helped to inform the worldwide educational community of the importance of this area of research.

The following two sections review literature related to the development of instruments to assess the learning environment (Section 2.3.2) and the types of past research that have been conducted within the field of learning environments (Section 2.3.3).

2.3.2 Instruments for Assessing Classroom Environments

Over the past 40 years, researchers have developed numerous questionnaires designed to assess students' perceptions of a range of dimensions pertinent to the learning environment (Fraser, 2007, 2012). These questionnaires have been used at different educational levels and translated and used in different countries. This section provides a brief description of nine historically-significant and contemporary instruments:

- Learning Environments Inventory (LEI);
- Classroom Environment Scale (CES);
- Individualised Classroom Environment Questionnaire (ICEQ);
- My Class Inventory (MCI);
- College and University Classroom Environment Inventory (CUCEI);
- Questionnaire on Teacher Interaction (QTI);
- Science Laboratory Environment Inventory (SLEI);
- Constructivist Learning Environment survey (CLES); and
- What Is Happening In this Class? (WIHIC) questionnaire.

A summary of the nine historically-important or contemporary instruments, designed to assess the learning environment, is provided in Table 2.1, which provides information about the scales of each of the instruments, the education level for which the instrument was intended to be used (primary, secondary or higher education), the number of items in each scale, and the classification of each scale according to Moos' (1974) scheme for classifying human environments (described previously in section 2.3.1).

Table 2.1 Overview of Nine Historically Important Learning Environment Questionnaires

Instrument	Level	Items per scale	Scales Classified According to Moos' Scheme: Relationship dimensions	Personal development dimensions	System maintenance and change dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganisation
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organisation Rule Clarity Teacher Control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)	Elementary	6--9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalisation Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualisation
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8--10	Leadership Understanding Helping/Friendly Freedom and Responsibility Uncertain Dissatisfied Admonishing Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Education	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation
What Is Happening In this Class? (WIHIC)	Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity

*Adapted from Fraser (2012) with permission

2.3.2.1 Learning Environment Inventory (LEI)

The initial development and validation of a preliminary version of the LEI began in the late 1960s in connection with the evaluation and research related to Harvard Project Physics (Fraser, Anderson & Walberg, 1982; Walberg & Anderson, 1968). The final version of the LEI contains a total of 105 items with seven items in each of 15 scales, namely, Cohesiveness, Friction, Favouritism, Cliqueness, Satisfaction, Apathy, Speed, Difficulty, Competitiveness, Diversity, Formality, Material Environment, Goal Direction, Disorganisation and Democracy. The items are presented in a cyclic order and the response scale involved the four alternatives of Strongly Disagree, Disagree, Agree or Strongly Agree. The scoring direction (or polarity) is reversed for some of the items. A typical item in the Cohesiveness scale is: “All students know each other very well” and in the Speed scale is: “The pace of the class is rushed”. Although some scales are still useful today, many were intended for more traditional, teacher-centred classrooms.

2.3.2.2 Classroom Environment Scale (CES)

The CES was developed by Rudolf Moos at Standard University (Moos & Trickett, 1974, 1987) as results of extensive research that involved perceptual measures of a variety of human environments, including psychiatric hospitals, prisons university residences and work milieus (Moos, 1974). The final published version of the CES contains nine scales, namely, Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organisation, Rule Clarity, Teacher Control and Innovation. There are 10 items in each scale with a True-False response format in each scale. Typical items in the CES are: “The teacher takes a personal interest in the students” (Teacher Support) and “There is a clear set of rules for students to follow” (Rule Clarity). As with the LEI, some scales have been modified and used in more recent learning environment instruments. However, the majority of scales are intended to examine more traditional classrooms.

2.3.2.3 Individualised Classroom Environment Questionnaire (ICEQ)

The Individualised Classroom Environment Questionnaire (ICEQ) assesses dimensions which distinguish individualised classrooms from traditional ones. The published version of the ICEQ (Fraser, 1990) contains 50 items with 10 items in each of 5 scales, namely, Personalisation, Participation, Independence, Investigation and Differentiation. Each item is responded to on a five-point frequency scale with the alternatives of Almost Never, Seldom, Sometimes, Often and Very Often. The scoring direction is reversed for some of the items. Typically items are: “The teacher considers students’ feelings” (Personalisation) and “Different students use different books, equipment and materials” (Differentiation).

2.3.2.4 My Class Inventory (MCI)

The LEI was simplified by Fraser et al. (1982) to form the MCI for use among children aged 8 to 12 years. Subsequently, Fisher and Fraser (1981) simplified the original version of the MCI, and then Fraser and O’Brien (1985) evolved and used a 25-item version. Although the MCI was developed originally for use at the primary-school level, it has also been found to be useful with students in the junior high school, especially those who might experience reading difficulties with other instruments.

The MCI differs from the LEI in four important ways. First, in order to minimise fatigue among younger children, the MCI contains only five of the LEI’s original 15 scales. Second, item wording has been simplified to enhance readability. Third, the LEI’s four-point response format has been reduced to a two-point (Yes–No) response format. Fourth, students answer on the questionnaire itself instead of on a separate response sheet to avoid errors in transferring responses from one place to another. The final form of the MCI contains 38 items (long form) or 25 items (short form). Typical items are: “Children are always fighting with each other” (Friction) and “Children seem to like the class” (Satisfaction). Although the MCI traditionally has been used with a Yes–No response format, Goh and Fraser (1998) modified it to involve a three-point frequency response format (Seldom, Sometimes and Most of the Time), and then they used it in research in Singapore among primary mathematics students.

In Brunei Darussalam, Majeed, Fraser and Aldridge (2002) used an English-language version of the MCI among 1,565 lower-secondary mathematics students in 81 classes in 15 government schools. They established a satisfactory factor structure and sound reliability for a refined three-scale version of the MCI assessing Cohesiveness, Difficulty and Competition. In the USA, two independent studies were carried out, one involving a sample of 2835 students in grades 4 to 6 (Sink & Spencer, 2005), and another involving 588 grade 3 to 5 students (Scott Houston, Fraser & Ledbetter, 2008). Both found the MCI to have satisfactory psychometric properties.

2.3.2.5 College and University Classroom Environment Inventory (CUCEI)

To fill the void of research in the area of classroom research at the higher education level, Fraser and Treagust developed the CUCEI for use in small classes (of up to 30 students) sometimes referred to as 'seminars' (Fraser & Treagust, 1986; Fraser, Treagust & Dennis, 1986) . The final form of the CUCEI contains seven, seven-item scales, namely, Personalisation, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation and Individualisation. Items are responded to on a four-point Likert scale of Strongly Agree, Agree, Disagree, or Strongly Disagree. The polarity is reversed for approximately half of the items. Typical items are: "Activities in this class are clearly and carefully planned" (Task Orientation) and "Teaching approaches allow students to proceed at their own pace" (Individualisation).

In an evaluation of alternative high schools, Fraser, Williamson and Tobin (1987) used the CUCEI with 536 students in 45 classes to identify more involvement, satisfaction, innovation and individualisation in the alternative schools. When used in computing classrooms in New Zealand, Logan, Crump and Rennie (2006) found that the psychometric properties of the CUCEI were not ideal. Given that the CUCEI was problematic with native English speakers, it was not considered to be a suitable choice for my study which involved students who spoke English as a foreign language.

2.3.2.6 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) was developed in the Netherlands to evaluate students' and teachers' perception of interpersonal teacher behaviour (Creton, Hermans & Wubbels, 1990; Wubbels & Brekelmans, 2005; Wubbels, Brekelmans & Hooymayers, 1991; Wubbels & Levy, 1993). The theoretical model maps interpersonal behaviour using an *influence* dimension (Dominance – Submission) and a *proximity* dimension (Cooperation – Opposition) (Wubbels & Brekelmans, 2005; Wubbels & Levy, 1993). These dimensions are represented in a coordinate system divided into eight equal sectors which are Leadership, Helping/Friendly, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing, and Strict behaviour. Each item has afive-point response scale ranging from Never to Always. Typical items are "She/he gives us a lot of free time" (Student responsibility and freedom behaviour) and "She/he gets angry" (Admonishing behaviour).

Although research with the QTI began at the senior high-school level in the Netherlands, cross-validation and comparative work has been completed at various grade levels in the USA (Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995), Singapore (Goh & Fraser, 1996), and a more economical 48-item version has been developed and validated in Singapore (Goh & Fraser, 1996). Also, Fisher and Creswell (1998) modified the QTI to form the Principal Interaction Questionnaire (PIQ) which assesses teachers' or principals' perceptions of the same eight dimensions of a principal's interaction with teachers. In Brunei Darussalam, Scott and Fisher (2004) validated a version of the QTI in Standard Malay with 3,104 students in 136 elementary-school classrooms and showed that achievement was related positively to cooperative behaviours and negatively to submissive behaviours. In Singapore, Quek, Wong and Fraser (2005) validated an English version of the QTI with 497 gifted and non-gifted secondary-school chemistry students and reported some stream (i.e. gifted and non-gifted) and sex differences in QTI scores. In Korea, a translated version of the QTI was validated and used by Lee, Fraser and Fisher (2003) among 439 science students and by Kim, Fisher and Fraser (2000) among 543 students. In Indonesia, a translated version of the QTI was validated with a sample of 422 university students by Fraser, Aldridge and Soerjaningsih (2010b). Although this questionnaire has been shown to be reliable in a range of contexts, it only assesses the teacher-student interpersonal relationships. For the focus of my study, this made the QTI unsuitable.

2.3.2.7 Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (SLEI) was developed by Fraser, Giddings and McRobbie (1995) to assess the environment of science laboratory classes at the senior high school or higher education levels. The SLEI has five scales (each with seven items), namely, Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment (Fraser et al., 1995; Fraser & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The response format involves a five-point frequency scale consisting of Almost Never, Seldom, Sometimes, Often and Very Often. Typical items are “I use the theory from my regular science class sessions during laboratory activities” (Integration) and “We know the results that we are supposed to get before we commence a laboratory activity” (Open-Endedness).

The SLEI has been used in studies around the world. It was originally field tested with a sample of over 5,447 students in 269 classes in six different countries (USA, Canada, England, Israel, Australia and Nigeria). Subsequently, it was cross-validated in Australia with 1,594 students in 92 classes by Fraser and McRobbie (1995) and 489 senior high-school biology students in Australia by Fisher, Henderson and Fraser (1997). Fraser and Lee (2009) translated the SLEI into the Korean language for use in a study of differences between the classroom environments of three streams (science-independent, science-oriented and humanities). The sample consisted of 439 high-school students divided among these three streams. The Korean version of the SLEI exhibited sound factorial validity and internal consistency reliability, and was able to differentiate between the perceptions of students in different classes. Working with a sample of 761 high-school biology students in 25 classes in south-eastern USA, Lightburn and Fraser (2007) used the SLEI in an evaluation of the effectiveness of using anthropometry activities. Data analyses supported not only the SLEI's validity (in terms of factor structure, internal consistency reliability and ability to differentiate between classrooms), but also suggested that there was a positive influence of using anthropometric activities in terms of both classroom learning environment and student attitudes.

2.3.2.8 Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) was developed by Taylor, Fraser and Fisher (1997) to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology. The CLES was developed to assist teachers to reflect on their epistemological assumptions and to reshape their teaching practice. To the constructivist, meaningful learning is a cognitive process in which individuals make sense of the world in relation to the knowledge which they already have constructed and this sense-making process involves active negotiation and consensus building (Fraser, 2012). The CLES has six items in each of five scales, namely, Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation. The response format involves a five-point frequency scale of Almost Never, Seldom, Sometimes, Often and Almost Always. The CLES was the first learning environment instrument to order the items in scales rather than cyclically to provide students with contextual cues, thereby improving the reliability of the instrument (Taylor et al., 1997). Two typical items are "I learn that Science has changed over time" (Uncertainty) and "It's okay for me to express my opinions" (Critical Voice).

The reliability and usefulness of the CLES has been reported in numerous studies. The CLES was used in a cross-national study involving students in Taiwan and Australia (Aldridge, Fraser, Taylor & Chen, 2000). The English version of the CLES was administered to 1,081 students in 50 classes in Australia while a Mandarin translation was administered to 1,879 students in 50 classes in Taiwan. The study reported sound validity (factor structure, reliability and ability to differentiate between classrooms) for both the English and Mandarin versions of the CLES. Additionally, these researchers reported that Australian classes were perceived as being more constructivist than Taiwanese classes (especially in terms of Critical Voice and Student Negotiation).

The CLES has been used in several studies in the USA. In a study involving a diverse sample of 1,079 students in 59 science classes in North Texas, Nix, Fraser and Ledbetter (2005) reported strong support for the validity of the CLES. Peiro and Fraser (2009) modified the CLES, translated it into Spanish, and administered the English and Spanish versions to 739 grade K–3 science students in Miami, USA. Analyses supported the validity of the modified English and Spanish versions when used with these young children. Strong and positive associations were found between students' attitudes and the nature of the classroom environment, and a three-month classroom intervention led to large and educationally important changes in classroom environment.

In South Africa, Aldridge, Fraser and Sebela (2004) administered the English version of the CLES to 1,864 grade 4–6 mathematics learners in 43 classes. This led to the cross-validation of this version of the CLES for this population in terms of factorial validity, internal consistency reliability and ability to differentiate between classrooms. The primary focus of that study was to assist South African teachers to become more reflective practitioners in their daily classroom teaching. Through the use of the CLES in teacher action research, some improvements in the constructivist orientation of classrooms were achieved during a 12-week intervention.

Ogbuehi and Fraser (2007) administered a modified form of the CLES to 661 middle-school mathematics students from 22 classrooms in four inner city schools in California, USA. This study focused on the effectiveness of using innovative teaching strategies for enhancing the classroom environment, students' attitudes and conceptual development. The study suggested that more positive student attitudes are associated with more emphasis on the aspects of constructivism as assessed by the CLES, especially Personal Relevance and Shared Control.

In a study in Florida, USA, Spinner and Fraser (2005) used the CLES with two separate samples of 53 and 66 fifth-grade students undertaking an innovative mathematics program called the Class Bank System (CBS). The study found that relative to non-CBS students, CBS students experienced more favourable changes in terms of mathematics concept development, attitudes to mathematics, and perceived classroom environments on two dimensions of the CLES (i.e., Personal Relevance and Shared Control).

Kim, Fisher, and Fraser (1999) translated the CLES into the Korean language and cross-validated it with a sample of 1,083 students in 24 grade 10 science students. The results supported the factor structure and reliability of the Korean version, revealed statistically significant relationships between classroom environment and students' attitudes to science, and confirmed that students exposed to a new curriculum perceived a more constructivist learning environment than did students who had not been exposed to the new curriculum.

In two other studies, Korean researchers collaborated with an American colleague in research involving the use of a Korean version of the CLES. As part of an action research project involving creating constructivist learning environments in grade 11 earth science classes, 136 Korean students responded to the CLES several times in a longitudinal study of the development of constructivist classrooms and students' attitudes (Oh & Yager, 2004) . Not only were there improvements in CLES scores over time, but students' attitudes to science became more positive as their classrooms became more constructivist. Cho, Yager, Park and Seo (1997) used this version of the CLES with 70 Korean high-school teachers who visited the University of Iowa for professional development programmes. When the CLES was administered three times (at the beginning and the end of workshops and 3 months later) to evaluate the programme in terms of the development of teachers' constructivist philosophies, initial improvements in CLES scores were found, but they were not retained over a longer time period.

2.3.2.9 What Is Happening In this Class? (WIHIC) Questionnaire

The What Is Happening In this Class? (WIHIC) Questionnaire was developed by Fraser, Fisher and McRobbie (1996) to address contemporary educational concerns.

The WIHIC combines modified versions of salient scales from different questionnaires with scales that address concerns such as equity and constructivism. The WIHIC is available in two versions, namely, a class form (which assesses a student's perceptions of the class as a whole) and personal form (which assesses a student's personal perceptions of his or her role in a classroom). The original 90-item version was later defined to include 56 items in seven scales, these being Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity (Aldridge, Fraser & Huang, 1999; Dorman, 2003b). Two typical items include "I give my opinions during class discussions" (Involvement) and "I receive the same encouragement from the teacher as other students do" (Equity).

The WIHIC questionnaire is one of the most frequently used classroom environment instruments. It has been translated into numerous languages and used in many countries. For example, Aldridge et al. (1999) cross validated the WIHIC with a sample of 1879 high school students in 50 classes in Taiwan and 1081 high school students in 50 classes in Australia. Also, the WIHIC has been validated in studies in Singapore (Chionh & Fraser, 2009; Khoo & Fraser, 2008), India (Koul & Fisher, 2005), Australia (Dorman, 2008), South Africa (Aldridge, Fraser & Ntuli, 2009), Indonesia (Fraser, Aldridge & Aldophe, 2010a; Wahyudi & Treagust, 2004), Korea (Kim et al., 2000), USA (Allen & Fraser, 2007; den Brok, Fisher, Rickards & Bull, 2006; Martin-Dunlop & Fraser, 2008; Wolf & Fraser, 2008; Pickett & Fraser, 2009; Robinson & Fraser, in press; Helding & Fraser, in press; Ogbeuhi & Fraser, 2007), UAE (Afari, Aldridge, Fraser & Khine, in press; MacLeod & Fraser, 2010), Uganda (Opolot-Okurut, 2010), Canada (Zandvleit & Fraser, 2004, 2005) and Australia, Canada and the UK (Dorman, 2003b).

A comprehensive validation of the WIHIC was conducted by Dorman (2003b) using a cross-national sample of 3,980 high-school students from Australia, the UK and Canada. Confirmatory factor analysis supported the seven-scale *a priori* structure, with fit statistics indicating a good fit of the model to the data. In a second study, Dorman (2008) used both the actual and preferred forms of the WIHIC with a sample of 978 secondary-school students from Australia. Separate confirmatory factor analyses for the actual and preferred forms supported the seven-scale a priori structure, with fit statistics indicating a good fit of the model to the data. The use of multitrait–multimethod modelling, with the seven scales as traits and the two forms of the instrument as methods, supported the WIHIC's construct validity.

The WIHIC scales have been incorporated into other questionnaires tailored to and for specific contexts and purposes. For example, Aldridge, Laugksch, Seopa and Fraser (2006b) developed and validated a classroom environment instrument in the Sepedi language for monitoring the implementation of outcomes-based classroom environments in South Africa. The questionnaire was used with a sample of 2,638 grade 8 science students from 50 classes in 50 schools in the Limpopo Province of South Africa. The Outcomes-Based Learning Environment Questionnaire (OBLEQ) contains four scales from the WIHIC, one scale each from the ICEQ and CLES, and a new scale (called Responsibility for Own Learning). As well as validating a widely applicable questionnaire suited for outcomes-based education, the researchers used case studies to support and check the accuracy of profiles of OBLEQ scores for specific classes.

Giallousi, Gialamas, Spyrellis and Pavlatou (2010) developed a learning environment questionnaire for use in Greece and Cyprus. The How Chemistry Class is Working (HCCW) questionnaire consists of three scales (with a total of 22 items), namely, Personal Relevance, Involvement, and Teacher Support. The three-scale HCCW questionnaire contains two WIHIC scales (Involvement and Teacher Support). Data analyses of questionnaire responses from 1,394 Greek students and 225 Cypriot students in grade 10 supported the factor structure of the questionnaire and revealed that Cypriot students had more positive classroom environment perceptions than their Greek counterparts.

Dorman (2001) combined the seven scales from the WIHIC with three scales from the CLES to form an instrument that was used to investigate associations between student academic efficacy and classroom environment among a sample of 1,055 mathematics students from Australian secondary schools. This research revealed that classroom environment related positively with academic efficacy. However, commonality analysis showed that the three CLES scales did not contribute much to explaining variance in academic efficacy beyond that attributed to the seven WIHIC scales.

Opolot-Okurut (2010) reported the first study of learning environment in Uganda, Africa, using a modified WIHIC questionnaire with five scales (Teacher Support, Involvement, Task Orientation, Cooperation, Equity) to investigate how students in high-performing and low-performing schools perceived their mathematics classroom environment. The sample consisted of 81 mathematics students (19 male and 62 female) attending two secondary schools in Uganda. This study revealed that students in the high-performing school perceived their classroom environment significantly more favourably than the students in the low performing school on the Cooperation scale. In contrast, students in the low-performing school perceived the learning environment significantly more favourably than the students in the high-performing school on the Teacher Support and Involvement scales.

One of the foci of my study was the relationship between the learning environment and student attitudes. Of the existing classroom environment instruments, discussed above, WIHIC questionnaire was selected for use in the present study because it stands out as a parsimonious instrument that can elicit the ‘actual’ state of the psychosocial classroom environment. Also, the WIHIC has proved to be useful, valid and reliable in numerous past studies in several countries.

In my study, I adapted and modified the original WIHIC in terms of scale selection, item selection and language, to ensure its suitability for college-level students studying mathematics in the UAE. Chapter 3 reports how the WIHIC was modified to suit the UAE context, describes the five, eight-item scales (Student Cohesiveness, Teacher Support, Involvement, Cooperation and Equity) that were used and explains the back translation process used.

2.3.3 Past Learning Environments Research

Past research on learning environments provides numerous research traditions, conceptual models and research methods that are relevant to my study. This study drew on the rich resource of diverse, valid, economical and widely-applicable assessment instruments that are available in the field of learning environments to investigate the effect of *Jeopardy!*-type games on students' perceptions of the learning environment and attitudes towards mathematics. In particular, the study draws on past research that has used learning environment dimensions as a criteria of effectiveness in evaluating: innovative mathematics programs (e.g. Spinner & Fraser, 2005); technology integration in the curriculum (Harwell, Gunter, Montgomery, Shelton & West, 2001; Zandvliet & Fraser, 2005); integrated science learning (Nix et al., 2005); inquiry-based computer-assisted learning (Maor & Fraser, 1996); and a K–5 mathematics program which integrates children's literature (Mink & Fraser, 2005).

There have been many different types of classroom environment studies conducted around the world with a variety of purposes over the past 40 years (Aldridge & Fraser, 2008; Fraser, 2007; Fraser, 2012; Goh & Khine, 2002). Of particular relevance to my study is past research related to two lines of research, which are described below: 1) associations between the learning environment and student outcomes; and 2) the evaluation of educational innovations.

2.3.3.1 Associations between the Learning Environment and Student Outcomes

Results of studies conducted over the past 40 years have provided convincing evidence that the quality of the classroom environment in schools is a significant determinant of student learning (Fraser, 2007, 2012). That is, students learn better when they perceive their classroom environment as more positive (Dorman & Fraser, 2009). Many of these studies have controlled for background variables with students' perceptions of the classroom environment accounting for appreciable amounts of variance in learning outcomes, often beyond that attributable to background student characteristics (Dorman & Fraser, 2009).

Recent studies have substantiated this position. For example, using a modified WIHIC, Opolot-Okurut (2010) established associations between students' perceptions of their mathematics classroom learning environment and motivation among a sample of 81 secondary school students in two schools in Uganda, Africa. Kerr, Fisher, Yaxley and Fraser (2006) established positive relationships between classroom environment and attitudinal outcomes in Australian science classes. Associations with students' cognitive and affective outcomes have been established, using the SLEI, for a sample of approximately 80 senior high-school chemistry classes in Australia (Fraser & McRobbie, 1995), 489 senior high-school biology students in Australia (Fisher et al., 1997) and 1,592 grade 10 chemistry students in Singapore (Wong & Fraser, 1996).

In California, USA, Ogbuehi and Fraser (2007) found associations between perceptions of classroom learning environment and students' attitudes to mathematics and conceptual development among a sample of 661 middle-school students in 22 classes using modified versions of the WIHIC, CLES and Test of Mathematics Related Attitudes (TOMRA) questionnaires.

In Singapore, Teh and Fraser (1995) established associations between classroom environment, achievement and attitudes among a sample of 671 high-school geography students in 24 classes using an instrument suited for computer-assisted instruction classrooms. Fisher et al. (1995) used the QTI to establish associations between student outcomes and perceived patterns of teacher-student interaction for samples of 489 senior high-school biology students in Australia.

Wong, Young and Fraser (1997) investigated associations between three student attitude measures and a modified version of the SLEI involving 1,592 grade 10 students in 56 chemistry classes in Singapore. In India, Koul and Fisher (2006) found positive associations between scales of the WIHIC questionnaire and students' attitude towards science. Similarly, Telli, Cakiroglu and den Brok (2006) found positive associations between scales of the WIHIC and students' attitude to biology in Turkish high schools. Telli, den Brok and Cakiroglu (2010) investigated the associations between teacher-student interpersonal behaviour and students' attitudes to science using the QTI with an attitude questionnaire for a sample of 7,484 grade 9–11 students from 278 classes in 55 public schools in 13 major Turkish cities. Their results revealed that the influence dimension of the QTI was related to student enjoyment, whilst the proximity dimension was associated with attitudes to inquiry.

Kyriakides (2006) administered the QTI (Wubbels & Levy, 1993) to elementary school students in Cyprus and established positive links between teacher interaction and affective outcomes. Other environment-outcomes studies have investigated school-level environments and student outcomes in mathematics (Webster & Fisher, 2004), the relationship between learning environments, family contexts, educational aspirations and attainment (Marjoribanks, 2004).

Some researchers have also investigated the relationship between learning environment, attitudes and achievement in middle schooling science classes (Wolf & Fraser, 2008); mathematics classroom environment and academic efficacy (Dorman, 2001); and school and classroom environment and teacher burnout (Dorman, 2003a). Table 2.2 summarises some studies which have reported associations between outcome measures and classroom environment perceptions that have been replicated for a variety of cognitive and affective outcome measures, a variety of classroom environment instruments and a variety of samples (ranging across numerous countries and grade levels).

2.3.3.2 Evaluating Educational Innovations

Researchers have used the field of learning environments to help to assess the effectiveness of education innovations (Maor & Fraser, 1996; Zandvliet, 2003). According to Fraser (2012), classroom environment instruments can be used as a source of process criteria in the evaluation of educational innovations. Maor and Fraser (1996) incorporated a classroom environment instrument within an evaluation of the use of a computerised database and they found that students perceived that their classes became more inquiry-oriented during the innovation.

Table 2.2 Some Studies of Associations between Student Outcomes and Classroom Learning Environment

Study	Outcome Measures	Sample
Studies Involving QTI		
Wei, den Brok & Zhou (2009)	Achievement	160 grade 8 students (4 classes) of secondary school in southwest part of China
Haladyna, Olsen & Shaughnessy (1982)	Attitudes	5,804 science, mathematics and social studies students in 277 Grade 4, 7 and 9 classes in Oregon, USA
Studies Involving CES		
Fisher & Fraser (1983)	Inquiry skills Attitudes	116 grade 8 and 9 science classes throughout Tasmania, Australia
Studies Involving MCI		
Fraser & Fisher (1982)	Inquiry skills Understanding the nature of science Attitudes	2,305 grade 7 science students in 100 classes in Tasmania, Australia
Goh, Young, & Fraser (1995)	Attitudes	1,512 primary school students in Singapore
Majeed et al. (2002)	Attitudes	1,565 mathematics students in 81 classes in Brunei Darussalam
Studies Involving WIHIC		
Okan (2008)	Attitudes	152 university students in Turkey
Wolf & Fraser (2008)	Attitudes Achievement	
Zandvliet & Fraser (2005)	Attitudes	1,404 students in 81 classes in Australia and Canada
Opolot-Okurut (2010)	Motivation	81 secondary school students in 2 schools in Uganda
Velayutham, Aldridge & Fraser (2012)	Motivation Self-regulation	1360 grade 8, 9 & 10 science students in Perth, Australia
MacLeod & Fraser (2010)	Attitude	763 college students in 82 classes in the UAE
Afari et al. (in press)	Enjoyment Academic efficacy	352 college students in 33 classes in the UAE
Studies Involving CLES		
Aldridge et al. (2004)	Attitudes	1,843 grade 4–9 students in 29 mathematics classes in South Africa
Nix et al. (2005)	Attitudes	1,079 high school students in 59 classes in Texas, USA
Studies Involving SLEI		
Fisher et al. (1997)	Attitudes	489 senior high school biology students in Australia
Fraser & McRobbie (1995)	Attitudes	Approximately 80 senior high school chemistry classes in Australia
Wong & Fraser (1996)	Attitudes	1,592 Grade 10 chemistry students in Singapore
Studies Involving WIHIC & CLES		
Ogbuehi & Fraser (2007)	Attitudes	661 middle-school mathematics students in 22 classes in California, USA

*Adapted from Fraser (1998) with permission

In Singapore, classroom environment measures were used as dependent variables in evaluations of computer-assisted learning by Teh and Fraser (1994) and computer application courses for adults by Khoo and Fraser (2008). In the evaluation of adult computer application courses, Khoo and Fraser (2008) adapted the WIHIC for use with a 250 working adults attending five computer education centres in Singapore. The results indicated that students perceived their classroom environments positively.

In California, USA, Ogbuehi and Fraser (2007) evaluated the effectiveness of using an innovative teaching method for the topic of systems of linear equations involving a numerical method (Cramer's method) in terms of learning environment, students' attitudes and students' conceptual development. Administration of the WIHIC, CLES to 661 middle-school mathematics students in 22 classes supported the validity of the WIHIC and CLES and analyses for the experimental group promoted more Shared Control, Shared Negotiations and Investigation than for the control group.

Nix et al. (2005) used the CLES in their evaluation of an innovative science teacher development programme (based on the Integrated Science Learning Environment model). Programmes were evaluated in terms of the types of school classroom environments created by these teachers as perceived by their 445 students in 25 classes. For this evaluation, Nix et al. (2005) evolved an innovative side-by-side response format for the CLES so that students could provide their perceptions of THIS classroom (the students' current class with the teacher who had experienced the professional development) and OTHER classroom (other classes at the same school taught by different teachers). Students of teachers who had experienced the professional development perceived their classrooms as having appreciably higher levels of the CLES scales of Personal Relevance and Uncertainty relative to the comparison classes.

An innovative science course for prospective elementary teachers in a large urban university in California was evaluated by Martin-Dunlop and Fraser (2008). Selected scales of the WIHIC and SLEI were administered to 525 females in 27 classes and very large differences were found on all scales (of over 1.5 standard deviations) between students' perceptions of the innovative course and their previous courses. The largest gains were observed for Open-Endedness and Material Environment (with effect sizes of 6.74 and 3.82 standard deviations, respectively).

In the USA, Lightburn and Fraser (2007) used the SLEI in an evaluation of the effectiveness of using anthropometric activities for a sample of 761 high-school biology students. Relative to a comparison group, the anthropometry group had significantly higher scores on some SLEI and attitude scales.

Wolf and Fraser (2008) evaluated the effectiveness of using inquiry-based laboratory activities in terms of learning environment, attitudes and achievement. The WIHIC was administered to 1,434 middle-school science students in 71 classes. The results revealed that inquiry instruction promoted more Student Cohesiveness than non-inquiry instruction (effect size of one-third of a standard deviation). Also, inquiry-based instruction was found to be differentially effective for male and female students.

In Australia, Aldridge and Fraser (2008, 2011) used the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) in monitoring and evaluating the success of an innovative new senior high school in Western Australia in promoting outcomes-focused education. The sample included 449 students in 2001, 626 students in 2002, 471 students in 2003 and 372 students in 2004. Changes in student perceptions of the classroom environments over the 4 years supported the efficacy of the school's educational programmes in that changes were statistically significant and of moderate magnitude (with effect sizes ranging from 0.20 to 0.38 standard deviations) for seven of the ten TROFLEI scales. However, the degree of change in the learning environment differed for different learning areas. Subsequent interviews with administrative staff provided explanations for differences in results between learning areas in terms of whether teachers were proactive in using outcomes-focused learning/teaching principles.

My study draws on and extends research that has involved the evaluation of educational innovations (Maor & Fraser 1996; Ogbuehi & Fraser, 2007; Wolf &

Fraser 2008; Nix et al., 2005; Martin-Dunlop & Fraser 2008; Aldridge & Fraser, 2008, 2011) from the field of learning environments to investigate the effectiveness of games in the mathematics classroom learning environments. The inclusion of a learning environment instrument was used to provide information related to the impact of mathematical games on the classroom environment, as recommended by Zandvliet (2003).

2.4 Students' Attitudes towards Mathematics

2.4.1 Defining Attitudes

The conceptions, attitudes and expectations of students regarding mathematics and mathematics teaching are considered to be significant factors underlying their school experience and achievement (Borasi, 1990; Reed, Drijvers & Kirschner, 2010). In reviewing the issue of students' attitudes towards mathematics, Westwood (2000, p. 31) cites the work of Wain who painted a rather dark image of mathematics:

> Many intelligent people after 1500 hours of instruction over eleven years of schooling still regard mathematics as a meaningless activity for which they have no aptitude. It is difficult to imagine how a subject could have achieved for itself such an appalling image as it now has in the popular mind to think that all our effort has led to a situation of fear.

While this picture of mathematics is not a pleasant one, it represents a 'wake-up call' for all of those involved in the teaching of mathematics (Swan, 2004). Davis (1993, p. 1) goes further when he states that:

> Some students seem naturally enthusiastic about learning, but many need-or-expect their instructors to inspire, challenge, and stimulate them. Whatever level of motivation your students bring to the classroom, will be transformed, for better or worse, by what happens in that classroom.

Learning clearly has an affective component and, according to Kind, Jones and Barmby (2007), developing a positive attitude is important for students' achievement. One definition that is commonly used to describe attitudes includes the three components of cognition, affect and behaviour (Kind et al., 2007; Rajecki, 1990). These three components are defined by Reid (2006, p. 4) as "a knowledge about the object, or the beliefs and ideas component (cognitive); a feeling about the object, or the like or dislike component (affective); and a tendency towards action, or the objective component (behavioural)".

As Kind et al. (2007) point out, this definition is a sensible view of attitudes because these components are closely linked. For example, we know about mathematics (cognitive) and therefore we have a feeling or an opinion about it (affective) that may cause us to take a particular action (behavioural). Other researchers have suggested that the three components should be treated more independently, and that attitudes should be viewed as basis for evaluative judgements (Ajzen, 2001; Crano & Prislin, 2006). According to Kind et al. (2007) when we have an attitude, we judge something along emotional dimensions, such as good or bad, harmful or beneficial, pleasant or unpleasant, important or unimportant. Crano and Prislin (2006) point out that it is important to notice that these evaluative judgements are always towards something, often called the attitude object. Although some researchers have defined attitudes solely in terms of the affective component (George, 2000; Germann, 1988), Fishbein and Ajzen (1975) viewed attitudes as being formed spontaneously and, inevitably, involving the attributes of an object. Attitudes or the affective component of attitudes, therefore, are linked to the beliefs that a person holds (Kind et al., 2007). It is with this in mind that the definition for attitude, used for my study, is the feelings that a person has about an object, based on their beliefs about that object.

When children start school, their attitude towards learning is derived primarily from their home environment (Lumsden, 1994). However, success or failure in the classroom impacts on these initial attitudes and is shaped by early school experiences which, in turn, impact on subsequent classroom situations (Lumsden, 1994; Reynolds & Walberg, 1992). In addition, students' attitudes are affected by their interactions with their peers (Fishbein & Ajzen, 1975; Reynolds & Walberg, 1992; Taylor, 1992). Positive and negative experiences of school activities produce learned responses which may then impact on students' attitudes as they get older (Dossey, Mullis, Lindquist & Chambers, 1988).

Students' attitudes towards mathematics influence the extent to which learning outcomes are realised (Reed et al., 2010). One aspect of my study involved determining whether the introduction of *Jeopardy!*-type games can help to improve students' attitudes towards mathematics, in particular, their enjoyment of mathematics lessons.

2.4.2 Assessing Attitudes towards Mathematics using the TOMRA

Previous studies have used different assessment methods to investigate students' attitudes towards mathematics and science classrooms (e.g. Mink & Fraser, 2005; Ogbuehi & Fraser, 2007; Sebela, Fraser & Aldridge, 2004; Spinner & Fraser, 2005; Zandvliet & Fraser, 2005). One instrument that has been used to assess students' attitudes towards science is the Test of Science-Related Attitudes (TOSRA). The TOSRA was designed to measure seven science-related attitudes among secondary science students: 1) Social implications of science, 2) Normality of scientists, 3) Attitude to scientific inquiry, 4) Adoption of scientific attitudes, 5) Enjoyment of science lessons, 6) leisure interest in science and 7) Career interest in science (Fraser, 1981). Each of these scales contains 10 items, making a total of 70 items for the whole instrument. The response format involves a four-point Likert scale of Strongly Agree, Agree, Disagree, or Strongly Disagree.

TOSRA has been field tested and applied in numerous studies and has shown to be valid and reliable (Aldridge et al, 1999; Fraser, 1981; Fraser et al., 2010a). While the TOSRA has been used to investigate associations between attitudes and achievement, it has also been used to investigate associations between classroom environment and attitudes (Wong & Fraser, 1996). In a cross-national study of learning environments and attitudes conducted with 1161 students in Australia and Indonesia, the TOSRA was found to be valid and reliable in both its Indonesia and English versions (Fraser et al., 2010a). To measure changes in attitudes over time, TOSRA can be used in studies as both a pre-test and a post-test (Fraser, 1981; Fraser et al., 2010a; Martin-Dunlop & Fraser, 2008).

Several studies have used the TOSRA, in a modified form, to assess the attitudes of students in a mathematics classes (Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). The modified form is referred to as Test of Mathematics Related Attitudes (TOMRA). The same seven scales were maintained but the word 'mathematics' replaces the word 'science'. In my study, one scale of TOSRA (Enjoyment of Science Lessons), modified for use in mathematics class by Spinner and Fraser (2005), was administered to gather information about changes in mathematics attitudes during the introduction of *Jeopardy!*-type games.

2.5 Students' Academic Efficacy

More than three decades ago, Bandura (1977) theorised that a potent influence on student behaviour is the beliefs that they hold about their capabilities. According to social cognitive theory, students are more likely to have an incentive to learn if they believe that they can produce the desired outcomes (Bandura, 1986). Hence, academic efficacy beliefs are powerful predictors of the choices that students make, the effort that they expend and their persistence in facing difficulties. Furthermore, aside from task value, a major motivational component of expectancy-value theory is ones academic efficacy beliefs. In their expectancy-value theory, Eccles and Wigfield (2002) envisage the direct influence of students' expectation beliefs on both achievement-related choices and performance. Furthermore, according to Pajares (2002), academic efficacy is intimately related to students' self-regulated learning. Students with high academic efficacy are more likely to put in more effort, consistently evaluate their progress and apply self-regulatory strategies (Schunk & Pajares, 2005).

Velayutham and Aldridge (2012) examined the influence of motivational constructs (learning goal orientation, science task value and academic efficacy) in science learning on students' effort regulation in science classrooms involving 1360 science students in grades 8, 9 and 10 in Perth, Australia. Their results revealed that motivational beliefs of learning goal orientation, task value and academic efficacy significantly influenced students' self-regulation in science learning.

Previous research has established that academic efficacy is a predictor of academic achievement (Bandura, 1997; Edman & Brazil, 2007; Gore, 2006; Hsieh, Sullivan, & Guerra, 2007; Tyler & Boelter, 2008) and influences academic motivation and learning (Adeyemo, 2007; Pajares, 1996). Researchers have demonstrated that self-efficacy beliefs predict students' mathematics performances (Bandura, 1986; Pajares, 1996; Schunk, 1991). Interestingly, Pajares and Kranzler (1995) found that the influence of academic efficacy on mathematics performance was as strong as was the influence of general mental ability.

The relationship between academic efficacy and classroom environment has been established, beginning with the research undertaken by Dorman (2001). His results indicate that the mathematics classroom environment is positively related to student academic efficacy. A study of classroom environment, perceptions of assessment tasks, academic efficacy and attitude to science revealed significant links between classroom environment and academic efficacy (Dorman & Fraser, 2009). A more recent study by Velayutham and Aldridge (2012) identified aspects of the psychosocial learning environment that influence student motivation (including academic efficacy). Structural equation modeling analysis suggested that the Student Cohesiveness, Task Orientation and Investigation scales were the most influential predictors of student academic efficacy.

2.6 Sex Differences

Past studies suggest that boys and girls have different perceptions of their classroom learning environment (Henderson & Fisher, 2008; Majeed et al., 2002; Wong & Fraser, 1995). For example, Kim et al.'s (2000) study involving 543 Korean science students' attitudes towards science and the use of the WIHIC and QTI revealed that boys perceived their learning environments and interpersonal behaviour more favourably than girls. Wahyudi and Treagust (2004) explored gender differences in students' perceptions of their classroom learning environment and found that female students generally held slightly more positive perceptions of both actual and preferred learning environments than their male counterparts. The results of their study replicated considerable previous research in which females held more favourable perceptions of the classroom learning environment than did males.

Waxman and Huang (1998) studied 13,000 students from urban elementary, middle and high school in the USA and reported that female students generally had more favourable perceptions of their classroom learning environment than did male students. In another study, Huang (2003) explored factors such as school, subject and several academic background variables that may be related to classroom learning environments of middle school students in Taiwan and investigated whether relationships varied by gender. The results of this study supported previous findings that reported that girls perceived their classroom learning environments more positively than did boys (den Brok, Fisher, Rickards & Bull, 2006; Goh & Fraser, 1998; Kaya, Ozay & Sezek, 2008; Waxman & Huang, 1998).

den Brok, Fisher, Rickards and Bull (2006) investigated the factors affecting Californian students' perceptions of their learning environment in relation to socioeconomic status, gender, class size. Student gender was found to be associated with Student Cohesiveness, Teacher Support, Task Orientation and Cooperation. They also reported that girls perceived their learning environment more positively than did boys.

Telli, den Brok, Tekkaya and Cakiroglu (2009) explored the effects of grade level and gender on students' perceptions of their learning environment in biology classes in Turkey with 1474 high school using the WIHIC. Their results also indicated that girls scored significantly higher than boys on three out of seven scales. Girls perceived their biology classrooms more task oriented and with greater teacher support and equity than did boys. However, Tamir and Caridin (1993) found no gender difference in Israeli Arabic students' perception of the classroom environment when the LEI was administered to those students.

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 in performance between males and females (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 computer 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 was differentially effective for male and female students in terms of student perceptions of the learning environment and attitudes towards mathematics.

2.7 Chapter Summary

My study investigated whether the introduction of *Jeopardy!*-type games into college-level mathematics classes can help to improve students' perceptions of the learning environment, their enjoyment of mathematics classes, academic efficacy, and achievement. In this chapter, the literature relevant to this study of learning environment, the use of games in mathematics classes, students' attitudes to mathematics, and students' academic efficacy was reviewed. Section 2.2 reviewed the background of college-level education in the UAE and this was followed in Section 2.3 with the use of games in mathematics classes.

Section 2.4 reviewed classroom learning environment from a theoretical and historical perspective. In particular, emphasis was placed on specific learning environment questionnaires utilized in my study. I also reviewed the development, validation, and application of other well-known classroom learning environment questionnaires. Subsections of section 2.4 highlighted the development and use of specific learning environment instruments beginning with two historically-significant questionnaires, namely, the Learning Environment Inventory (LEI, Walberg & Anderson, 1968), the Classroom Environment Scale (CES, Moos & Trickett, 1974), and the individualized Classroom Environment Questionnaire (ICEQ, Fraser, 1990). This was followed by the My Class Inventory (MCI, Fraser & O'Brien, 1985), the College and University Classroom Environment Inventory (CUCEI, Fraser & Treagust, 1986), the Questionnaire on Teacher Interaction (QTI, Wubbels & Levy, 1993), the Science Laboratory Environment Inventory (SLEI, Fraser, Giddings, & McRobbie, 1995), and the Constructivist Learning Environment Survey (CLES, Taylor et al., 1997). A few additional learning environment instruments were also reviewed.

A review of literature was devoted to the development, validation, application of the What is Happening In This Class (WIHIC, Fraser et al., 1996) because it was used in my study. Subsection 2.4.3 provided a review of past learning environment research, which included associations between learning environment and student outcomes and evaluating educational innovations. Section 2, literature on students' attitudes towards mathematics was reviewed. My study investigated whether there is a relationship between students' academic efficacy and their perceptions of the learning environment, so in section 2.6, the literature review of students' academic efficacy was reviewed. My study investigated whether the effectiveness of mathematical games was different for male and female students. Therefore, a review of literature on gender difference was included in section 2.7.

This chapter has provided a review of literature relevant to the study. The next chapter presents the research methodology utilized in this study.

CHAPTER 3

RESEARCH METHODS

3.1 Introduction

Whereas chapter 2 reviewed literature pertinent to the present study, this chapter outlines the research methods used to collect and analyse the data. The overarching aim of the study was to examine the effectiveness of mathematics games when used at the college level in the UAE in terms of changes in students' learning environment and outcomes (attitudes and achievement). The research methods used in the present study are outlined in this chapter using the following headings:

- Specific Research Questions (Section 3.2);
- Research Design (Section 3.3);
- Sample for the Study (Section 3.4);
- Quantitative Data Collection (Section 3.5);
- Qualitative Data Collection (Section 3.6);
- Data Analyses (Section 3.8);
- Ethical Issues (Section 3.7); and
- Chapter Summary (Section 3.9).

3.2 Specific Research Questions

The four research questions, presented in Chapter 1, are outlined below.

i. Are the learning environment questionnaire and attitude questionnaire valid and reliable when used with a sample of 18 to 35 year-old college-level mathematics students in the UAE?

ii. Is there a relationship between the nature of the classroom learning environment and student attitudes to mathematics?

iii. Is using mathematical games effective in improving:
    i. the classroom learning environment?
    ii. students’ attitudes to mathematics?
    iii. students’ mathematics achievement?

iv. Is the use of games activities in mathematics instruction differentially effective for males and females in terms of:
    i. classroom learning environment?
    ii. students’ attitudes to mathematics?
    iii. students’ mathematics achievement?

3.3 Research Design

Mixed-methods research has become increasingly popular (Creswell & Plano-Clark, 2010). It has become increasingly recognised that the use of multiple research methods can provide more comprehensive evidence for studying a research problem than the use of quantitative or qualitative research methods alone (Creswell, 2009, 2011; Creswell & Plano Clark, 2010; Greene, Caracelli & Graham, 1989; Tashakkori & Teddlie, 2010). My study involves a mixed-methods research design which involves philosophical assumptions that guide the direction of the collection and analysis of data as well as the mixture of qualitative and quantitative approaches in the research process (Creswell & Plano Clark, 2010). As such, my mixed-methods design will involve the use of multiple worldviews or paradigms rather than the typical association of certain paradigms for quantitative researchers and others for qualitative researchers (Creswell & Plano Clark, 2010).

There are four major types of mixed-method designs, namely, triangulation design, embedded design, explanatory design and exploratory design (Creswell & Plano Clark, 2010). My study incorporated a triangulation design to “obtain different but complementary data on the same topic” that were used to help to understand the research problem (Morse, 1991, p. 122). Using a triangulation design allowed me to bring together different strengths of quantitative and qualitative methods (Patton,

2002) whilst recognising and helping to overcome the limitations of the various methods. In my study, quantitative data, collected using questionnaires, were supplemented with qualitative data derived from interviews, observations and narrative stories to provide contextual information. The effectiveness of the mathematics games was assessed in terms of classroom environment and the outcomes of attitudes and achievement of the subsample of the 90 students.

3.4 Sample for the Study

The sample for my study involved a total of 352 students in 33 classes, 231 of whom were females and 121 were males. The classes were drawn from three tertiary-level institutions located in Abu Dhabi, the capital and largest emirate (by area) of the UAE. All of the participants were in the foundation programmes of their respective college, preparing for careers in primary school teaching, engineering and business. The participants of the three institutions differed in terms of the mathematical abilities of the students. Those students attending the primary school teaching college, for the most part, had majored in Arts in high school and were considered to have an intermediate level of mastery in mathematics. However the participants in the engineering college had majored in science at high school and were considered to have a strong background in mathematics. The participants in the business college were all mature age students who had left school prior to completion, and therefore, they were considered to have a low level of mathematics ability.

Approximately 95% of the students were UAE nationals and the remaining 5% was made up of other Arab nationals. The students' ages ranged between 18 years and 35 years. Table 3.1 provides a breakdown of the number of students and classes in each college. After the large-scale quantitative data collection (described in the following section), *Jeopardy!*-type games (described in Section 1.2) were introduced to students in eight of the 33 classes.

Table 3.1 Description of Whole Sample

College	Classes	Students: Male	Female	Total
1	9	75	0	75
2	7	40	25	65
3	17	6	206	212
Total	33	121	231	352

Four teachers (one from College 1, two from College 2, and one from College 3) volunteered to use *Jeopardy!*-type games in their classrooms. This provided a sample of 90 students who were attending classes that included the use of games. Table 3.2 shows the description of the sub-sample selected to use the *Jeopardy!*-type games.

Table 3.2 Description of Sub-Sample for Trial of *Jeopardy!*-type Games

College	Teacher	Classes	Students: Male	Female	Total
1	1	2	22	0	22
2	2	4	30	0	30
3	1	2	0	38	38
Total	4	8	52	38	90

The selection of the classes was based on the teachers' willingness to be involved. All of the students in the classes of these four teachers volunteered to participate and none of them opted out the *Jeopardy!*-type games. The mathematics topics taught by the teachers in the three colleges during the six-week treatment are provided in Appendix B. I created *Jeopardy!*-type games covering these topics. The games lasted about 30 minutes per session.

Three of the four teachers also volunteered to be interviewed. In addition, 20 of the students (seven females and 13 males) who were exposed to mathematics games also volunteered to be interviewed. Of these students, seven were from College Three, 11 were from College Two and two were from College One. The sample size for interviews with teachers and students is summarised in Table 3.3.

Table 3.3 Description of Interview Sample of Teachers and Students

		Students		
College	Teacher	Male	Female	Total
1	1	20	0	2
2	1	11	0	11
3	1	0	7	7
Total	3	13	7	20

3.5 Quantitative Data Collection

Two instruments were used to gather data for the quantitative component of this study. The first was an instrument used to assess students' perceptions of the learning environment and the second was used to assess students' attitudes. This section describes both of these instruments, their modification and their translation into Arabic.

3.5.1 Assessing the Learning Environment

The WIHIC questionnaire was modified for use in college-level mathematics classrooms in the UAE. As described in chapter 2, the WIHIC (Aldridge et al., 1999) was developed to assess students' perceptions of the learning environment. The original version included a total of 90 items (ten in each of nine scales). Subsequent versions, however, involved a refined questionnaire that provided a more economical format with seven 8-item scales, namely, Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity.

The WIHIC has been used to assess a range of subjects including high school science (Aldridge & Fraser, 2000; Aldridge et al., 1999), mathematics (Afari et al., in press; Ogbuehi & Fraser, 2007; Opolot-Okurut, 2010) and mathematics and geography (Chionh & Fraser, 2009). The WIHIC has also been used successfully across a range of different levels, including higher education (MacLeod & Fraser, 2010), high school (Aldridge & Fraser, 2000; den Brok, Telli, Cakiroglu, Taconis & Tekkaya, 2010) and primary school (Allen & Fraser, 2007). In each of these cases, the WIHIC has been found to be a robust and reliable instrument.

Of note, is Dorman's (2003b) study involving a sample of 3980 high school students (Grade 8, 10 and 12 mathematics classes) from Australia, the UK and Canada, in which confirmatory factor analysis supported the seven-scale *a priori* structure of the WIHIC. In this study, all items loaded strongly on their own scale, although model fit indices revealed a degree of overlap, the factor structure was found to be invariant for country, grade level and gender. The wide international applicability of the WIHIC as a valid measure of the classroom psychosocial environment in a range of settings and countries made it a suitable choice for use in my study.

In my study, modifications were made to the WIHIC, in terms of scale selection, item selection and language, to ensure its suitability to college-level students in the UAE. Careful consideration of which scales would be retained or omitted, to ensure a meaningful evaluation of the effectiveness of games in the mathematics classroom, led to a refined version of the WIHIC. Two of the scales, Investigation and Task Orientation were omitted as they were considered to be unsuitable for the purpose of the study. The Investigation scale assesses the extent to which emphasis is placed on the skills and processes of inquiry and their use in problem solving and investigation and the Task Orientation scale assesses the extent to which it is important to complete activities planned and to stay on the subject matter. These scales were not considered to be helpful in evaluating the effectiveness of mathematics games and were omitted.

The teacher's ability to make use of students' everyday experiences as a meaningful context for the development of students' mathematical knowledge is integral to their success (Taylor et al., 1997). Because it was anticipated that the use of *Jeopardy!*-type games might increase the relevance of mathematics to students, the Personal Relevance scale from the CLES (Taylor et al., 1997) was added to the remaining WIHIC scales to assess the extent to which there is a link between what the student is taught in the classroom and his/her out-of-school experiences. The refined version of the WIHIC, used in the present study, involved the six scales of Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity, and Personal

Relevance. A description of each scale in the modified WIHIC used in my study is provided in Table 3.4 along with a sample item for each scale.

Once the scales were selected for inclusion, each item was scrutinised, by me, to ensure the suitability of its language and phrasing for the UAE setting. For example, an item in the Teacher Support scale of the WIHIC that states "The teacher takes a personal interest in me" was changed to "The teacher is interested in my problems", to ensure that students did not misinterpret the intent of the statement.

Historically, negatively-worded items have been used to guard against passive responses and response bias (Aldridge & Fraser, 2008). Past studies have revealed, however, that using positively-worded items helps to improve the response accuracy and internal consistency of an instrument (Chamberlain & Cummings, 1984; Schreisheim, Eisenbach & Hill, 1991; Schriesheim & Hill, 1981).

Table 3.4 Scale Description and Sample Item for Each Scale in the translated English Version of the What Is Happening In this Class? (WIHIC) Questionnaire

Scale	Scale Description	Sample Item
	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.

In my study, I considered it appropriate, therefore, to use only items with a positive scoring direction. I also considered it appropriate to group together in blocks consisting of all items that belong to the same scale instead of arranging them randomly or cyclically to provide contextual cues and to minimise confusion to students (Aldridge et al., 2000; Aldridge & Fraser, 2008). Finally, the original, unchanged format involved a five-point frequency scale of Almost Never, Seldom, Sometimes, Often, and Almost Always. A copy of the Arabic version of the What Is Happening In this Class? (WIHIC) questionnaire used in the present study can be found in Appendix C.

3.5.2 Assessing Students' Attitudes towards Mathematics

Two scales, namely, Enjoyment of Mathematics Lessons and Academic Efficacy, were used to assess the attitudes of students in their mathematics classes. The Enjoyment of Mathematics Lessons scale was adapted from the Test of Science-Related Attitudes (TOSRA; Fraser, 1981). The TOSRA measures students' attitudes towards their science classes using scales based on Klopfer's (1976) taxonomy of the affective domain related to science education (Fraser, 1981). Because my study aimed to determine whether or not the introduction of *Jeopardy!*-type games can help to improve students' enjoyment of mathematics lessons, I was interested in examining how students regard their mathematics class in terms of enjoyment. Therefore, the Enjoyment of Science Lessons scale, modified for use in mathematics class by Spinner and Fraser (2005), was used. Spinner and Fraser's (2005) eight-item version involved only items with a positive scoring direction and was reworded so that the word 'science' was changed to 'mathematics'. For example, the item "Science lessons are fun" was changed to "Mathematics lessons are fun". As the WIHIC involved the use of a frequency response scale, to minimise confusion, I change the original format (Strongly Agree, Agree, Disagree, Strongly Disagree) to the same five-point frequency response format of Almost Always, Often, Sometimes, Seldom and Almost Never. Wording to Spinner and Fraser's version was changed to ensure that all items were meaningful when used with this response format.

The second scale, Academic Efficacy (see Section 2.6), was based on the Morgan Jinks Student Efficacy Scale (MJSES) developed by Jinks and Morgan (1999). A student's sense of academic efficacy can influence behaviour that is important to learning (Aldridge & Fraser, 2008). Past research has revealed that self-efficacy positively affects engagement, effort, persistence, goal setting and performance (Bandura, 1982, 1989; Schunk, 1989; Zimmerman, Bandura, & Martinez-Pons, 1992). Students' academic efficacy beliefs regarding competence could have important implications for improving learning environments and, therefore, student outcomes (Lorsbach & Jinks, 1999). My study investigated whether associations exist between students' belief in themselves as learners of mathematics and their perceptions of the learning environment. The academic efficacy scale, used in my study, consisted of eight items, all of which have a positive scoring direction, and was responded to using a five-point frequency scale of Almost Always, Often, Sometimes, Seldom and Almost Never (to conform to the response format of the learning environment scale). A scale, description and sample item for the Enjoyment of Mathematics Lessons and Academic Efficacy is provided in Table 3.5. A copy of the Enjoyment of Mathematics Lessons and Academic Efficacy scales used in the present study can be found in Appendix D.

Table 3.5 Scale Description and Sample Item for the Enjoyment of Mathematics and Academic Efficacy Scales

Scale	Scale Description	Sample Item
Enjoyment of Mathematics Lessons	The extent to which 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.

3.5.3 Translation of the Instruments

The translation of learning environment questionnaires and the development of new instruments in languages other than English has provided useful tools for researchers in many parts of the world (MacLeod & Fraser, 2010). Table 3.6 provides a summary of the learning environment questionnaires that have been translated into other languages. Of relevance to my study is the WIHIC, which has been translated and validated into many different languages, namely, Chinese (Aldridge et al., 1999; Aldridge & Fraser, 2000; Yang, Huang & Aldridge, 2002), Indonesian (Fraser et al., 2010a), Korean (Kim et al., 2000), Arabic (Afari et al., in press; MacLeod & Fraser, 2010) and IsiZulu (Aldridge et al., 2009).

All of the questionnaires used in my study were originally developed in English. The participants all spoke English as a second language, and so an Arabic translation was created for those participants who were more comfortable with responding in their mother tongue. All of the items were translated into Arabic using the 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 and instructor from within my college. The next step involved an independent back translation of the Arabic version into English by another professional translator and instructor, also from my college, who was not involved in the original translation (as recommended by Brislin, 1970). 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.

3.5.4 Layout of the questionnaires

Historically, in studies in which both the English and the translated version of the questionnaire is used, researchers have administered separate English and the translated versions of the questionnaires (see MacLeod & Fraser, 2010). However, to provide a more economical format in my study, the questionnaires were presented to the students using a dual layout, used successfully in learning environment research in South Africa (Aldridge, Laugksch & Fraser, 2006a). For each item the Arabic translation was placed beneath the English item. This dual layout is illustrated below in Figure 3.1.

PERSONAL RELEVANCE **الإرتباط الشخصي**		**Almost Never** **تقريبا أبدا**	**Seldom** **نادرا**	**Some-times** **أحيانا**	**Often** **غالبا**	**Almost Always** **تقريبا دائما**
41.	I relate what I learn in this class to life outside college. اقوم بربط ما تعلمته بامور الحياة المختلفة خارج الكلية	1	2	3	4	5

Figure 3.1 Illustration of the Dual Layout of the Arabic version of the Questionnaire

Table 3.6 Translation Language of Classroom Learning Environment Questionnaires and Authors

Language	Questionnaire	Authors
Chinese	What Is Happening In this Class? (WIHIC)	Aldridge et al. (1999)
		Aldridge & Fraser (2000)
		Yang et al. (2002)
	Chinese language Classroom Environment Inventory (CLCEI)	Chua, Wong & Chen (2009)
	Constructivist Learning Environment Survey	Aldridge et al. (2000)
Hebrew	Learning Environment Inventory (LEI)	Hofstein, Gluzman, Ben-Zvi & Samuel (1979, 1980)
	Science Laboratory Environment Inventory (SLEI)	Hofstein & Lazarowitz (1986)
		Hofstein, Levy-Nahum & Shore (2001)
Hindi	Learning Environment Inventory (LEI)	Walberg, Singh & Rasher (1977)
Turkish	Questionnaire on Teacher Interaction (QTI)	Telli, den Brok & Cakiroglu (2007)
Indonesian	Classroom Environment Scale (CES)	Paige (1979)
	Learning Environment Inventory (LEI)	Paige (1979)
	Questionnaire on Teacher Interaction (QTI)	Fraser et al. (2010b)
	What Is Happening In this Class? (WIHIC)	Wahyudi & Treagust (2004), Fraser et al. (2010a)
Japanese	Classroom Environment Scale (CES)	Hirata & Sako (1998)
Korean	Constructivist Learning Environment Survey (CLES)	Kim et al. (1999)
	Science Laboratory Environment Inventory (SLEI)	Kim & Lee (1997), Fraser & Lee (2009)
	What Is Happening In this Class? (WIHIC)	Kim et al. (2000)
	Questionnaire on Teacher Interaction (QTI)	Kim et al. (2000), Lee et al. (2003)
Malay	Questionnaire on Teacher Interaction (QTI)	Scott & Fisher (2004)
North Sotho (South Africa)	Outcomes-Based Learning Environment Questionnaire (OBLEQ)	Aldridge et al. (2006b)
IsiZulu (South Africa)	What Is Happening In this Class? (WIHIC-primary)	Aldridge et al. (2009)
Arabic	What Is Happening In this Class? (WIHIC)	Afari et al (in press), MacLeod & Fraser (2010)
Thai	Constructivist Learning Environment Survey (CLES)	Wanpen & Fisher (2006)
	Questionnaire on Teacher Interaction (QTI)	Kijkosol & Fisher (2006)
Spanish	What Is Happening In this Class? (WIHIC)	Allen & Fraser (2007), Helding & Fraser (in press), Robinson & Fraser (in press)
	Constructivist Learning Environment Survey (CLES)	Peiro & Fraser (2009)

Adapted from MacLeod & Fraser (2010) with permission

3.5.5 Assessing Student Achievement

Achievement tests are the primary sources of data collection for most educational systems, although they are not without their critics, they are generally accepted measures of achievement (Bragg, 2012). Therefore, in order to evaluate effectiveness of *Jeopardy!*-type games in mathematics classes in terms of student achievement, the students were given a mid-semester test (pre-test) and a final test (post-test) covering the mathematical topics taught during the six-week period (see Appendix E for sample items on the achievement test). These tests were used to evaluate whether the students' mathematical ability improved during the use the *Jeopardy!*-type games.

Spinner and Fraser (2005) used achievement tests to evaluate how well the students learned mathematics while using the Class Banking program in the elementary classroom. Student responses on the pre- and post-assignments were used to document student conceptions and to assess any changes in student conceptions after the lessons (Moschkovich, 1999). The results of several meta-analyses indicate an overall positive effect on student achievement for learning with computer games relative to traditional instruction (Lou, Abrami, & d'Apollonia, 2001).

3.6 Qualitative Data Collection

In addition to the quantitative data described above, important qualitative information were gathered to triangulate, clarify and explain students' responses to the learning environment and attitude questionnaires. Qualitative data information was gathered using observations, interviews with students and teachers, and narratives, each of which is described below.

3.6.1 Observations

Observations of classrooms during the playing of *Jeopardy!*-type games were used to examine the students' interactions and teachers' reactions to the introduction of games in the college context in the UAE. The observations added to the richness of the data base as a whole. All eight of the classes that were exposed to mathematics games were observed three times during the six-week period (once at the beginning, once in the middle and once at the end). The observations focused on the students' and teachers' reactions to the games and how these reactions influenced the learning environment and students' attitudes. Also observations were made of the interactions between students and how they worked together as they played the *Jeopardy!*-type games. In addition to field notes, all observations were video-recorded for later analysis (Onwuegbuzie, Leech & Collins, 2010; Sparrman, 2005) and a narrative, based on observations in all classes, was written to provide insights into games in action in the classrooms.

3.6.2 Interviews with Students

Interviews with students that were exposed to the games were conducted to provide insights into their responses to the questionnaires and their reactions to the use of the games. These interviews involved a semi-structured format, with questions that were used to guide the researcher, thereby providing a degree of consistency across all interviews whilst ensuring a degree of flexibility to pursue avenues that were of interest (Creswell, 2009; Kvale, 1996, 2007; Kvale & Brinkmann, 2009). These interviews included questions, based on the observations of the classrooms, to help me to better understand the students' comprehension of, and interaction with, the games. In addition, students were asked to provide information related to their response to items on both questionnaires. Questions such as "What was your experience of team-work with your class-mates when playing the mathematics games?" and "How do you compare your enjoyment of mathematics lessons before the use of games in your classroom and now?" were used to prompt valuable feedback from students. Each interview lasted for about 30 minutes. These interviews were tape recorded and later transcribed for analysis. The interview schedule and a sample transcript for one of the students can be found in Appendix F and G, respectively.

3.6.3 Interviews with Teachers

In-depth interviews were conducted with three of the four teachers who used the mathematics games in their classes (Kvale, 1996, 2007). These interviews sought teachers' views of the games and their comments on problems that they encountered. Like the student interviews, these interviews were semi-structured to allow a degree of flexibility in the interviewing process (Kvale, 1996, 2007; Kvale & Brinkmann, 2009). The teachers responded to questions such as "In your opinion, what are the benefits of using games in the classroom?" and "Do you think that the use mathematics games affected your students' attitudes towards mathematics?" These interviews with the three teachers were tape recorded and later transcribed for analysis. The teachers' interview guide and a sample transcript can be found in Appendix H and I, respectively.

3.6.4 Narratives

Clandinin and Connelly (2000) defined narrative as the study of the ways in which humans experience the world. The attractiveness of storytelling in contemporary research on teaching is that it is grounded in the notion that a story represents a way of knowing and thinking that is particularly suited for explicating issues (Avraamidou & Osborne, 2009; Carter, 1993; Ellis, 2009). To capture the essence of classroom life in the classes that were observed, narrative was written (as recommended by Clandinin & Connelly, 2000). Following the narrative, a commentary was used to interpret the narratives and to help to make sense of data from interviews and observation, as recommended by Polkinghorne (1995).

During the writing, I was aware of the need to represent research participants in a socially-honest manner in written text. According to Stacey (1988), there is a major difficulty with representing the experiences of others. She argues that, despite the desire to 'engage in egalitarian research', there is a contradiction in the power relationship between the researcher and the subject that always poses a risk of betrayal and manipulation. Lincoln and Denzin's (1994) description of the 'fifth moment' in qualitative research encompasses issues associated with representation and legitimisation, which I addressed in two ways. First, I ensured that any quotations included in my narrative were in fact spoken by the people portrayed. Second, I acknowledged that this narrative and subsequent commentary was, in fact, my interpretations of situations, experiences and interviews. I attempted to address the important issue of legitimisation in the writing of the texts in three ways. First, I triangulated data from different sources, following Denzin and Lincoln's (1994, p. 2) advice that "...the use of multiple methods, or triangulation, reflects an attempt to secure an in-depth understanding of the phenomenon in question. Objective reality can never be captured. Triangulation is not a tool or a strategy of validation, but an alternative to validation." Second, I asked members of the group involved to read the stories to verify their authenticity. Third, I attempted to represent those whom I studied and their classroom environment using verisimilitude (i.e., to resemble truth or reality).

3.7 Data Analysis

The questionnaire data were entered into a database personally to ensure accuracy. After completion of the data entry, the quantitative data were analysed using the Statistical Package for Social Scientists (SPSS) version 17. The interviews were transcribed verbatim and a narrative, based on the classroom observations, was written. These data were analysed to answer the research questions, a description of which is provided under the following headings:

- Choice of Unit for Statistical Analysis (Section 3.7.1);
- Validity and Reliability of the modified WIHIC and Attitudes Scales (Section 3.7.2);
- Associations between Learning Environment and Outcomes (Section 3.7.3);
- Effectiveness of Mathematics Games (Section 3.7.4); and
- Differential Effectiveness of Mathematics Games for Different Sexes (Section 3.7.5).

3.7.1 Choice of Unit for Statistical Analysis

Statistical analysis was performed using two separate units of analysis, the individual and the class mean. These two units of analysis reflect the distinction between 'private beta press' (the distinctive view of the environment held by an individual) and 'consensual beta press' (the shared view that members of a group hold about the environment) (Pace & Stern, 1958). There is a growing body of literature which indicates that the choice of level of analysis is important (Bock, 1989; Bryk & Raudenbush 1992; Fraser, 2007) because it can affect the interpretation of the data, the magnitude of relationships between variables, and whether or not statistically significant results are obtained.

The choice to use both levels of analysis was influenced by two factors. Firstly, using the class means as opposed to the individual student as the unit of analysis involves the testing of a conceptually different hypothesis. My study used a personal form of the WIHIC which elicits students' perceptions from their own view rather than that of the class. By using the class mean as a unit of analysis, as well as the individual student, it was possible to assess the merits of using the class mean as the unit of analysis when analysing the personal form of a questionnaire. Secondly, because past literature involving learning environment research has reported the use of two levels of analysis, it was desirable to incorporate the same units of analysis in order to be able to compare the findings with past studies.

3.7.2 Validity and Reliability of the Modified WIHIC and Attitudes Scales

To examine the reliability and validity of the modified WIHIC and the attitudes scales, when used with college students in the UAE, factor analysis, Cronbach alpha reliability, discriminant validity and ability to differentiate between the perceptions of students in different classrooms were used.

3.7.2.1 *Factor Analysis*

Factor analysis is a data-reduction technique used to reduce a large number of items to a smaller set of underlying factors (Coakes & Ong, 2010). There are two main approaches to rotation, resulting in either orthogonal (eg. varimax-uncorrelated) or oblique (correlated) factor solution (Pallant, 2007). According to Tabachnick and Fidell (2007), orthogonal rotation results in solutions that are easier to interpret and to report; however, they do require the researcher to assume that the underlying constructs are independent (not correlated). Oblique approaches allow for the factors to be correlated, but they are more difficult to interpret, describe and report (Tabachnick & Fidell, 2007). In practice, the two approaches (varimax and oblique) often result in very similar solutions, particularly when the pattern of correlations among the items is clear (Tabachnick and Fidell, 2007). Many researchers conduct both varimax and oblique rotations and then report whatever is the clearest and easiest to interpret (Pallant, 2007).

Principal axis factor analysis with oblique rotations was used to determine whether the 48 items of the modified WIHIC measured the six *a priori* dimensions of the learning environment (Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity and Personal Relevance). Oblique rotation was considered to be appropriate because it can be assumed that the factors within a learning environment are related (Coakes & Ong, 2010). The two criteria used for retaining any item were that it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other five modified WIHIC scales. In choosing 0.40 as the cut-off value for factor loadings, I followed the recommendation of Thompson (2004), Stevens (1992) and Field (2005).

Because the scales of the attitude instrument are not assumed to overlap, a similar principal components factor analysis with varimax rotation was used to determine whether all 16 items from the two scales of the Enjoyment of Mathematics lessons and Academic Efficacy measure the two *a priori* dimensions of the instrument.

3.7.2.2 Internal Consistency Reliability

In the development of a questionnaire, it is necessary to establish that each item in a scale assesses a common construct. If this is the case, then the scale is referred to as being 'homogenous' or having internal consistency. The internal consistency reliability of each of the six modified WIHIC scales and the two attitude scales were established using the Cronbach's alpha coefficient for two units of analysis (the individual student and the class mean).

3.7.2.3 Discriminant Validity

The discriminant validity assesses the extent to which a scale is unique in the dimension that it covers (i.e. the construct is not included in another scale of the instrument). The factor analysis provided support for the independence of factor scores and evidence relevant to the discriminant validity of factor scores on the WIHIC and attitude scales. As a convenient index of the discriminant validity of raw scores on different scales, the mean magnitude of the correlation of one scale with other scales in the modified WIHIC and each attitude scale was calculated using two units of analysis (individual and class mean).

3.7.2.4 Ability to Differentiate Between Classes

To determine whether the modified WIHIC was capable of differentiating between the perceptions of students in different classes, a one-way analysis of variance (ANOVA), with class membership as the independent variable, was computed for each WIHIC scale. The proportion of variance accounted for by class membership was calculated using the eta^2 statistics (the ratio of 'between' to 'total' sums of squares).

3.7.3 Associations between Learning Environment and Attitudes

Past research has revealed associations between students' cognitive and affective outcomes and their perceptions of classroom learning environment (Fraser, 2007, 2012). In my study, associations between two student attitudes scales (Enjoyment of Mathematics Lessons and Academic Efficacy) and the six learning environment scales of the modified WIHIC were investigated. A simple correlation analysis of relationships between each of the two attitudes and each of the six learning environment scales was performed to provide information about the bivariate association between each learning environment scale and each student outcome. Simple correlations were calculated for two units of analysis, namely, the individual student and the class mean.

A multiple regression analysis of relationships between each outcome and the set of six learning environment scales was conducted to provide a more complete picture of the joint influence of correlated environment dimensions on outcomes and to reduce the Type I error rate associated with the simple correlation analysis. To interpret which individual scales make the largest contribution to explaining variance in student outcomes, the regression weights were examined to see which ones were significantly greater than zero ($p<0.05$). The regression weights describe the influence of a particular environment variable on an outcome when all other environment variables in the regression analysis are mutually controlled. Multiple regression analyses were performed for two units of analysis (the student and the class mean).

3.7.4 Effectiveness of Mathematics Games

To examine the effectiveness of mathematics games, my study involved the triangulation of quantitative data and qualitative information. First, a narrative, based on observations in all classes that were exposed to the games, was used to provide an understanding of the games in action. The narrative was then interpreted using a commentary, following the approach recommended and used in other learning environment studies (Aldridge et al., 1999; Aldridge et al., 2009).

Using a pre-test–post-test design, questionnaires were administered before and after the introduction of mathematics games. 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, Academic Efficacy scales, and mathematics achievement scores (mid-semester and final exams grades) were used. Pre-test–post-test 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, the two attitude scales of Enjoyment of Mathematics Lessons and Academic Efficacy scales, and achievement constituted the dependent variables and the testing occasion (pre-test/post-test) constituted the independent variable. To estimate the magnitudes of the differences (in addition to their statistical significance), effect sizes were calculated (as recommended by Thompson, 2002), in terms of the differences in means divided by the pooled standard deviation. Because the number of items in different scales differed, the average item mean, or scale score divided by the number of items in that scale, was chosen to provide a meaningful comparison between scales.

Finally, interviews with teachers and students who were exposed to the games were analysed to provide insights into students' responses to the questionnaires and information regarding their reactions to the use of games in their lessons. Through these interviews, I sought to understand teachers' views of the games. Based upon Patton's (2002) inductive analysis approach, common themes and their relations were investigated from the interview transcripts.

3.7.5 Differential Effectiveness of Mathematics Games for Different Sexes

Finally, the pre-test–post-test data collected from 90 students (52 male and 38 female) in eight classes were used to investigate the differential effectiveness of mathematics games for males and females. 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 differential effectiveness of using mathematics games was the occasion (pre-test–post-test) × sex (male-female) interaction.

The independent variables for the two-way MANOVA were the testing occasion (pre-test and post-test) and sex (male and female) and the dependent variables were the six learning environment scales, two attitudes scales and achievement score. The 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 eta^2 statistics was calculated to provide an estimate of the strength of association for each effect (testing occasion, sex and the interaction) for each modified WIHIC and Attitude scale and achievement score.

3.8 Ethical Issues

Prior to approaching colleges and teachers to invite them to participate in the research, ethics approval was sought (see Appendix I for a copy of the letter confirming ethics approval). In the 2008/2009 academic year of the spring semester, prior to the administration of the questionnaires, I obtained permission from the mathematics department chair persons of each participating college. Teachers from those colleges whose department chairs had granted permission were solicited to be volunteers. I provided an explanation of the aims and expected outcomes of my research. During this study, I carefully considered providing participants with detailed information about my research (discussed in Section 3.8.1) and organisational issues related to the students (discussed in Section 3.8.2), and I ensured that participants were not disadvantaged by the study and that there was confidentiality (discussed in Section 3.8.3).

3.8.1 Informed Consent

All of the participants were provided with detailed information about the study including an explanation of the purpose of the research and the procedures that were to be used. Participants were given the opportunity to ask questions about the research procedures. All students were provided with an information sheet and a consent forms (see Appendix J and K, respectively). Students were verbally informed that participation was completely voluntary and that they had the option to withdraw at any time. They were also told that non-participation in the research would not affect any marks in their courses. This was also stated clearly in the information sheet.

3.8.2 Consideration

In my study, the practicalities of data collection, such as administering instruments and conducting interviews were considered in relation to the possible disadvantages to the students as a result of their involvement. Consideration was given to ensure that data collection did not require students to miss any part of the curriculum, or disrupt the dynamics of a class. Therefore, the teachers decided on a convenient time to administer the questions to the students. The process took about 30 minutes. Interview for students took place during lunch breaks in one of the classrooms in the participant's college. The interview lasted about 20 minutes for each of the students and teachers. Timing was also considered for teacher interviews to reduce interruptions. The teachers were also interviewed during their lunch break.

3.8.3 Confidentiality

To ensure confidentiality, the anonymity of the participants was maintained at all times. All questionnaires were anonymous, but those students in the classes where the *Jeopardy!*-type games were introduced were asked to put their names on each form of the questionnaire to enable matching, for the purpose of statistical analysis of the pre-test–post-test forms. Upon receipt of data, all teacher and school information was encoded, using arbitrary numbers. Surveys were encoded with unique identification numbers. As each class set of the questionnaire responses were returned, I wrote a unique identification number on each survey for tracking purposes. At the conclusion of the interviews, student names were changed to pseudonyms to preserve confidentiality.

3.9 Chapter Summary

Chapter 3 discussed the sample and methods of data collection and analysis used. As a first step, quantitative data were collected from a large sample of students (N=352) to enable me to ensure the validity of the questionnaires and to provide baseline data for the pre-test. Two surveys were used, one to assess students' perceptions of the learning environment and another to assess attitudes. 90 students were later exposed to mathematics games for six weeks.

The study incorporated a mixed-method approach that involved surveys, interviews and classroom observations. To assess students' perceptions of the learning environment, a modified What is Happening In this Class? (WIHIC) questionnaire was used. The modified version used in the present study included 48 items, with 8 items in each of 6 scales, namely, Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity and Personal Relevance. To assess students' attitudes, my study adapted selected scales from two existing instruments, one to assess students' enjoyment of mathematics lessons (Fraser, 1981) and the other to assess students' academic efficacy (Jinks & Morgan, 1999). The instrument consisted of 16 items, with 8 items in each of two scales. Mid-semester and final exam grades of students who were exposed to mathematics games were used to assess their achievement (see Appendix for a sample of achievement test).

Both learning environment and attitudes questionnaires were scrutinised and, where appropriate, modified to ensure that they were suitable for use at the college-level and in the UAE context. The two questionnaires were translated into Arabic using a process of back-translation, verification and modification (Ercikan, 1998). Both instruments used a dual layout, in which both the English and Arabic versions of each item were provided one under the other. The response format for both questionnaires involved a frequency scale consisting of Almost Always, Often, Sometimes, Seldom and Almost Never.

To examine the reliability and validity of the modified WIHIC, principal axis factoring with oblique rotation was used to examine the factor structure of the WIHIC. In addition, the Cronbach alpha reliability coefficient was used as an index of scale internal consistency. Finally, to examine the ability of each scale of the modified WIHIC to differentiate between perceptions of students in different classrooms, an analysis of variance (ANOVA) with class membership as the main effect was used. To examine the internal structure of the Enjoyment of Mathematics Lessons and the Academic Efficacy scales, factor analysis and alpha reliabilities were used.

To investigate associations between the learning environment perceptions of college students in the UAE and their attitudes towards mathematics (enjoyment and academic efficacy), simple correlations and multiple regression were conducted using the sample of 352 college students in 33 classes. Simple correlation analysis was used to examine the bivariate relationship between each learning environment scale and each attitude measure. Multiple regression analyses were carried out to determine the joint influence of the set of WIHIC scales on each attitude scale. In both cases, all analyses were conducted separately for both the individual and class mean as the unit of analysis.

The *Jeopardy!*-type games were introduced to 90 students in eight classes over a six-week period. The WIHIC and attitude scales were administered to all students before the introduction of the games and again at the end of six weeks. 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, and achievement scores were used. The pre-test and post-test scores on the modified WIHIC, Enjoyment of Mathematics Lessons and Academic Efficacy scales, and achievement of students who were exposed to the mathematics games were analysed using a one-way multivariate analysis of variance (MANOVA) with repeated measures. Using the individual as the unit of analysis, effect sizes were calculated to express the magnitude of the difference between the pre-test and post-test scores in standard deviation units.

Interviews with students were conducted to provide insights into their responses to the questionnaires and their reactions to the use of games. Also, these interviews helped to clarify teachers' views of the games and to identify successes and problems that were encountered during their implementation. The interviews conducted with students and teachers who were involved in the mathematics games were transcribed.

A two-way ANOVA for repeated measures was used to investigate whether the games activities in mathematics instruction were differentially effective for males and females. The independent variables were the testing occasion (pre-test and post-test results) and sex, and the dependent variables were the six learning environment scales and the two attitudes scales. To provide an estimate of the strength of association between each effect (testing occasion, sex and the interaction) for each modified WIHIC and the Attitude scale, the eta^2 statistics was calculated.

The next chapter provides the results from quantitative and qualitative data analyses, a discussion of the findings and answers to the research questions.

CHAPTER 4

DATA ANALYSES AND RESULTS

4.1 Introduction

This chapter is devoted to describing the data analyses and reporting the findings from the quantitative survey and qualitative data, and also achievement test data from my study. These findings are discussed in six sections. Each section of this chapter provides results relating to classroom environment, student attitudes to mathematics and achievement.

The findings of this study are reported using the following headings:

- Reliability and Validity of the Arabic Version of WIHIC and Attitude Survey (Section 4.2);
- Associations between Student Attitudes and their Perceptions of the Learning Environment (Section 4.3);
- Effectiveness of Mathematics Games (Section 4.4);
- Differential Effectiveness of Mathematics Games for Different Sexes (Section 4.5); and
- Chapter Summary (Section 4.6).

4.2 Reliability and Validity of the Arabic Version of What Is Happening In this Class? (WIHIC) and Attitude Survey

To examine whether the instruments used in the study were valid and reliable, the first research question was delineated:

> *Are the learning environment questionnaire and attitude questionnaire valid and reliable when used with a sample of 18 to 35*

year-old college-level mathematics students in the United Arab Emirates?

This section describes the reliability and validity of the two instruments under the following subheadings:

- Reliability and Validity of the What Is Happening In this Class? (WIHIC) Questionnaire (Section 4.2.1); and
- Reliability and Validity of the Attitude Scales (Section 4.2.2).

4.2.1 Reliability and Validity of the Arabic version of WIHIC Questionnaire

To examine the reliability and validity of the modified WIHIC when translated into Arabic and used at the college level in the UAE, factor analysis (described in Section 4.2.1.1), internal consistency reliability analysis (described in Section 4.2.1.2) and ANOVA for class membership differences (described in Section 4.2.1.3) were performed with the sample of 352 students from 33 classes.

4.2.1.1 Factor Analysis

As a first step, item and factor analyses were conducted to identify those items whose removal would improve the internal consistency reliability and factorial validity of the WIHIC scales. Principal axis factoring with oblique rotation was used because one can assume that the scales of the WIHIC are somewhat related (Coakes & Ong, 2010). Prior to conducting the factor analysis, the assumptions which underlie the application of the principal axis factor analysis, including the proportion of sampling units to variables and the sample being selected on the basis of representation, were considered. Factor analysis (reported in Table 4.1) confirmed a slightly-refined structure for the modified WIHIC comprising 46 items in the 6 scales. The two criteria used for retaining any item were that it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other five modified WIHIC scales.

Table 4.1 Factor Loadings, Percentage of Variance and Eigenvalues for the Arabic version of WIHIC

Item Number	Factor Loading					
	Student Cohesiveness	Teacher Support	Involvement	Cooperation	Equity	Personal Relevance
1	0.62					
2	0.60					
3	0.70					
4	0.75					
5	0.52					
7	0.62					
8	0.49					
9		0.71				
10		0.66				
11		0.74				
12		0.72				
13		0.75				
14		0.79				
15		0.69				
16		0.69				
18			0.60			
19			0.67			
20			0.78			
21			0.60			
22			0.65			
23			0.60			
24			0.53			
25				0.67		
26				0.68		
27				0.66		
28				0.71		
29				0.69		
30				0.73		
31				0.71		
32				0.58		
33		0.46			0.41	
34					0.75	
35					0.68	
36					0.76	
37					0.75	
38					0.67	
39					0.64	
40					0.68	
41						0.69
42						0.56
43						0.80
44						0.81
45						0.80
46						0.75
47						0.65
48						0.66
% Variance	3.78	6.83	3.91	28.61	5.32	8.12
Eigenvalue	1.74	3.14	1.80	13.16	2.45	3.73

Factor loadings smaller than 0.40 have been omitted.
N =352 students in 33 classes.
Items 6 and 17 were removed

Item analysis indicated that, of the 48 items, all but two items had sizeable item-remainder correlations (i.e. correlations between a certain item and the rest of the scale excluding that item). These two items, Item 6 from the Student Cohesiveness scale and Item 17 from the Involvement scale (whose loadings were less than 0.40 on every scale), were removed from further analysis to improve the factorial validity and internal consistency reliability. Table 4.1 reports the factor loadings for the sample of 352 students for the modified version of the WIHIC.

The remaining 46 items of the modified WIHIC had a loading of at least 0.40 on their *a priori* scale and no other scale, with exception of Item 33 from the Equity scale, which had a loading greater than 0.40 on the Teacher Support scale as well as its own scale. The percentage of variance and the eigenvalue associated with each factor are recorded at the bottom of Table 4.1. The percentage of variance for different scales ranged between 3.78% and 28.61%, with the total percentage of variance accounted for by the 46 items being 56.57%. The largest contribution to variance was for the Cooperation scale (28.61%). The eigenvalues for different WIHIC scales ranged from 1.74 to 13.16.

The results for the factor analysis with oblique rotation, reported in Table 4.1, strongly support the factorial validity of the 46-item, six-scale, Arabic version of the WIHIC when used in college-level classes in the UAE. These findings are consistent with previous research involving use of the WIHIC when translated into the Arabic (Afari et al., in press; MacLeod & Fraser, 2010), Mandarin (Aldridge et al., 1999) and IsiZulu (South Africa) (Aldridge et al., 2009) languages.

4.2.1.2 Internal Consistency Reliability

Internal consistency reliability (Cronbach alpha coefficient) is a measure of the extent to which items in the same scale measure a common construct. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency. Table 4.2 reports the Cronbach alpha coefficient for the revised 46-item version of the Arabic version of the WIHIC, for two unit of analysis (individual and the class mean). The scale reliability estimates ranged from 0.81 to 0.89 with the individual as the unit of analysis. The reliability estimates were higher when the class mean was used as the unit of analysis, ranging from 0.84 to 0.92. As a reliability coefficient of 0.70 or higher is considered to be 'acceptable' in most social science research situations (Streiner & Norman. 2003) these reliability coefficients can be considered satisfactory and are similar to coefficients reported by other studies that have used a translated version of the WIHIC, in countries such as the UAE (Afari et al., in press: MacLeod & Fraser, 2010), South Africa (Aldridge et al., 2009), Korea (Kim et al., 2000) and Turkey (Telli et al., 2006).

Table 4.2 Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with Other Scales) and Ability to Differentiate Between Classrooms (ANOVA Results) for Two Units of Analysis for the Arabic Version of WIHIC

Scale	Number of Items	Unit of Analysis	Alpha Reliability	Discriminant Validity	ANOVA Eta^2
Student Cohesiveness	7	Individual	0.81	0.43	0.15*
		Class Mean	0.84	0.43	
Teacher Support	8	Individual	0.89	0.40	0.15**
		Class Mean	0.90	0.41	
Involvement	7	Individual	0.85	0.47	0.16**
		Class Mean	0.88	0.57	
Cooperation	8	Individual	0.89	0.46	0.18**
		Class Mean	0.91	0.60	
Equity	8	Individual	0.89	0.43	0.13*
		Class Mean	0.88	0.52	
Personal Relevance	8	Individual	0.89	0.33	0.18**
		Class Mean	0.92	0.32	

*p<0.05, **p<0.01
The sample consisted of 352 students in 33 classes.
The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

4.2.1.3 Discriminant Validity

To ensure that the individual scales of the Arabic version of the WIHIC each measure a unique aspect of the learning environment, the discriminant validity was examined. Discriminant validity is a measure of the extent to which scales that should not be related to each other, actually are not related. The mean correlation of a scale with the other scales was calculated as an index of discriminant validity with both the individual and the class mean as the unit of analysis. Table 4.2 reports the results of these analyses.

The mean correlation of a scale with the other scales varied from 0.33 to 0.47 with the individual as the unit of analysis and from 0.32 to 0.60 with the class mean as the unit of analysis, as shown in Table 4.2. These results suggest that the raw scores on the WIHIC assess unique aspects of learning environment, despite some overlap. These results replicate findings from past studies that have utilised the WIHIC (Aldridge et al., 1999; Kim et al., 2000; Velayuthum & Aldridge, 2012).

4.2.1.4 Ability to Differentiate between Classrooms

To examine the ability of each scale of the Arabic version of the WIHIC to differentiate between perceptions of students in different classrooms, an analysis of variance (ANOVA) with class membership as the main effect was used. The last column of Table 4.2 reports the ANOVA results, which indicate the extent to which students in the same class perceive the learning environment relatively similarly, while perceptions vary from class to class. The analysis revealed significant differences ($p<0.05$) between students' perceptions in different classes for all six WIHIC scales. The eta^2 statistic represents the proportion of variance in a scale score accounted for by class membership. The eta^2 values ranged from 0.13 to 0.18 for the different modified WIHIC scales. These results are similar to those of other studies that have utilised the WIHIC (Aldridge et al., 2009; Kim et al., 2000; MacLeod & Fraser, 2010).

4.2.2 Reliability and Validity of the Attitude Scales

Two scales, namely, Enjoyment of Mathematics Lessons and Academic Efficacy, were used to assess the attitudes of students in their mathematics classes (the selection and description of which were provided in Section 3.5.2).

4.2.2.1 Factor Analysis

To examine the internal structure of the Enjoyment of Mathematics Lessons and the Academic Efficacy scales, principal axis factoring with varimax rotation was used. Table 4.3 provides the factor loadings for the modified attitudes scales. As mentioned earlier, the two criteria used for retaining any item were that it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on the other scale.

Table 4.3 Factor Loadings, Percentage of Variance and Eigenvalues for Items for the Enjoyment of Mathematics and Efficacy Scales

	Factor Loading	
Item Number	Enjoyment of Mathematics Lessons	Academic Efficacy
1	0.79	
2	0.79	
4	0.76	
5	0.63	
6	0.88	
7	0.83	
8	0.86	
9		0.70
10		0.83
11		0.75
12		0.81
13		0.69
14		0.81
15		0.58
16		0.70
% Variance	33.61	32.78
Eigenvalue	5.04	4.92

Factor loadings smaller than 0.40 have been omitted
N =352 students in 33 classes

Factor analysis revealed that Item 3 from the Enjoyment of Mathematics Lessons scale loaded below 0.40, and was removed from further analysis to improve the factorial validity and internal consistency reliability. The remaining items all loaded above 0.40 on their own scale and no other scale. The total variance accounted for by these two scales was 66.39%. The eigenvalues for the two scales were 4.92 for Enjoyment of Mathematics Lessons and 5.04 for Academic Efficacy. The results of the factor analysis, reported in Table 4.3, support the factorial validity of the attitudes scales when used with the sample of 352 students.

4.2.2.2 Internal Consistency Reliability

The internal consistency reliability (Cronbach alpha coefficient) for the Enjoyment of Mathematics Lessons and Academic Efficacy scales for two unit of analysis (individual and the class mean), reported in Table 4.4, were 0.92 and 0.94 using the individual as the unit of analysis and 0.94 and 0.97 using the class mean as the unit of analysis, respectively. The high reliability scores for the modified versions of the Enjoyment of Mathematics Lessons and the Academic Efficacy scales are similar to past studies (Henderson, Fisher & Fraser, 2000; Aldridge & Fraser, 2008).

Table 4.4 Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of Analysis for the Enjoyment of Mathematics Lessons and Academic Efficacy Scales.

Scale	Number of Items	Unit of Analysis	Alpha Reliability
Enjoyment of Mathematics Lessons	7	Individual	0.94
		Class Mean	0.97
Academic Efficacy	8	Individual	0.92
		Class Mean	0.94

*p<0.05, **p<0.01 The sample consisted of 352 students in 33 classes.

4.3 Associations between Students' Attitudes and their Perceptions of the Learning Environment

Within the field of learning environments, there has been a strong tradition of investigating associations between various components of the environment and other areas of the educational system and operations (Fraser, 2007, 2012). In particular, there has been a strong history of looking at the relationships between learning environments and attitudes towards a specific subject area (den Brok et al., 2010; Fraser et al., 2010b). In this study, associations between the learning environment perceptions of college students in the UAE and their attitudes towards mathematics were investigated to answer research question 2.

> *Is there a relationship between the nature of the classroom learning environment and student attitudes to mathematics?*

To answer the second research question, the sample of 352 students in 33 classes was used. Simple correlation analysis was considered to be a suitable method for examining the bivariate relationship between each learning environment scale and attitude measure. Simple correlations were calculated for two units of analysis, namely, the individual student and the class mean. In addition, multiple regression analyses were used to determine the joint influence of the set of modified WIHIC scales as independent variables and the Enjoyment of Mathematics Lessons and Academic Efficacy scales as dependent variables, using the individual and the class mean as the units of analysis. Multiple regression analysis provided information about the association between an attitude scale and the set of six learning environment scales. It provides a more parsimonious picture of the joint influence of correlated learning environment scales on an attitude outcome. To identify which of the learning environment scales contributed uniquely and significantly to the explanation of the variance in students attitudes, standardised regression coefficients (β) were examined.

The results for the simple correlation and multiple regression are reported using the following subheadings:

- Associations between Perceptions of the Learning Environment and Enjoyment of Mathematics Lessons (Section 4.3.1); and
- Associations between Perceptions of the Learning Environment and Academic Efficacy (Section 4.3.2).

4.3.1 Associations between Perceptions of the Learning Environment and Enjoyment of Mathematics Lessons

For the simple correlations, reported in Table 4.5, all six WIHIC scales were statistically significant (p<0.01) with the Enjoyment of Mathematics Lessons scale with the individual student as the unit of analysis. With the class mean as the unit of analysis, however, none of the WIHIC scales were statistically significant to the Enjoyment of Mathematics Lessons scale.

The multiple correlation between Enjoyment of Mathematics Lessons scale and the set of six classroom environment scales of the modified WIHIC, reported in Table 4.5, was 0.43 with the individual as the unit of analysis and 0.57 with the class mean as the unit of analysis. The multiple correlation was statistically significant (p<0.01) for both units of analysis. The results for the multiple regression analysis (β), using the individual as the unit of analysis (reported in Table 4.5), indicate that two of the six learning environment scales (namely, Teacher Support and Personal Relevance) uniquely accounted for a significant (p<0.01) amount of variance in student Enjoyment of Mathematics. Using the class mean as the unit of analysis, two of the six learning environment scales (namely, Teacher Support and Cooperation) account for significant (p<0.05) amount of variance in students' Enjoyment beyond that attributable to other environment scales.

4.3.2 Associations between Perceptions of the Learning Environment and Academic Efficacy

The simple correlation between each learning environment scale and the Academic Efficacy scale also are reported in Table 4.5 The correlation was positive and statistically significant (p<0.05) for all six WIHIC scales with the individual as the unit of analysis, but was not statistically significant for any of the WIHIC scales with the class mean as the unit of analysis.

The results reported in Table 4.5 indicate that the multiple correlation (R) for Academic Efficacy and the set of the learning environment scales was 0.30 and statistically significant (p<0.01) with the individual as the unit of analysis. Inspection of the standardised regression coefficients (β) indicates that one of the six WIHIC scales, Personal Relevance, was statistically significant (p<0.01) to Academic Efficacy.

Table 4.5 Simple Correlation and Multiple Regression Analyses for Associations between Enjoyment of Mathematics Lessons and Academic Efficacy and Classroom Environment Using the Individual and Class Mean as the Units of Analysis

Scale	Unit of Analysis	Attitude-Environment Associations			
		Enjoyment		Academic Efficacy	
		r	β	r	β
Student Cohesiveness	Individual	0.14**	-0.04	0.17**	0.08
	Class Mean	0.06	0.08	0.15	0.07
Teacher Support	Individual	0.31**	0.23**	0.19**	0.07
	Class Mean	0.28	0.48*	0.26	0.31
Involvement	Individual	0.21**	0.08	0.18**	0.06
	Class Mean	0.19	0.21	0.27	0.22
Cooperation	Individual	0.17**	-0.07	0.11*	-0.11
	Class Mean	0.07	0.68*	0.20	-0.33
Equity	Individual	0.22**	0.02	0.19**	0.07
	Class Mean	0.23	0.01	0.23	0.04
Personal Relevance	Individual	0.36**	0.31**	0.25**	0.21**
	Class Mean	0.35	0.54	0.31	0.34
Multiple Correlation (R)	Individual		0.43**		0.30**
	Class Mean		0.57**		0.41

The sample consisted of 352 students in 33 classes in the UAE.
*p<0.05
**p<0.01.

4.4 Effectiveness of Mathematics Games

The second phase of the study involved investigation of the effectiveness of the *Jeopardy!*-type games in mathematics classes in the UAE. Hence the third question asked:

Is using mathematical games effective in improving:

- *i. the classroom learning environment?*
- *ii. students' attitudes to mathematics?*
- *iii. students' mathematics achievement?*

As described in Chapter 3, the present study involved a mixed-method approach in which quantitative data were supplemented with qualitative data collected from students and teacher interviews and observations of classes that were exposed to the *Jeopardy!*-type games. A narrative, based on observations in all of the classes, was used to provide an understanding of the games in action and then analysed to examine the effectiveness of the use of games in terms of the classroom learning environment and students' attitudes towards mathematics, following the recommendation of Polkinghorne (1995).

Second, a pre-test–post-test design, involving the administration of questionnaires and achievement test (mid-semester and final examination), before and after the introduction of mathematics games, was used to determine effectiveness. Finally, interviews with students who participated in the games activities were conducted to help to explain the quantitative data. Interviews were also conducted with the teachers who used the mathematics games in their classes.

This section reports the results of the analysis and triangulation of quantitative data and qualitative information using the following subheadings:

- Narrative of Classroom Observations (Section 4.4.1);
- Pre-test–post-test Differences in Learning Environment and Student Outcomes (Section 4.4.2); and
- Explaining Pre-test–post-test Differences (Section 4.4.3).

4.4.1 Narrative of Classroom Observations

The following narrative is based on a number of visits to different classes in which the games had been introduced. For each of the teachers, I created a *Jeopardy!*-type game (a PDF interactive, based on the topic for the week) and worked with teachers to ensure that they were confident about using the game with their students. Because the conditions and observations in these classrooms bore a great deal of similarity, the narrative provided below describes a typical lesson involving *Jeopardy!*-type games. The narrative is then interpreted with a commentary immediately after to discuss ways in which the games were effective, following the approach recommended and used in other learning environment studies (Aldridge et al., 1999; Aldridge et al., 2009).

I met Fatima, the teacher of the class that I was visiting, at the college's staff room. As we were already known to each other, the atmosphere was relaxed. As we walked to the classroom, Fatima, an experienced mathematics teacher of 12 years, told me that she is keen to try new teaching methods but does not do so because of time constraints. Although Fatima had read of different methods of teaching, she had not tried them for fear that her students' grades might be jeopardised.

When we arrived at the class, it was about 10 minutes before the start of the lesson. The students were aware that I was coming and most of them were already seated when we got there. This was to be the first lesson involving jeopardy games to which they had been exposed. The classroom, as with all of the college classrooms in the UAE, was well equipped with an interactive white board, an LCD projector and a desktop computer for the teacher's use. The 12 students were all male UAE nationals, dressed in the traditional white 'kandoura' (robe) and 'ghutrah' (head cloth) with a black 'aqal' (rope) around the ghutrah. The students were aged between 19 and 23 years and were studying mathematics as part of their engineering program. When Fatima introduced me, they shouted the customary "Welcome to our class".

In readiness for today's lesson, Fatima had assigned the students to two groups that were relatively similar in terms of the number of low and high achievers. At this point, she reminded the students about the groups to which they had been allocated, and instructed them to arrange the tables so that they were facing each other. During the shuffle of desks and chairs, there was a great deal of excitement and noise. This was something new, as traditionally in UAE settings, desks are arranged so that students face the front of the class.

Once the students were settled, Fatima explained the rules of the game. She told them that today's game was based on trigonometric identities, a topic that they had studied in the previous lesson. Fatima started the session with some revision and 'warmed' up the students with problems similar to the ones that they would *encounter during the game. The revision session was fast, lasting less than 10 minutes, and the students listened intently, apparently keen to give their team an advantage. Fatima then proceeded to introduce the Jeopardy!-type game.*

The game board was projected onto the whiteboard and Fatima carefully explained the rules. She explained that the game included questions related to trigonometric identities and involved four categories of (1) Fundamental Identities, (2) Using Fundamental Identities, (3) Verifying Identities and (4) Applying the Cosine and Sine difference to Voltage. As she read each one out aloud, she pointed to the column that included questions for that category. She then indicated the four blocks beneath each category, and explained that the numbers on each were the point value for each of the questions. The higher the point value, the more difficult the question was likely to be. She went on to explain that each group would take turns in selecting a category and a question and that, once the group had selected a category, she would click on the cell and the corresponding question would become visible.

Once Fatima was satisfied that the rules of the games had been understood, she flipped a coin to help to decide which of the two groups (Group 1 or Group 2) would make the first selection. When the toss indicated that Group 2 had won, students cheered loudly. The hush from the members of Group 1 made their disappointment clear. Fatima's quick reassurance, that the first selection did not have any bearing on who would win the game, helped them to overcome their disappointment.

The second group was instructed to select a category and a block. Students were clearly hesitant and, after considerable deliberation, they decided to select the fundamental identities category (which included questions related to expressing one function in terms of another) and the cell with the lowest value of points – clearly 'testing the water'.

Fatima clicked on the selected block and read out the question: "Express cos x in terms of tan x". The group began to talk excitedly to each other but, after a couple of minutes when it became clear that students were confused about how to answer the question, Fatima stepped in to give them a clue – because sec x is related to both cos x and tan x by identities, they should start with $1 + tan^2x = sec^2x$*. With this clue, the members of the group proceeded to try to solve the problem* *individually. Fatima encouraged the other group also to try solving the problem. The members of Group 2 began to compare their answers and, as some of the answers were different, students started to explain to each other how they had calculated their answer. It was clear from the discussion generated within the group that students were forced to negotiate their answers and, if convinced that they were correct, justify and persuade the other group members that theirs was the one to choose. Once the group members had agreed on an answer, they shared it with Fatima. It was correct and the group jumped and shouted boisterously. The value for that question was given to the team and Fatima went on to ask one of the team members to solve the problem on the board for the benefit of all of the students.*

It was now Group 1's turn to make a selection. Fatima also provided this group with a hint when students appeared to be struggling. After several minutes of sharing and discussing ideas, they agreed on an answer, which was correct. Again there was much shouting and hugging.

Both teams had to answer eight questions. As the game progressed, students became more confident. After all of the questions have been answered, the game was declared a tie. Each of the teams promised to win the next time that they play the game. The students expressed how much they had enjoyed playing the game and asked Fatima to let them play games after every lesson.

4.4.2 Commentary Based on Narrative

The narrative describes how the members of the group worked together to solve problems. The amount of talking and excited hand gestures, as students tried to decide which answer was correct, suggested a high level of engagement among the students. According to Park (2005) and Finn and Voelkl (1993), one of the most persistent issues impeding student learning in mathematics is the lack of student engagement. A study conducted by Park (2005) indicated that higher levels of student engagement had positive effects on student academic growth in mathematics.

In addition to being engaged, students exhibited excitement, suggesting that the games made them more motivated. All of the teachers who were interviewed felt that games had made their students more motivated to learn and to be involved. One teacher stated: “I have enjoyed playing games with my students because the students became more motivated.” Another teacher commented: “I think playing games affects the students in a very positive way. When using traditional methods of teaching, some of the students think that mathematics is dry and uninteresting but, with the games, they realise that mathematics can be fun.” A third teacher commented that “the advantage of using the games is that it makes my students more motivated.”

The narrative suggests that the use of games provided opportunities for students to interact with each other. Research indicates that student interaction through classroom discussion and other forms of interactive participation is foundational to deep understanding and is related to student achievement (Bruce, 2007). In a study of mathematics classroom activity, student interaction was one of the essential characteristics of effective mathematics teaching (Ross, McDougall, Hogaboan-Gray & LeSage, 2003).

According to the narrative, students shared ideas and helped one another and, if the answer was correct, the teacher would ask one of the members of the group to present the solution to the rest of the class. Alternatively, if the answer was incorrect, the teacher explained the solution to the whole class. According to Bruce (2007), encouraging productive argumentation and justification in class discussions leads to greater student understanding in mathematics. As students played the *Jeopardy!*-type games in class, they continuously argued and justified their solutions before agreeing on an answer.

The teachers who introduced the games in their classes commented on their six-week experience with the *Jeopardy!*-type games. Like most teachers, these teachers faced many challenges related to the complexities of teaching mathematics in ways that they had not experienced themselves when they were students. These teachers lacked any sustained professional development opportunities in addition to a lack of time, especially in the face of curricular demands. The interview data suggest that the introduction of games changed the teachers’ perceptions of the use of games in mathematics classroom. When asked to briefly describe whether they enjoyed playing mathematics *Jeopardy!*-type games with their students, one of the teachers commented: “I enjoyed it a lot and I think my students enjoyed it too. I think the reason that they enjoyed it is that they were all able to participate and really had fun experiencing something other than classroom lecturing and listening.” Another stated: “I enjoyed it very much. It is good to see the students involved in teamwork with each other and the designated speaker to get the final answer.”

All the teachers who introduced the *Jeopardy!*-type games in their classrooms felt that the mathematics games were beneficial, but that they had not used them because of time constraints and the pressures associated with having to complete the syllabus. When asked to relay what they considered to be the benefits and pitfalls of using *Jeopardy!*-type games in the classroom, one teacher stated that “I see lots of benefits because I think that the students find it different, and it makes them more active as active learners. The pitfall will be the timing. When you are tight with timing, it is difficult to play many games with them.” Another disadvantage perceived by a teacher was that “the class sometimes becomes too noisy during the game playing. The students often seem to be aggravated and shout out the answers – not fighting, but raising their voices at each other. It’s just a matter of noisy classroom, that’s all.”

According to the narrative, the teacher gave the students support during the game, by providing hints and ideas to help them to solve the problems. The students enjoyed playing the *Jeopardy!*-type game and urged their teacher to play mathematics games with them more often.

4.4.3 Pre-test–post-test Differences in Learning Environment and Student Outcomes

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, attitude scales and achievement tests were administered to all students. To provide a measure of the effectiveness, differences between students’ pre-test and post-test scores on the WIHIC, attitudes (Enjoyment of Mathematics Lessons and Academic Efficacy scales) and achievement 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 (WIHIC) and student outcomes (attitudes and achievement) constituted the dependent variables and the testing occasion (pre-test/post-test) constituted the independent variable. Table 4.6 reports the average item mean, average item standard deviation, effect size, and MANOVA results for pre-test–post-test differences for each of the WIHIC scales and student outcomes (attitudes and achievement). The average item means indicate that, for all six WIHIC scales and student outcomes (attitudes and achievement), students' scores increased during the use of games.

Because the multivariate test yielded significant pre-test–post-test differences, overall using Wilks' lambda criterion, the univariate ANOVA for each individual scale was interpreted and recorded (last column of Table 4.2). Statistically significant pre-test–post-test differences emerged for three of the six WIHIC scales (namely, Teacher Support ($p<0.05$), Involvement ($p<0.01$) and Personal Relevance ($p<0.01$)) and for both the attitudes (Enjoyment of Mathematics Lessons and Academic Efficacy) and achievement ($p<0.01$).

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 ranged between 0.12 to 0.18 standard deviations, which are considered to be 'small' according to Cohen's (1992) criteria. There was also a statistically significant pre-test–post-test difference in achievement (effect size = 0.38 standard deviations). The According to the quantitative 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 improved student outcomes (Enjoyment of Mathematics Lessons, Academic Efficacy and Achievement).

Table 4.6 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 Arabic Version of the WIHIC, Attitude Scale and Achievement

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**
Achievement	76.23	84.13	10.86	8.29	0.38	4.24**

N=90 student in 8 classes present for both the pre-test and post-test
**p*<0.05 ***p*<0.01
Effect size was calculated using formula of $d= M_1-M_2/\sqrt{[(\sigma_1^2+\sigma_2^2)/2]}$, $r_{Y\lambda}=d/\sqrt{(d^2+4)}$

4.4.4 Explaining Pre-test–Post-test Differences

To help to explain the statistically-significant pre–post differences for specific scales, information gleaned from interviews and observations with students and teachers was used. As reported in Chapter 3, the interviews involved three of the teachers who introduced the games in their classrooms and 20 of the students (seven females and 13 males) who were exposed to mathematics games. Analyses of the information collected during interviews and observations were used to help explain the statistically significant pre-post differences for Teacher Support (described in Section 4.4.4.1), Involvement (described in Section 4.4.4.2), Personal Relevance (described in Section 4.4.4.3), Enjoyment of Mathematics Lessons (described in Section 4.4.4.4), Academic Efficacy (described in Section 4.4.4.5) and achievement (described in Section 4.4.4.6.

4.4.4.1 Teacher Support

The Teacher Support scale assesses the extent to which the teacher helps, relates to, trusts and is interested in students. The teacher's relationship with his or her students is an important aspect of any learning environment, which can lead the student to love or hate a subject, and to be inspired or turned away from learning (Aldridge, Fraser, Bell & Dorman, in press). The supportiveness of a teacher helps to give students the courage and confidence needed to tackle new problems, take risks in their learning, and work on and complete challenging tasks. If students consider a teacher to be approachable and interested in them, then they are more likely to seek the teacher's help if there is a problem with their work. The teacher's relationship with his or her students, in many ways, is integral to a student's success and to creating a cooperative learning environment (Hijzen, Boekaerts & Vedder, 2007).

Almost all students who were interviewed agreed that they felt that their teachers were more approachable after the use of games and that they were more comfortable about seeking help from the teacher if there was a problem with their work. To this end, one student commented, "If I have trouble with my work, I ask my teacher for help and she works with me to solve the problem. My teacher gives me strategies, ideas and information to solve the problem." The students who were interviewed, perceived their teachers to be more supportive after the use of games. These students also generally agreed that the teacher seemed to be more interested in their learning.

4.4.4.2 Involvement

The Involvement scale assesses the extent to which students feel that they have opportunities to participate in discussions and have attentive interest in what is happening in the classroom. The Involvement scale assumes that language plays an important part in helping students to understand what they are learning (Taylor & Campbell-Williams, 1993) and that giving students the opportunity to participate in classroom discussions and to negotiate ideas and understandings with peers, rather than listening passively, is an important aspect of the learning process (Aldridge et al., in press). Classroom observations that were undertaken as the games were played in mathematics lessons indicated that students were actively involved when they were playing the *Jeopardy!*-type game. They were engaged in discussions with their team-mates and often they were forced to negotiate their ideas. An interesting point made by one of the students was that, "when we play the game, it gives us a chance to challenge the information that we have in our minds".

When the students were asked to comment on the level of involvement, they all agreed that there were more opportunities to discuss their ideas during lessons with games than during their regular mathematics classes. The students who were interviewed generally felt that their comments were respected by their fellow students and that the games enabled students to be more involved in the learning process. One student commented: "We gather all of the ideas and we decide on the best one. We respect each student's ideas." Another student remarked: "Discussing ideas in class was very important. We needed to understand what each student was talking about so that we could answer correctly." Research supports the notion that, if students are actively involved in learning activities such as playing mathematics games, then it is likely that learning will be more meaningful to students (Kangas, 2010; Kember, Ho & Hong, 2010).

4.4.4.3 Personal Relevance

To ensure that students engage in their learning, it is necessary for teachers to make mathematical content relevant to students' lives outside school (Nicol, 2002; Taylor et al., 1997). The Personal Relevance scale assesses the connectedness of a subject with students' out-of-school experiences. Interviews with students did not make clear how the mathematics games led to increased students' scores on the Personal Relevance scale. However, students agreed that mathematics in general was relevant to their lives. One student commented that "mathematics is not only in our studies, but we use mathematics everywhere, even in our lives." Another commented: "Mathematics is very important because we can use it in our lives. In my life, I use maths every day. If I buy or sell something, I use maths." Another student commented that often teachers did not identify applications of a mathematics topic to real life and suggested that, "when we start a new lesson, maths teachers should tell us how the lesson is related to real life because sometimes we take lessons and we don't know how we can use it.”

4.4.4.4 Enjoyment of Mathematics Lessons

The Enjoyment of Mathematics scale assesses the extent to which students enjoy their mathematics lessons (Spinner & Fraser, 2005). I was interested in finding out how students regarded their mathematics class. Students were asked about their enjoyment of mathematics both before and after the use of games in their classroom. The students who were interviewed generally felt that they did enjoy mathematics more when the games were included. One student commented: “In my opinion, having games in mathematics makes the lesson interesting. Games help me to understand the topic more easily than when the teacher is on the board explaining. With games, we did not feel bored, it was fun and I had a better understanding of mathematics.” According to another student: “Without using the games, mathematics lessons are not interesting. When we use games, the information sticks in our memories.” Another stated: “Games make mathematics fun. They also help students to understand more.”

The students who were interviewed generally agreed that the introduction of games in their mathematics class improved their enjoyment of mathematics lessons. All teachers who were involved agreed that the introduction of mathematics games increased the enjoyment of mathematics lessons for their students. One teacher commented: “When games are used, the students can see that mathematics can be fun. They enjoyed playing games together.” Another stated: “Playing games has a big impact on the students, especially those who are bored with worksheets and textbooks.”

4.4.4.5 Academic Efficacy

A student’s academic efficacy positively affects engagement and effort and is important to learning (Aldridge & Fraser, 2008; Bandura, 1989; Velayutham et al., 2012; Zimmerman et al., 1992). Many of the students who were interviewed commented about how the use of mathematics games had affected how well that they felt that they were performing in mathematics. One student commented: "Before we started using games, I thought mathematics was complicated, but now I have realised that, if I try, I can solve it."

Many of the students felt that the use of games helped them to understand and remember concepts. Various students commented:

5 The games helped me to understand more.
6 In general, people think that mathematics is very difficult, but sometimes I find it easy when we play games.
7 The games make the mathematics lesson easier and more interesting.
8 Actually it makes the ideas stick in my mind. In the test, I actually remembered one question that we played in the class; so, it is kind of fun and important.

Some students felt that the competitive aspect of the game encouraged students to work harder than they would have otherwise. Students commented:

- When we are put in groups and have to compete, we work harder.
- The games affected all the students in the class not just me, because when you play games in mathematics it is a challenge for us to answer the questions before my friends or the other team answers the question. This gives me a proof of how I am doing in mathematics and also prove to my friends that I am clever.

Of the 20 students who were interviewed, one of the students did not feel that games made a difference to the way in which he felt about his ability. This student commented that "the games did not really affect my feelings about how well I will do, but I find them better than doing work from the book."

Finally, some of the students who were interviewed felt that the use of mathematics games positively affected their outcomes. One student commented that "I am doing well because I like mathematics with games." Another stated: "The games were very good. After the lessons, students are prepared to answer each question correctly.

Some of the questions that we have seen in the games might be in the final exam. In a funny way, the games have helped us."

4.4.4.6 Achievement

This section reports the results of the students' achievement before and after the introduction of *Jeopardy!*-type games for the sample of 90 students from three colleges-level in the UAE. Table 4.6 presents students' achievement for the students who were exposed to *Jeopardy!*-type games in terms of average item mean scores and average item standard deviation. Table 4.6 also reports differences between pre-test and post-test in terms of both effect size (the difference in means expressed in standard deviation units) and MANOVA with repeated measures. The results in Table 4.6 show that the students' post-test scores was significantly higher than their pre-test scores. The effect size was 0.38 standard deviations. This effect size suggests that the difference between the pre-test and post-test was of moderate magnitude. These results suggest an improvement in the students' achievement with the introduction of the *Jeopardy!*-type games.

It would appear that the six weeks of including *Jeopardy!*-type games in college mathematics classes had impacted positively on both the teachers and students. All teachers stated that they were planning to incorporate games in their lessons in the future and the students who were interviewed were keen for them to do so.

4.5 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. The fourth question was:

> *Is the use of games activities in mathematics instruction differentially effective for males and females in terms of:*
>
> *i. classroom learning environment?*
> *ii. students' attitudes towards mathematics?*
> *iii. students' mathematics achievement?*

This section reports the use of a two-way MANOVA with repeated measures to investigate 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 the statistical significance of the interaction between the occasion (pre-test or post-test) and sex (male or female) interaction.

For the two-way MANOVA, the independent variables were the testing occasion (pre-test or post-test) and sex, and the dependent variables were the eight learning environment scales and attitudes scales. Testing occasion was the repeated measures 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 4.7).

As anticipated, the results in Table 4.7 for testing occasion from the two-way ANOVAs (with control for sex) match the results of the MANOVA for pre-test–post-test differences for each of the modified WIHIC and attitude scales. 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, Academic Efficacy and achievement.

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 attitude scale. For example, Table 4.7 shows that 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 0.03 to 0.04 for the attitude scales.

Table 4.7 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
Achievement	32.39**	0.15	8.32**	0.04	1.07	0.01

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

The results in Table 4.7 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, the two-way ANOVA focuses on whether differences exist between females and males regardless of testing occasion. As shown in Table 4.7, 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 and male students scoring higher on the achievement test than their female counterparts. The proportion of variance for these significant differences (eta²) ranged from 0.04 to 0.11.

For the only statistically significant interaction, Student Cohesiveness, the amount of variance accounted for was 0.06. Figure 4.1 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 4.1 suggests that males' perception of Student Cohesiveness improved, while female scores deteriorated, during the use of games. The reason why the male students' perception of Student Cohesiveness improved 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. This interaction, and the reasons why it occurred, would make an interesting and important subject for future research.

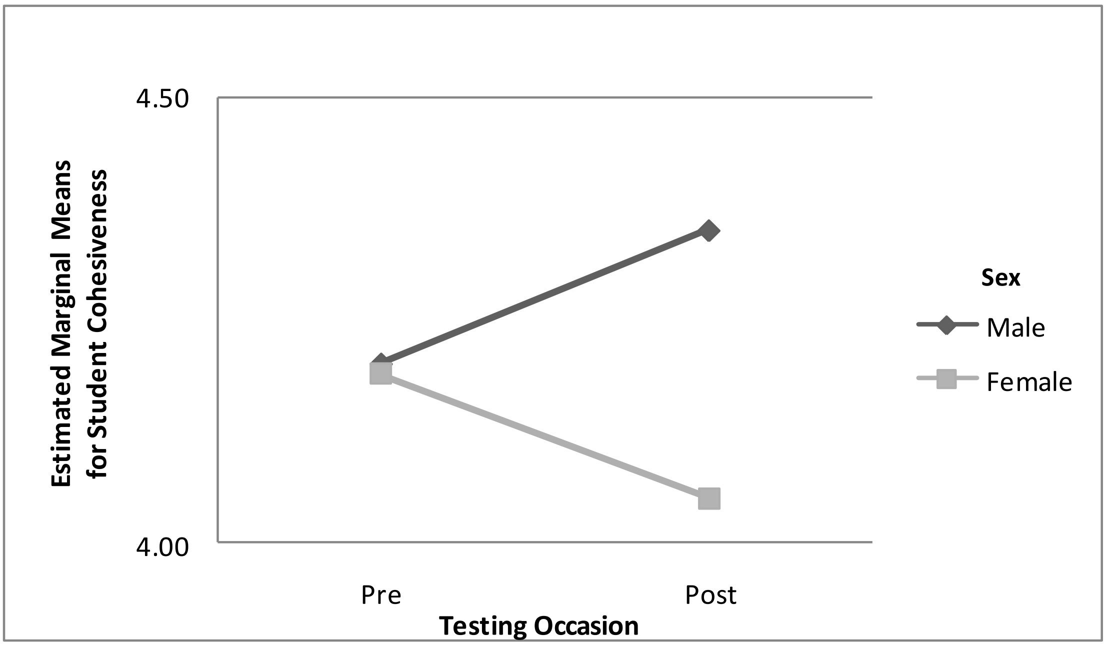

Figure 4.1 Interaction between Testing Occasion and Sex for Student Cohesiveness

4.6 Summary of Analyses and Results

This chapter reported results and analyses for my study which involved a mixed-method approach. In order to answer the research questions, a sample of 352 college-level students in 33 classrooms from the UAE and a subsample of 90 students, who were exposed to the *Jeopardy!*-type games, participated in the study. Chapter 4 has provided the results of the following:

- Reliability and Validity of the Arabic Version of the WIHIC and Attitude Survey (Section 4.2);

- Associations between Student Attitudes and their Perceptions of the Learning Environment (Section 4.3);
- Effectiveness of Mathematics Games (Section 4.4);
- Differential Effectiveness of Mathematics Games for Different Sexes (Section 4.5).

In order to answer the first research question, which examined whether scales assessing classroom environments and attitudes to mathematics were valid and reliable when used with college-level students in the UAE, data were collected from the administration of a modified WIHIC and two attitudes scales (namely, Enjoyment of Mathematics Lessons and Academic Efficacy) to a sample 352 college-level students. The data gathered were analysed to provide evidence with respect to the factor structure, internal consistency reliability, and discriminant validity. As well, the ability of the modified WIHIC to differentiate between classrooms was investigated. The findings are summarized below:

Finding 1: The modified WIHIC and Attitude scales displayed satisfactory factorial validity. The total proportion of variance accounted for was 56.57% for the modified WIHIC and was 66.39% for the attitude scales.

Findings 2: The modified WIHIC and Attitude scales demonstrated satisfactory internal consistency reliability for two units of analysis (individual and the class mean).

Findings 3: Discriminant validity for each scale of the modified WIHIC (using the mean correlation of a scale with the other scales) was satisfactory for both units of analysis.

Findings 4: ANOVA revealed that each scale of the modified WIHIC was able to differentiate significantly between the perceptions of students in different classrooms.

The findings for the second question involving the associations between Student Attitudes and their perceptions of the Learning Environment are summarized below:

Findings 5: There was a statistically significant simple correlation between each attitude scale (Enjoyment of Mathematics Lessons and Academic Efficacy) and each of the six WIHIC scales with the individual as the unit of analysis, but not with the class mean as the unit of analysis.

Findings 6: Multiple regression analysis suggested that students' enjoyment of their mathematics lessons was more positive in classrooms with greater Teacher Support, Cooperation and Personal Relevance, and that academic efficacy was higher in classes with more Personal Relevance.

In order to answer the third research question involving an investigation of the effectiveness of games activities in mathematics instruction, changes between pre-test and post-test in students' perceptions of the learning environment and their outcomes (attitudes and achievement) were analysed for 90 students who were introduced to *Jeopardy!*-type mathematics games. A narrative, based on classroom observations of students playing *Jeopardy!*-type mathematics games, provided insights into games in action in the classrooms. The data were analysed to examine students' interactions during the games and to triangulate, clarify and explain students' responses to the learning environment and attitude questionnaires.

Findings 7: The narrative suggested that, with the introduction of games in the classroom, students were given the opportunity to interact with each other and to explain and compare their mathematical solutions with those of their team-mates.

Findings 8: Pre-test–post-test differences for three of the six learning environment scales, namely, Teacher Support (effect size = 0.12 standard deviations), Involvement (effect size = 0.15 standard deviations), and Personal Relevance (effect size = 0.18 standard deviations) and both attitude scales, namely, Enjoyment of Mathematics Lessons (effect size = 0.13 standard deviations) and Academic Efficacy (effect size = 0.13 standard deviations) and achievement (effect size = 0.38 standard deviations) were positive and statistically significant.

Findings 9: Analysis of the interviews suggested that the students generally enjoyed mathematics more when games were included in their lessons. The information obtained from interviews with students and teachers helped to explain pre-test–post-test differences for those scales for which differences were statistically significant (Teacher Support, Involvement, Personal Relevance, Enjoyment of Mathematics Lessons and Academic Efficacy scales).

Finally, the result for the fourth question, which addressed whether the effectiveness of mathematical games was different for male and female students in terms of classroom learning environment and outcomes (attitudes to mathematics and mathematics achievement) are summarized below:

Findings 10: The results suggests that, whereas the Student Cohesiveness scores of 90 males and females were similar for the pre-test, males' perceived greater cohesiveness than did females for the post-test. Males' perception of Student Cohesiveness improved, while female score deteriorated, during the use of games. This might be because, during the playing of the Jeopardy!-type games in class, male students seemed eager to win and so they worked more closely together to win the game than did female students.

Whilst this chapter reported the results of the analyses of data collected using a mixed-method approach involving surveys, students' achievement scores, interviews, observations of classes and narratives, the next chapter provides a summary of my thesis and discusses the findings of my study. It also includes a discussion of my study's significance, limitations, and educational implications, as well as recommendations for further research.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a discussion of the significance, findings, limitations of the study, as well as providing recommendations for future studies. The theoretical framework of my study commenced from a positivistic approach and moved to a more interpretative approach as the study progressed (Creswell, 2009; Creswell & Plano Clarke, 2010; Denzin & Lincoln, 2000).

A mixed-method approach, combining quantitative and qualitative research methods, was used to assess student perceptions of the learning environment and students' attitudes towards their mathematics class. A feature of recent research in the field of learning environment has been the combination of quantitative and qualitative methods to provide a clearer picture of the data and those subjects involved in the sample (Fraser, 2012; Fraser & Tobin, 1991; Tobin & Fraser, 1998). For example, Aldridge et al. (1999) combined the use of the WIHIC questionnaire with classroom observations, narrative stories and interviews with students and teachers in their study of the nature of classroom environments in a cross-national study involving Taiwan and Australia. In that study, the qualitative information complemented the quantitative information and clarified patterns within the two countries and differences between them.

In a mixed-methods approach, the researcher draws from both quantitative and qualitative assumptions, involving different worldviews and different assumptions (Cherryholmes, 1992; Creswell, 2009; Creswell & Plano Clarke, 2010). By bringing together both quantitative and qualitative data collection, research is likely to lead to a better understanding of research problems than when reliant on a single approach (Creswell & Garrett, 2008). Therefore, both qualitative and quantitative research methods were used in the present study to investigate associations between the perceived learning environment of students and their attitudes.

The final chapter of this thesis is presented under the following headings:

- Discussion of Results (Section 5.2);
- Significance of the Study (Section 5.3);
- Limitations of the Study (Section 5.4);
- Recommendations for Further Research (Section 5.5); and
- Educational Implications (Section 5.6)

5.2 Discussion of Results

This section summarises the research method of my study in terms of: the reliability and validity of the modified What Is Happening In this Class? (WIHIC) questionnaire and attitudes scales (discussed in section 5.3.1); relationships between learning environment and attitudes (discussed in section 5.3.2); effectiveness of mathematics games (discussed in section 5.3.3); and differential effectiveness of mathematics games for males and females (discussed in section 5.3.4).

5.2.1 Reliability and Validity of the Arabic version of the WIHIC and Attitudes Scales

The modified WIHIC questionnaire used in my study had 48 items with eight items in each of six dimensions that can be considered relevant to mathematics classes, namely, Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity and Personal Relevance. The two attitude scales, Enjoyment of Mathematics Lessons and Academic Efficacy scales, also had 8 items in each. The modified WIHIC questionnaire and the two attitude scales (Enjoyment of Mathematics Lessons and Academic Efficacy) were administered to 33 mathematics classes selected from three colleges in the UAE. The administration provided a sample of 352 students.

The reliability and validity of the modified WIHIC was examined by using principal axis factoring with oblique rotation. Factor analysis identified those items whose removal would improve the factorial validity of the WIHIC scales. In checking the reliability of a scale, it is necessary to establish that each item in a scale assesses a common construct. If this is the case, then the scale is referred to a having internal consistency (Pallant, 2007). One of the most commonly-used indicators is Cronbach's alpha coefficient. According to DeVellis (2003), Cronbach alpha coefficient of a scale should be above 0.7. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency in my study. The scale reliability estimates ranged from 0.81 to 0.89 with the individual as the unit of analysis.

To examine the ability of each scale of the modified WIHIC to differentiate between perceptions of students in different classrooms, an analysis of variance (ANOVA) with class membership as the main effect was used. The analysis revealed statistically significant differences ($p<0.05$) between students' perceptions in different classes for all six WIHIC scales.

The results of the factor analysis of the Enjoyment of Mathematics Lessons and the Academic Efficacy scales with principal axis factoring with varimax rotation supported the factorial validity of the attitudes scales when used with the sample of 352 students. When the internal consistency reliability (Cronbach alpha coefficient) for the Enjoyment of Mathematics Lessons and Academic Efficacy scales for two unit of analysis (individual and the class mean) were calculated, scale reliability estimates were 0.92 and 0.94, respectively, using the individual as the unit of analysis and 0.94 and 0.97, using the class mean as the unit of analysis.

The results related to the reliability and validity of the modified WIHIC when administered to 352 college students in the UAE, compared favourably with past research with diverse samples in numerous countries. For example, my research compared favourably with validation studies involving translated versions of the WIHIC in:

- The Arabic language among 763 female college students in the UAE (MacLeod & Fraser, 2010);
- The Chinese language among 1879 junior high school science students in Taiwan (Aldridge et al., 1999);
- The IsiZulu language among 1077 primary school students in South Africa (Aldridge et al., 2009);
- The Indonesian language among 594 junior high school science students (Fraser et al., 2010a); and
- The Korean language among 543 secondary science students (Kim et al., 2000).

In addition my study compared favourably with the validity findings of diverse studies that have used versions of the WIHIC in the English language in numerous countries, including:

- The USA with 665 middle-school science students in California (den Brok et al., 2006), 1434 middle-school science students in New York (Wolf & Fraser, 2008), 661 middle-school mathematics students in California (Ogbuehi & Fraser, 2007) and 520 elementary science students in Miami (Allen & Fraser, 2007);
- Australia with samples of junior high school science students consisting of 1081 student (Aldridge et al. 1999) and 567 students (Fraser et al., 2010a);
- Singapore with 2310 grade 10 geography and mathematics students (Chionh & Fraser, 2009) and 250 working adults attending computer application courses (Khoo & Fraser, 2008);
- Canada and Australia with 1404 students in technology-rich classrooms (Zandvliet & Fraser, 2004; 2005);

- In Jammu, India among 1021 middle-school science students (Koul & Fisher, 2005); and
- Australia, the UK and Canada with 3980 high school students (Dorman, 2003b).

The sound factorial validity and internal consistency reliability of the two attitude scales (Enjoyment of Lessons and Academic Efficacy), when used with college students in the UAE, also replicates past research (Aldridge & Fraser, 2008; Fraser et al., 2010a; Ogbuehi & Fraser, 2007).

5.2.2 Relationships between Learning Environment and Attitudes towards Mathematics

The sample of 352 college-level students in the UAE was also used to explore associations between learning environment perceptions and their attitudes towards mathematics. Simple correlation analysis was used to examine the bivariate relationship between each learning environment scale (Student Cohesiveness, Teacher Support, Involvement, Cooperation, Equity and Personal Relevance) and attitude measure (Enjoyment of Mathematics Lessons and Academic Efficacy). With the individual student as the unit of analysis, all six WIHIC scales were positively and statistically significantly correlated with both Enjoyment of Mathematics Lessons and Academic Efficacy. With the class mean as the unit of analysis, however, none of the WIHIC scales were statistically significant and correlated to either students' Enjoyment of Mathematics or Academic Efficacy.

Multiple regression analysis was used to provide a more parsimonious picture of the joint influence of correlated learning environment scales on each attitude outcome. To identify which learning environment scales contributed uniquely and significantly to the explanation of the variance in students' attitudes, standardised regression coefficients (β) were examined. The correlation between Enjoyment of Mathematics Lessons and the six classroom environment scales of the modified WIHIC was 0.43 with the individual as the unit of analysis and 0.57 with the class mean as the unit of analysis and was statistically significant for both units of analysis. The multiple regression analysis (β), using the individual as the unit of analysis, revealed that two of the six learning environment scales (Teacher Support and Personal Relevance) uniquely accounted for a significant amount of variance in student Enjoyment of Mathematics. Using the class mean as the unit of analysis, the two learning environment scales of Teacher Support and Cooperation accounted for significant amounts of variance in students' academic efficacy beyond that attributable to other environment scales.

The multiple correlation for Academic Efficacy and the set of the learning environment scales was statistically significant with the individual as the unit of analysis but not for class means. Inspection of the standardised regression coefficients indicated that one of the six WIHIC scales, Personal Relevance, was statistically significant and independently related to Academic Efficacy. Importantly, every statistically significant simple correlation and regression coefficient was positive, thus replicating considerable past research which has consistently reported positive associations between the classroom environment and students' attitudes (Fraser 2007, 2012).

5.2.3 Effectiveness of Mathematics Games

My study evaluated the effectiveness of games activities in mathematics instruction at the college-level in the UAE in terms of changes in students' learning environment and student outcomes (attitudes and achievement). A subsample of 90 students responded to achievement tests in addition to classroom environment and attitude questionnaires before and after the *Jeopardy!*-type games.

Differences between students' pre-test and post-test scores on the modified WIHIC and student outcomes (attitudes and achievement) 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, and achievement 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-test–post-test differences for each of the modified WIHIC and student outcomes were reported. The average item means indicated that, for all six WIHIC scales and student outcomes (attitudes and achievement), students' scores increased after the games had been introduced, and suggesting improved perceptions of the learning environment.

An ANOVA with repeated measures was interpreted for each modified WIHIC and student outcomes (attitudes and achievement). There were statistically significant pre-test–post-test differences (p<0.05) in learning environment scores for three of the six WIHIC scales, namely, Teacher Support, Involvement and Personal Relevance, as well as for Enjoyment of Mathematics (p<0.01), Academic Efficacy (p<0.01) and Achievement (p<0.01).

To help to explain the statistically significant differences and to add depth and richness to the quantitative data, qualitative information was collected using observations (in those classes in which students were exposed to mathematics games) and interviews with 20 students and three teachers. This rich qualitative data provided information regarding students' and teachers' reactions to the use of games in their mathematics lessons.

First, a narrative, based on observations in all of the classes whose students were exposed to the *Jeopardy!*-type games was used to provide an understanding of the games in action. The narrative suggests that, with the introduction of games in the classroom, students had more opportunities to interact with each other. There was a high level of engagement among the students who were excited when playing the games, suggesting high levels of motivation and increased involvement in the learning process. Also, when students were encouraged by their teachers to explain and compare their solutions with their team-mates, there was productive argumentation and justification. According to the Common Core State Standards for Mathematics (2012, p. 4):

> One hallmark of mathematical understanding is the ability to justify, in a way appropriate to the student's mathematical maturity, why a particular mathematical

> statement is true or where a mathematical rule comes from. There is a world of difference between a student who can summon a mnemonic device to expand a product such as $(a + b)(x + y)$ and a student who can explain where the mnemonic comes from. The student who can explain the rule understands the mathematics, and may have a better chance to succeed at a less familiar task such as expanding $(a + b)(x + y)$.

Informed by this, whilst playing games, the students were encouraged by their teachers to share ideas and help one another. These observations, coupled with interviews with students, suggested greater student interactions during the mathematics lesson. Such interaction in the mathematics classroom has been recognised as the foundation for deep understanding, leading to more effective teaching and learning in mathematics (Bruce, 2007; Ross et al., 2003).

Analyses of the information gathered through interviews with students and teachers were used to help to explain the statistically significant pre-test–post-test differences for Teacher Support, Involvement, Personal Relevance, Enjoyment of Mathematics Lessons and Academic Efficacy scales. Analyses of students' interviews indicated that they viewed their teachers as being more supportive, approachable and interested in their learning after the use of games. It was not clear from the interviews with students how mathematics games led to increased students' score on the Personal Relevance scale, but students agreed that mathematics was relevant to their lives. Analysis of the interviews also indicated that the students generally felt that they did enjoy mathematics more when the games were included in their lessons. Students' comments about their academic efficacy revealed how the use of mathematics games affected how well they felt that they were performing in mathematics.

The results of my 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.

5.2.4 Differential Effectiveness of Mathematics Games for Different Sexes

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 the presence of a statistically significant 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 eight 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. The results for testing occasion from the two-way ANOVAs (with control for sexes) matched the results of the MANOVA for pre-test–post-test differences for each of the modified WIHIC and attitude scales and achievement score, 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, Academic Efficacy and achievement score.

Whereas the Student Cohesiveness scores were similar for males and females before the introduction of games, there was a pre-test–post-test increase in Student Cohesiveness for males and a pre-test–post-test decrease for females. Analyses of the qualitative data suggested that these results might be because of the competitive nature of the male students in these classes. Each of the male teams was anxious to win the game and so it appears that the level of engagement was higher for males than for females. Male students spent more time negotiating and justifying their answers before agreeing, as opposed to the female students who did not do much negotiation or justification of their answers. 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 them 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.

Whereas this section summarized the methods from the study, the results and findings from this study are summarized in the next section.

5.3 Significance of the Study

This research is significant because it is one of the first learning environment studies to be conducted in the UAE and because carefully modified and translated versions of the WIHIC and attitudes (Enjoyment of Mathematics Lessons and Academic Efficacy) questionnaires have been made available for researchers and mathematics educators in Arabic-speaking countries. As well, my research represents one of the few learning environment studies anywhere in the world that has focused on the effect of mathematical games on the classroom environment as perceived by students.

A distinctive contribution is the modification, translation and validation of a learning environment and attitudes scales. The modified WIHIC questionnaire and Enjoyment of Mathematics Lessons and Academic Efficacy scales were translated into the Arabic language through a rigorous process of back-translation (as recommended by Brislin, 1970). The questionnaires include both English and Arabic items on the same form to ensure that UAE college students, who are taught in English but for whom first language is Arabic, have the choice of both languages. The modified WIHIC questionnaire and Enjoyment of Mathematics Lessons and Academic Efficacy scales provide economical and useful instruments that have been made available to mathematics teachers and researchers in the UAE to assess students' perception of their learning environment and attitudes in their mathematics classes.

Methodologically, my study has contributed to the field of learning environments by supplementing the quantitative data with information gathered using student and teacher interview and a narrative, based on observations of classes. This has provided a more complete and coherent picture of the learning environments in the UAE and has better explained students' responses to the questionnaire. The narrative suggested that, with the introduction of games in the classroom, there was a high level of engagement, strong interaction among students and support from their teacher. The narrative also highlighted the productive argumentation and justification in class discussions, factors not possible to discern through questionnaires alone. A narrative of students playing mathematics games suggests that, with the introduction of games in the classroom, students were given the opportunity to interact with each other and to explain and compare their solutions with those of their team-mates. In a typical mathematics classroom in the UAE, students are taught to listen passively and are not given the opportunity to participate in class. Therefore, this research is significant by suggesting to mathematics teachers that the use of games can enhance students' participation and engagement in class. For the students, the findings of my study provide a better understanding of the students' perceptions of their mathematics classroom environment and attitudes towards mathematics that could help them to learn better in the future.

The study reports positive class-level links between attitudes and Teacher Support, Involvement and Personal Relevance. 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. These results will likely make mathematics teachers and educators aware of the types of learning environment that they create and those aspects of the environment that are likely to promote student attitudes and achievement.

The use of games promoted a positive classroom environment indicating that it is worthwhile introducing games into mathematics lessons. It is likely, therefore, that these results will encourage teachers of mathematics to use games activities that can help to improve the learning environment and students' attitudes. It is possible that the feedback information, provided through students' perceptions of the learning environment, could help mathematics teachers of the UAE to make changes to the learning environment of their mathematics classes.

5.4 Limitations of the Study

The generalisation of the results to other populations should be made with caution as the present study involved a relatively small number of teachers, students and classes. The UAE 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. So the representativeness of the sample could be limiting factor in that, compared to the general college population in the UAE, my sample could not be representative of the full range of colleges and students. It is therefore unclear whether my findings would apply to other college-level institutions in the UAE.

The statistical power could be limited in some data analyses in this study due to the sample size of 352 students. A larger sample would have permitted pre-test–post-test differences in perceptions of learning environment and outcomes to be identified more clearly. In particular, out of these 352 students, only 90 students were introduced to the *Jeopardy!*-type games, thus making the lack of statistical power especially relevant for analyses involving this subsample. In addition to the limitations associated with the quantitative data, only 20 students were interviewed. Conducting extensive qualitative data collection would have been preferable, Nonetheless, a narrative, based on observation of students playing *Jeopardy!*-type games in mathematics was provided in an attempt to reduce this shortcoming.

Finally, because students were exposed to the mathematics games for only six weeks, a longer period of exposure might have provided more insights into the effect of games activities on students' attitudes and the learning environment.

5.5 Recommendations for Further Research

To overcome the limitations discussed in Section 5.4 concerning limited sample, future research should be undertaken with bigger and broader samples to improve confidence in the findings. Such studies could include samples from primary, secondary and college levels in the UAE. It is recommended, therefore, that further similar research be carried out to examine whether the findings of the present study can be generalised to other emirates (states) within the UAE by including more grade levels and educational levels and other emirates. It is also suggested that future studies include outcomes beyond student attitudes, such as academic achievement. Associations between learning environment and student outcomes could be investigated at different grade levels and for different learning areas.

Education in the UAE is undergoing profound transformation. Critical within this process is the introduction of advanced educational techniques, improvement of the innovative skills of teachers, and the enhancement of the self-learning ability of students. All of these processes require evaluation at all levels of their development – from policy formulation at government level through to implementation of the curriculum framework at the school and classroom levels. These processes require different approaches to evaluation. Research involving the use of learning environment instruments, such as the WIHIC, could prove generally useful in evaluating the impact of these innovative curricula in terms of the learning environment created at the school and classroom levels.

Some of the past research directions discussed in my literature review (Chapter 2) have a wide scope for adoption in the UAE. For example, studies in the UAE involving classroom environment perceptions could follow past research involving the effectiveness of: innovative mathematics programs; technology integration in the curriculum; integrated science learning; inquiry-based computer-assisted learning; and a K–5 mathematics program which integrates children’s literature.

5.7 Educational Implications

For many teachers, finding time to implement different strategies, such as mathematics games, can be problematic. In some cases, teachers resort to traditional review activities, such as paper-and-pencil worksheets, because they perceive the inflexibility of the curriculum and time pressures as major obstacles (McDonald & Hannafin, 2003). Given that a student's attitudes, shaped by school experiences, are likely to impact on his or her achievement (Lumsden, 1994; Ogbuehi & Fraser, 2007; Opolot-Okurut, 2010; 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 mathematics teachers in the UAE 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 UAE compare favourably with 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 UAE, there is a push for teachers to shift 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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APPENDIX A

Map of the United Arab Emirates

Source of map
http://www.worldatlas.com/webimage/countrys/asia/lgcolor/aecolor.htm

WorldAtlas.Com
©GraphicMaps.com
Iran
Persian Gulf
Strait of Hormuz
Qatar
Ra's al Khaymah
Umm al Quain
Ajman
Al Fujayrah
Sharjah
Doha
Das
Palm Islands
Dubai
Abu Dhabi
Dalma
Abu al Abyad
Oman
Al Ayn
United Arab Emirates
Saudi Arabia
Ghuwayfat
Ar Ruways
Tarif
TROPIC OF CANCER
Aradah
Hamim
60 mi
Liwa Oasis
60 km
Rub' Al Khali DESERT
Oman
U.A.E.
DESERT FLAT MOUNTAINS
Saudi Arabia

APPENDIX B

Mathematics Topics taught During the Six-Week Treatment Period

College	Mathematics Topics
College 1	• Whole Numbers: Operations and Properties (Addition and subtraction, multiplication and division, ordering and exponents). • Clock Arithmetic (Addition, multiplication, subtraction on the twelve-hour clock). • Fractions (Addition and subtraction, multiplication and division). • Decimals, ratio, proportion, and percent (Decimals, operations with decimals, ratio and proportion, percent).
College 2	1) Logic (Statements, truth tables, types of statements, arguments). 2) Probability and Counting Techniques (Sample spaces, classical probability, tree diagrams, addition rules for probability, permutations and combinations).
College 3	1) Trigonometric Functions and applications (Angles and their measures, trigonometric functions and fundamental identities, evaluating trigonometric functions, applications of right angles, the circular functions, graphs of sine and cosine functions). 2) Trigonometric Identities and Equations (Trigonometric Identities, sums and difference identities, trigonometric equations).

APPENDIX C

What Is Happening In this Class? (WIHIC) Questionnaire

Source of scales
Aldridge and Fraser (1999); Taylor, Fraser and Fisher (1997)
Used with permission of the authors

Student Cohesiveness **الصداقة مع الطلبة**	Almost Never **تقريبا أبدا**	Seldom **نادرا**	Some-times **أحيانا**	Often **غالبا**	Almost Always **تقريبا دائما**
1. I make friends among students in this class. أقوم بإنشاء علاقات صداقة مع طلاب صفي	1	2	3	4	5
2. I know other students in this class. اعرف الطلاب الآخرين في صفي	1	2	3	4	5
3. I am friendly to members of this class. انا ودود مع اعضاء الصف	1	2	3	4	5
4. Members of the class are my friends. اعضاء الصف اصحابي	1	2	3	4	5
5. I work well with other class members. اعمل جيدا مع اعضاء الصف الآخرين	1	2	3	4	5
6. I help other class members who are having trouble with their work. اساعد اعضاء الصف الذين يواجهون مشاكل في العمل	1	2	3	4	5
7. Students in this class like me. طلاب هذا الصف يحبونني	1	2	3	4	5
8. In this class, I get help from other students. احصل على المساعدة من الطلاب الآخرين في الصف	1	2	3	4	5
Teacher Support **دعم المعلم**	Almost Never **تقريبا أبد**	Seldom **نادرا**	Some-times **أحيانا**	Often **غالبا**	Almost Always **تقريبا دائما**
9. The teacher is interested in my problems. يهتم المدرس بمشاكلي	1	2	3	4	5
10. The teacher goes out of his/her way to help me. يتوقف المدرس احيانا عن الشرح لمساعدتي	1	2	3	4	5
11. The teacher considers my feelings. يهتم المدرس بمشاعري	1	2	3	4	5
12. The teacher helps me when I have trouble with the work. يساعدني المدرس حين اواجه مشاكل في العمل	1	2	3	4	5
13. The teacher talks with me. يتحدث المدرس معي	1	2	3	4	5
14. The teacher takes an interest in my progress. يهتم المدرس بتقدمي	1	2	3	4	5
15. The teacher moves about the class to talk with me. يتحرك المدرس في الصف للتحدث معي	1	2	3	4	5
16. The teacher's questions help me to understand. اسئلة المدرس تساعدني على الفهم	1	2	3	4	5

Involvement **الإنهماك**		Almost Never **تقريبا أبدا**	Seldom **نادرا**	Some-times **أحيانا**	Often **غالبا**	Almost Always **تقريبا دائما**
17.	I discuss ideas in class. اناقش الافكار في الصف	1	2	3	4	5
18.	I give my opinions during class discussions. اعطي رأيي اثناء المناقشات الصفية	1	2	3	4	5
19.	Other students listen carefully to my ideas. يستمع الطلاب الآخرين لافكاري بحرص	1	2	3	4	5
20.	My ideas and suggestions are used during classroom discussions. يؤخذ بارائي واقتراحاتي خلال المناقشات الصفية	1	2	3	4	5
21.	I ask other students to explain their ideas. اطلب من الطلاب توضيح افكارهم	1	2	3	4	5
22.	I explain my ideas to other students. أوضح افكاري للطلبة الآخرين	1	2	3	4	5
23.	Students discuss with me how to go about solving problems. يناقش الطلبة معي كيفية حل المشاكل	1	2	3	4	5
24.	I am asked to explain how I solve problems. يطلب مني توضيح كيفية حل المشاكل	1	2	3	4	5
Cooperation **التعاون**		Almost Never **تقريبا أبدا**	Seldom **نادرا**	Some-times **أحيانا**	Often **غالبا**	Almost Always **تقريبا دائما**
25.	I cooperate with other students when doing assignment work. اتعاون مع الطلبة الآخرين اثناء عمل الواجب	1	2	3	4	5
26.	I share my books and resources with other students when doing assignments. اشارك الطلبة الكتب والمصادر حين عمل الواجب	1	2	3	4	5
27.	When I work in groups in this class, there is teamwork. تسود روح الفريق حين العمل ضمن مجموعات	1	2	3	4	5
28.	I work with other students on projects in this class. اعمل مع طلبة آخرين لإنجاز المشاريع في الصف	1	2	3	4	5
29.	I learn from other students in this class. اتعلم من الطلبة الآخرين في الصف	1	2	3	4	5
30.	I work with other students in this class. اعمل مع الآخرين في الصف	1	2	3	4	5
31.	I cooperate with other students on class activities. اتعاون مع الآخرين في الأنشطة الصفية	1	2	3	4	5
32.	Students work with me to achieve class goals. يعمل الطلبة الآخرون معي لتحقيق اهداف الصف	1	2	3	4	5

Equity **العدالة (الإنصاف)**	Almost Never **تقريبا أبدا**	Seldom **نادرا**	Some-times **أحيانا**	Often **غالبا**	Almost Always **تقريبا دائما**
33. The teacher gives as much attention to my questions as to other students' questions. يعطي المدرس اهتمامه لأسئلتي بنفس القدر الذي يوليه للآخرين	1	2	3	4	5
34. I get the same amount of help from the teacher as do other students. احصل على نفس المساعدة التي يحصل عليها الاخرون في الصف	1	2	3	4	5
35. I have the same amount of say in this class as other students. امنح نفس الفرصة الممنوحة للآخرين لأبداء الرأي والحديث	1	2	3	4	5
36. I am treated the same as other students in this class. يتم معاملتي بنفس الطريقة التي يعامل بها الآخرون	1	2	3	4	5
37. I receive the same encouragement from the teacher as other students do. احصل على نفس التشجيع الذي يتلقاه الآخرون	1	2	3	4	5
38. I get the same opportunity to contribute to class discussions as other students. امنح نفس الفرصة للمشاركة في النقاش كالآخرين	1	2	3	4	5
39. My work receives as much praise as other students' work. يتم الثناء على اعمالي بنفس الطريقة التي يثنى بها على الآخرين	1	2	3	4	5
40. I get the same opportunity to answer questions as other students. اعطى نفس الفرصة للأجابة على الأسئلة كالآخرين	1	2	3	4	5
Personal Relevance **الإرتباط الشخصي**	Almost Never **تقريبا أبدا**	Seldom **نادرا**	Some-times **أحيانا**	Often **غالبا**	Almost Always **تقريبا دائما**
41. I relate what I learn in this class to life outside college. اقوم بربط ما تعلمته بامور الحياة المختلفة خارج الكلية	1	2	3	4	5
42. I draw on past experiences to help me in this class. اعتمد على خبراتي السابقة لتساعدني في الصف	1	2	3	4	5
43. What I learn in this class is relevant to my everyday life. ما اتعلمه في الصف على ارتباط بحياتي اليومية	1	2	3	4	5
44. I apply my everyday experiences in this class. اطبق خبراتي اليومية في هذا الصف	1	2	3	4	5
45. This class is relevant to my life outside of college. ترتبط غرفة الصف بحياتي خارج الكلية	1	2	3	4	5
46. I link my class work to my life outside of this class. اقوم بربط ما اعمله في غرفة الصف بامور حياتي خارج الكلية	1	2	3	4	5
47. In this class, I get an understanding of life outside college. افهم الحياة خارج نطاق الكلية في هذا الصف	1	2	3	4	5
48. I apply my past experience to the work in this class. أطبق خبراتي السابقة على الاعمال المختلفة في غرفة الصف	1	2	3	4	5

APPENDIX D

Attitude Scales

Source of scales
Aldridge and Fraser (2008)
Used with permission of the authors

Enjoyment of Mathematics Lessons الإستمتاع بحصص الرياضيات		**Almost Never** **تقريبا أبدا**	**Seldom** **نادرا**	**Some-times** **أحيانا**	**Often** **غالبا**	**Almost Always** **تقريبا دائما**
1.	I look forward to lessons in mathematics. أتطلع بلهفة وشوق لحصص الرياضيات	1	2	3	4	5
2.	Lessons in mathematics are fun. حصص الرياضيات ممتعة ومسلية	1	2	3	4	5
3.	Mathematics is one of my favourite college subjects. الرياضيات أحدى المواضيع المفضلة لدي	1	2	3	4	5
4.	Lessons in mathematics interest me. حصص الرياضيات تثير إهتمامي	1	2	3	4	5
5.	There should be more lessons in mathematics. يجب زيادة عدد حصص الرياضيات	1	2	3	4	5
6.	I enjoy lessons in mathematics. استمتع بحصص الرياضيات	1	2	3	4	5
7.	I enjoy the activities that we do in mathematics. استمتع بانشطة مادة الرياضيات	1	2	3	4	5
8.	These lessons make me interested in mathematics. حصص الرياضيات تزيد اهتمامي بالمادة	1	2	3	4	5
Academic Efficacy الفعالية الأكاديمية		**Almost Never** **تقريبا أبدا**	**Seldom** **نادرا**	**Some-times** **أحيانا**	**Often** **غالبا**	**Almost Always** **تقريبا دائما**
9.	I find it easy to get good grades in mathematics. استطيع الحصول على علآمات جيدة في الرياضيات بسهولة	1	2	3	4	5
10.	I am good at mathematics. أنا جيد في الرياضيات	1	2	3	4	5
11.	My friends ask me for help in mathematics. يطلب مني اصحابي العون في الرياضيات	1	2	3	4	5
12.	I find mathematics easy. مادة الرياضيات سهلة بالنسبة لي	1	2	3	4	5
13.	I outdo most of my classmates in mathematics. أتفوق على معظم زملائي في الصف في مادة الرياضيات	1	2	3	4	5
14.	I feel that I will pass mathematics with ease. أعتقد بانني سوف أنجح في الرياضيات بسهولة	1	2	3	4	5
15.	I feel that I am an intelligent student. أشعر بانني طالب ذكي	1	2	3	4	5
16.	I help my friends with their homework in mathematics. أساعد أصدقائي في واجبات الرياضيات	1	2	3	4	5

APPENDIX E

Sample Questions on the Achievement Tests

1) Give the exact value of

a. $\cos\frac{3\pi}{4}$

b. $\sin 600°$

2) Give the reference angle for $-211°$

3) A pulley makes 60 rotations in one minute. What is the **exact** angular velocity
in radians per second?

4) Given the following:

$$amplitude \quad |a| = 3 \quad , \quad period = 2 \quad , \quad phase\ shift = 0 \quad , \quad vertical\ shift = 1$$

Write a cosine function which models this data.

5) Find the exact value of $\sin 82° \cos 22° - \cos 82° \sin 22°$

6) Convert the following angle to degrees, minutes and seconds $\frac{7\pi}{24}$

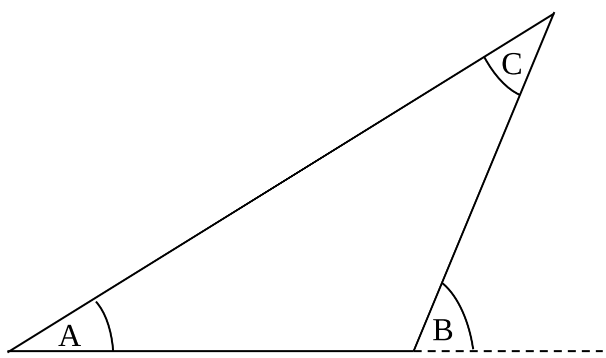
7) Solve over the interval $[0, 2\pi)$ $\quad 2\sin x + 3 = 4$

8) Find the exact value of $\cos\frac{\theta}{2}$ if $\sin\theta = -\frac{4}{5}$ and $\frac{3\pi}{2} < \theta < 2\pi$

9) Verify analytically $\quad \dfrac{\csc\theta}{\cot\theta + \tan\theta} = \cos\theta$

10) The angle $A = 30°$ and angle $B = 60°$. The distance from A to B is 1 unit.

Find the **exact** lengths of the sides *AC* and *BC*.



APPENDIX F

Sample Interview Schedule for Students

1.	How well have you been working with students in your class?
2.	Tell me about how your teacher has been helping you when you are having trouble with your work.
3.	What has been your experience discussing your ideas with other students in your class?
4.	What is your experience of team work with your class mates when doing assignments or playing mathematics games in class?
5.	What do you think about importance of mathematics in your study?
6.	How do you compare your enjoyment of mathematics before the use of games in your classroom and now?
7.	How has the use of mathematics games in your classroom affected your feelings about mathematics?
8.	How do you compare the way your teacher treats you and the other students in your class?
9.	What are your comments in this statement? “Lessons in mathematics are fun.”
10.	How well are you performing in mathematics?

APPENDIX G

Sample Interview Transcript – Student

Q1: ***How well have you been working with students in your class?***
Sometimes when we get an assignment in class, we do it in group. If they don't understand anything I explain it to them and I don't understand anything someone from the group explains it to me.

Q2: ***What has been your experience discussing your ideas with other students in the class?***
Discussing ideas in class was very important to understand what each student is talking about so we can answer correctly. For example one question with more ideas is helpful.

Q3: ***Tell me about how your teacher has been helping you when you are having trouble with your work?***
If I have trouble with my work, I tell my teacher and he comes to my table and helps me solve the problem. Then he gives me a similar question to answer to make sure that I have understood the question.

Q4: ***What is your experience of team work with your class mates when doing assignments or playing mathematics games in class?***
Of course I like group working, because it helps me a lot, and it saves time and we are able to do a lot of work. It's just like killing one bird with one stone. I am able to get ideas, knowledge and information from other students and also share my ideas with them. Also I think it is helpful for us because group work teach us how to be cooperative with others. Although we might have different level intelligent, we all learn from each other.

Q5: ***What do you think about the importance of mathematics in your study?***
Mathematics is always important for students from very early age to their whole life, starting with counting. For example If you want start a business or a company, we will need people who know mathematics.

Q6: ***(a) How do you compare your enjoyment of mathematics before the use of games in your classroom and now?***
Before the use of games we were working in groups only writing on paper, sometimes we skip something and we postponed the discussion, but with games, we have discuss it at that moment to get the answer and the group has to give one answer and so we have to agree with answer. This gives us experience with working in group. It also makes us cooperative. Games is more interesting, enjoy the games more and it also makes work hard as a group to make the other group lose.

Q6: ***(b) What are your comments in this statement? "Lessons in mathematics are fun."***
Mathematics is fun but sometimes, the fun makes you nervous, confusing and sometimes, it gives stress because if you don't know how to solve the problems, you will hate mathematics so it is not fun, it is challenging.

Q6: *(c) In your opinion, how can your teacher help you enjoy mathematics more?*
The teacher has to make mathematics as a game, he has to make the class interesting and bring energy to the class. He has to make the class active and he has to present mathematics as a story, because we can accept the story more than the worksheets every day. May be PowerPoint or some games or competition between students will help us in Mathematics.

He should give us like those games. It was really fun. Much better than giving us assignments on paper. Like giving us some tricky question also, or questions with some interest that students like. Something about cars for example. Like mix mathematics with cars, something like that will be nice

Q7: *(a) How has the use of mathematics games affected your feelings about mathematics?*
The games affected all the students in the class not just me, because when you make games in mathematics it is a challenge for us to answer the questions before my friends or the other team answers the question. This gives me a proof of how I am doing in Math and also prove to my friends that I am clever than them. There is a competition between the two groups

Q7: *(b) How well are you performing in mathematics?*
I like mathematics, which makes me do well in mathematics. For many years, I always get 'A' in math. Of course if you like something, you will always get high scores.

Q8: *How do you compare the way your teacher treats you and the other students in your class?*
To be honest my teacher treats all of us the same. He doesn't treat any student better than the others. He treats us all the same.

APPENDIX H

Sample Interview Schedule for Teachers

1. Before this study, had you previously been incorporating mathematics games in your lessons? If so, in which ways. Give examples. If no, why not?

2. Could you please briefly describe how you enjoyed playing mathematics *Jeopardy!* games with your students?

3. In your opinion, what are the benefits and pitfalls of using games in the classroom?

4. Do you think the use mathematics games affected your students' attitudes towards mathematics and the learning environment?

APPENDIX I

Sample Interview Transcript - Teacher

Q1: ***Before this study, had you previously been incorporating mathematics games in your lessons?***
Yes.

In which ways? I have but not computer games. It was a board games that I buy from the library or I create myself or I down load from the internet then I make it into card board. The game the students played was converting mixed fractions into improper fractions. I put the students into 2 groups. One group had mixed fractions and the other had improper fractions and they had to mix and match so that was good but mainly not a computer game.

Q2: ***Could you please briefly describe how you enjoyed playing mathematics jeopardy games with your students?***
I have enjoyed it because they started to feel that they need to compete with each other, and it made them more motivated, it make time go faster than just opening the book or sitting in front of work sheets as the traditional way. So I find the mathematics games to be significant.

Q3: ***In your opinion, what are the benefits and pitfalls of using games in the classroom?***
Well the advantages of using the games as I said previously make my students more motivated. And I feel they like to compete with each other. The advantages I can only think about is the class, sometimes becomes too noisy during the game, while when they are sitting in group, they seem to be aggregated and shouting out the answers, also not fighting but raise their voices at each other. It's just a matter of noisy classroom, that's all.

Q4: ***How do you think the use mathematics games can positively affect students' attitudes towards mathematics and the learning environment?***
It does have a big impact on the students, especially those who are bored with worksheets and text books. I feel, yes, it is a good way and a good method to use this computerized games. It is especially good for those students who love computers more than worksheet and the textbooks.

Q5: ***Do you have any other comments you want to make?***
From the feedback I have had from the students, they really enjoyed the games but they would like a time limit to be put on the questions.

APPENDIX J

Copy of Ethics Approval
Curtin University

memorandum

Curtin
University of Technology

To	Ernest Afari, SMEC
From	Pauline Howat, Coordinator for Human Research Ethics, Science and Maths Education Centre
Subject	Protocol Approval **SMEC-12-09**
Date	11 May 2009
Copy	Jill Aldridge, SMEC Divisional Graduate Studies Officer, Division of Science and Engineering

Office of Research and Development

Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Minimal Risk (Ethical Requirements)" for the project titled "*INVESTIGTING THE IMPACT OF MATHEMATICS GAMES ON STUDENTS' ATTITUDES AND THEIR PERCEPTIONS OF THE LEARNING ENVIRONMENT*". On behalf of the Human Research Ethics Committee I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **30th April 2009** to **29th April 2010**.

If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **SMEC-12-09**. *Please quote this number in any future correspondence.*

Pauline

PAULINE HOWAT
Coordinator for Human Research Ethics
Science and Maths Education Centre

Please Note: The following standard statement must be included in the information sheet to participants: *This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number SMEC-12-09). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.*

J:\office\Pauline\ETHICS\Ethics Approval Letter 2009\Afari.doc

APPENDIX K

Participant Information Sheet

Science and Mathematics Education Centre (SMEC)
Perth, Australia

Participant Information Sheet

My name is Ernest Afari. I am currently completing a piece of research for my Doctor of Philosophy at Curtin University.

Purpose of Research
I am investigating the effectiveness of mathematics games on student's attitudes and the learning environment.

Your Role
I am interested in finding out whether the use of games will have any effect on your Classroom learning environment and attitudes towards Mathematics. I will ask you to answer some questionnaires about your perception of your classroom learning environment and your attitude towards Mathematics. Filling out the questionnaire will take approximately 30 minutes. I will ask some of you to volunteer to be interviewed. The interview process will take approximately 20 minutes.

Consent to Participate
Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
The information you provide will be kept separate from your personal details, and only myself and my supervisor will have access to this. The interview transcript will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number: SMEC-12-09). If you would like further information about the study, please feel free to contact me on +971 50 825 9705 or my email: ernest.afari@gmail.com. Alternatively, you can contact my supervisor Dr. Jill Aldridge on +61 (0)8 9266 3592 or by email: j.aldridge@curtin.edu.au

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

APPENDIX L

Consent Form

CONSENT FORM

1) I understand the purpose and procedures of the study.
2) I have been provided with the participant information sheet.
3) I understand that the procedure itself may not benefit me.
4) I understand that my involvement is voluntary and I can withdraw at any time without problem.
5) I understand that no personal identifying information like my name and address will be used in any published materials.
6) I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
7) I have been given the opportunity to ask questions about this research.
8) I agree to participate in the study outlined to me.

Name: ____

Signature: ____

Date ___________________________