School of Education

An Investigation of the Impact of Inquiry-Based Learning in Mathematics on the Students' Perceptions of the Learning Environment and Attitudes Towards Mathematics in some Abu Dhabi Schools

Jennifer Maree Robinson

This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

May 2020

DECLARATION

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

Jennifer Maree Robinson

Date: 10 May 2020

ACKNOWLEDGEMENTS

When I started this process so many years ago, I had no idea of what I was getting myself into. The journey, which has been far from easy, would have been impossible was it not for the endless support from family and friends.

First, I would like to thank my amazing husband, Jeremy, who has stood by me through the good and extremely ugly stages of my doctorate. He has truly been my rock, my never-ending source of confidence when I had none left, and giver of tough love when I needed it. He has also been my personal IT technician whenever I came close to throwing my laptop.

My thanks go out to my incredible girls, Mia and Imogen, in whom I am extremely proud. They have put up with a grumpy, stressed mum long enough, but have been so tolerant and supportive throughout. I want them to look at this achievement and realise that girls truly can do anything they set their minds to. Aim high, stand tall, and simply be magnificent!

I must also thank my wonderful parents, Kem and Jo Price, who have encouraged me, regardless of the physical distance between us, through phone calls and emails. I appreciate your support and for not letting me give up, even when I wanted to.

I want to thank the many friends have been with me during this journey. Thanks to those who have rung or sent messages asking me how it's going – thank you! Your interest in my research and support of me has been so appreciated. I must add a particular thank you to Melissa McMinn, whose support towards the end of the project when motivation and confidence were low, was like a medicine to my soul.

Next, I am grateful to the Abu Dhabi Education Council (ADEC), Abu Dhabi, United Arab Emirates, that has allowed me to complete such interesting research in a diverse and fascinating context. The educational reform led by ADEC has created opportunities for studies such as mine and the support of ADEC to allow me to have access to schools for data collection has been invaluable. Of particular mention within ADEC, are Raeda Tayem and Ekhlas Alsousou, whose expert knowledge and skills with the translation of my instruments made the process almost easy. To Nigel Crawford and Richard Ferguson, who have listened to hours of research thoughts, musings and complaints, thank you!

Lastly, I must thank my supervisor, Associate Professor Jill Aldridge. She has been with me through thick and thin, through drama and triumph, and has helped me be victorious (finally!). Her constant support and calm review of work has enabled me to discover what research is all about within the safe confines of this study.

ABSTRACT

The overarching aim of my study was to investigate the effectiveness of implementing inquiry-based learning in mathematics classes in Abu Dhabi, by comparing differences between students' perceptions of the learning environment and attitudes towards mathematics, in classes with teachers exemplary in the use of explorations and those who were not. A mixed methods approach, where the quantitative phase was followed by a qualitative research phase, was used. In the first phase, the collection of quantitative data from a sample of 291 students taught by four teachers, two of whom were exemplary in their implementation of explorations and two who were not. The teachers whose classes were involved in the study were selected through a recommendation process, with the use of criteria for teachers exemplary in the use of explorations, by subject-specific expert mathematics education advisors. In the second phase, qualitative data was collected through lesson observations (in classes taught by teachers exemplary in the use of explorations and those who were not) and focus group interviews with students (N=27) after each observation.

Two instruments were developed to collect the quantitative data, the Learning Environment in Inquiry Survey (LEIS), to assess students' perceptions of the learning environment, and the Students' Attitudes Towards Mathematics Survey (SATMS), to assess students' attitudes towards mathematics. Development of the surveys was carried out to ensure that they were suitable to the context in which the study took place and were suitable for use with middle school students in the United Arab Emirates (UAE). Whilst the surveys both were developed in English, they underwent a thorough process of back translation into Arabic to make them suitable for use with students in classrooms in the UAE.

As a first step it was important to establish the reliability and validity of the newly developed survey to ensure confidence in the results (Research Objective 1). For both instruments, there was strong evidence to support reliability and validity with respect to their content validity, factor structure, internal consistency reliability, discriminant validity and ability to differentiate between classes.

To investigate associations between students' perceptions of the learning environment and attitudes towards mathematics (Research Objective 2), simple correlation and multiple regression analyses were used. The results of the simple correlation indicated that there were positive and statistically significant (p<.01) associations between all six learning environment scales and the three attitudes scales. In addition, the results of the multiple regression analyses indicated positive and statistically significant (p<.01) correlations for all three attitude outcomes. The beta values indicated that the learning environment scales were positively related to different attitude scales. Specifically, five of the six learning environment scales (Personal Relevance, Critical Voice, Shared Control, Involvement and Investigation) were positive, independent and statistically significant (p<.01) predictors of students' enjoyment of mathematics. Two of the six LEIS scales (Involvement and Investigation) were positive and statistically significant (p<.01) predictors of students' self-efficacy and three of the six learning environment scales (Personal Relevance, Shared Control and Investigation) were positive and statistically significantly (p<.01) predictors of task value.

A one-way multivariate analysis of variance (MANOVA) was used to examine whether there were statistically significant differences, for students in classes with teachers exemplary in the use of explorations and those who were not (Research Objective 3). For all scales, students who were taught by teachers exemplary in the use of explorations scored higher, in terms of their perceptions of the learning environment and attitudes towards mathematics, than their peers in classes with teachers who were not. The ANOVA results, interpreted because Wilks' Lambda was significant, indicated that the differences, for all six learning environment scales, were statistically significant (p<.01), these being, Personal Relevance (effect size=.41 standard deviations), Critical Voice (effect size=.24 standard deviations), Shared Control (effect size=.32 standard deviations), Student Negotiation (effect size=.26 standard deviations), Involvement (effect size=.34 standard deviations) and Investigation (effect size=.41 standard deviations). Similarly, for all three attitude scales, statistically significant (p<.01) differences were found, these being Enjoyment of Mathematics (effect size=.52 standard deviations), Self-Efficacy (effect size=.42 standard deviations) and Task Value (effect size=.44 standard deviations). Effect sizes were considered to be between small and medium for all of the scales.

During the second phase of the study, qualitative data was collected through observations and focus group interviews. This data was used to provide causal explanations for the differences between the learning environment perceptions and attitudes of students of teachers exemplary in the use of explorations and those who were not (Research Objective 4). As a result of the analysis of the data, three major themes emerged. First, students in classes with teachers exemplary in the use of explorations experienced more engagement and involvement in their learning than their peers in classes with teachers who were not. Secondly, in classes with teachers exemplary in the use of explorations, students experienced more task value and opportunities for real-life application. Lastly, students had more opportunities to experience inquiry and investigation in their lessons with teachers exemplary in the use of explorations.

In this study, the field of research into learning environments has been extended, as it is one of the first studies of its kind to examine inquiry-based learning in mathematics classes in Abu Dhabi, UAE. The results offer important insights into how exemplary implementation of inquiry-based learning could impact students' perceptions of the learning environment and attitudes towards mathematics. The findings will appeal to a wide audience as they shed light not only on how inquiry-based learning can be an effective means of improving students' perceptions of the learning environment and attitudes towards mathematics, but also can be used at a policy level to inform professional development programmes. The findings, therefore, are likely to be of interest to researchers, educators and policy makers.

LIST OF ACRONYMS

ADEC	Abu Dhabi Education Council
ANOVA	Analysis of Variance
BSCS	Biological Science Curriculum Study
CES	Classroom Environment Scale
CLES	Constructivist Learning Environment Survey
CUCEI	College and University Classroom Environment Inventory
GIS	Geographic Information Systems
ICEQ	Individualised Classroom Environment Questionnaire
KG	Kindergarten
LEI	Learning Environment Inventory
LEIS	Learning Environment in Inquiry Survey
MANOVA	Multivariate Analysis of Variance
MCI	My Class Inventory
MoE	Ministry of Education
NASA	National Aeronautics and Space Administration
NSM	New School Model
P-12	Pre-primary to grade 12
PPP	Public Private Partnership
QTI	Questionnaire on Teacher Interaction
SALES	Student Adaptive Learning Engagement in Science questionnaire
SATMS	Student Attitudes Towards Mathematics Survey
SLEI	Science Laboratory Environment Inventory
SPSS	Statistical Package for Social Scientists
STEM	Science, Technology, Engineering and Mathematics
TOMRA	Test of Mathematics Related Attitudes
UAE	United Arab Emirates
WIHIC	What Is Happening In this Class? questionnaire

DEFINITIONS

For the purpose of this thesis, terms that are central to the study, have been defined here to clarify the key concepts.

Inquiry-based learning. Inquiry-based learning is a student-centered pedagogy that uses purposeful, extended investigations, set in the context of real-life problems, as both a means for increasing student capacities and as a feedback loop for increasing teachers' insights into student thought processes. Note that the terms inquiry-based learning, inquiry, and inquiry-based exploration approach are used interchangeably throughout the thesis.

Learning environments. The learning environment has two distinct elements with the human aspect including the students and teachers and the interactions between them, while the physical environment incorporates the furniture, equipment, resources, classroom displays and lighting. For the purpose of this study, the term learning environment refers to the psychosocial climate, which takes into consideration the culture, ambience or atmosphere where learning takes place.

Student attitudes. For the purpose of this study, student attitudes are considered to have three parts, including: the cognitive component (that describes the knowledge, beliefs and ideas about an object); the affective component (which describes the feeling about an object in terms of like or dislike); and the behavioural component (which describes a tendency-towards-action).

Teachers exemplary in the use of inquiry-based learning. For the purpose of this study, a teacher exemplary in the use of inquiry-based learning was one who was identified through a process of recommendation with the use of set criteria. Criteria include demonstration of skills required in the teaching, learning and assessing of explorations; opportunities for students to explore; excellent questioning skills; regular reflection; collaboration; and use of extended community of learners.

Teachers non-exemplary in the use of inquiry-based learning, A teacher non-exemplary in the use of explorations is one who does not meet the criteria of exemplary use of inquiry. Often, they believe they are using inquiry-based learning in their teaching and exhibit a lack of understanding of what effective inquiry looks like.

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

CHAPTER 1

Introduction

1.1 Introduction

At the time that this study was designed, I was working for the Abu Dhabi Education Council (ADEC) amidst a large-scale reform effort being carried out in public schools. Expatriate educators were recruited to participate in the ambitious reform that incorporated all aspects of education: from facilities and educational resources, to changes in teaching, learning and assessment. One of the significant changes in mathematics teaching during the education reform, was the shift to inquiry-based learning techniques. This change required teachers to teach and assess through the use of explorations that were projects based on real-world contexts. The focus of my study was the use of these inquiry-based learning approaches and compared students' perceptions of their learning environment and attitudes towards mathematics in classes with teachers exemplary in the use of explorations and those who were not. As an educator working in the United Arab Emirates, initially mentoring and coaching teachers to support new pedagogies and assessment methods in the teaching of mathematics, I saw the need for a method to assess whether the changes were impacting positively for students in terms of their perceptions of the learning environment and their attitudes towards mathematics.

The results of past research suggest that there are many benefits to the use of inquiry-based learning, including, increased motivation, enhanced understanding of mathematics and development of positive attitudes about mathematics as well as relevance of mathematics for life and further learning (Bruder & Prescott, 2013). Past research findings also indicate that, "overall, inquiry-based instruction was shown to produce transferable critical thinking skills as well as significant domain benefits, improved achievement, and improved attitude towards the subject" (Hattie, 2009, pp. 209-210). Research in the UAE into the use of inquiry-based learning and its effect on student perceptions of the learning environment and attitudes towards mathematics is sparse, and so my study adds value to the educational reform efforts and produces a foundation for further investigation in this field.

The introduction of the study is organised using the following headings:

- Context of the study (Section 1.2);
- Research objectives (Section 1.3);
- Significance of the study (Section 1.4); and
- Overview of the thesis (Section 1.5).

1.2 Context of the Study

Information about the context in which the study took place is explained in this section. In Section 1.2.1, information about the history of the United Arab Emirates (UAE) is provided. In Section 1.2.2, an overview of the education system in the UAE and, in particular, in Abu Dhabi public schools is given. In Section 1.2.3, background information related to the educational reform that was taking place in Abu Dhabi is provided. In Section 1.2.4, the theory of constructivism is described. Finally, in Section 1.2.5 a description of the inquiry mathematics approach that was being implemented as part of the reform efforts is given.

1.2.1 History of the United Arab Emirates

The UAE is situated in the Middle East on the Arabian Gulf, bordering Oman, Qatar, and Saudi Arabia. The land area of the UAE is approximately 83,600 km^2, roughly the size of Austria. Prior to 1971, the UAE was called the Trucial States and was governed by the British. On 2 December 1971, the federation of the seven emirates was formed and the United Arab Emirates was born. The seven emirates are: Abu Dhabi, Dubai, Sharjah, Ajman, Um Al Quwain, Ras Al Khaimah, and Fujairah. The Emirate of Abu Dhabi is the largest of the seven emirates accounting for 87% of the UAE’s land. In 1958, when oil was discovered in Abu Dhabi, significant development of Abu Dhabi City and the surrounding areas began to occur.

The early history of the UAE was based on a nomadic, herding, and fishing existence of the people. The society was based on a Bedouin tribal system where tribes moved between the ocean, where survival was based on pearl diving and fishing, to the desert, where camels and herds could graze, to the oasis, where it was possible to gain sustenance from farming of dates and crops due to irrigation systems. The Bedouin were known for their ability to be resourceful in the harsh climate and environment, and maintain their independence (Zayed University, n.d.).

The arrival of representatives from the Prophet Muhammad in 630 AD commenced the conversion of the region to Islam (UAE National Media Council, 1995). Islamic armies based themselves in Julfar, Ras Al Khaimah, as a launching site for their battles into Iran. During the next few centuries, Julfar became a city of consequence; with wealthy ports and pearling centres where large wooden dhows (cargo boats) were launched, travelling throughout the Indian Ocean.

The Portuguese arrived in 1498, when Vasco de Gamma circumnavigated the Cape of Good Hope. Their arrival brought bloody battles for the residents of Julfar and ports on the east coast, such as, Dibba, Bidiya, Khor Fakkan, and Kalba. While many European countries were fighting to rule regionally within the country, a tribal group called the Qawasim were gathering strength. By the beginning of the nineteenth century, the Qawasim had established a fleet of over 60 large vessels and had nearly 20,000 sailors that could be sent to sea. The British realised the importance of controlling the trade routes by sea between the Gulf and India and, therefore, came into conflict with the Qawasim. As a result, the area became known as ‘Pirate Coast’.

In 1820, the British fleet defeated the Qawasim and then signed several accords with the sheikhs of the individual emirates that began the process of developing a treaty to preserve a maritime truce. The British also founded a garrison in the area and the region became known as ‘The Trucial States’. The agreements included that the emirates would not have any other contracts or connections with any country except the United Kingdom (UK) and would not make business or commerce agreements with any foreign government without permission from the UK. In return, the British undertook to protect the coast from any attack from the sea, and to give support if attacks were made on land (Embassy of the UAE, 2011).

While much of this was occurring in the coastal areas, inland the villages at Liwa in the western region of the modern Emirate of Abu Dhabi, the Bani Yas tribe was gaining attention for their economy and social activities. By the early 1790s, the sheikh of the Al Bu Falah (Al Nahyan family), the leader of all the Bani Yas groups, moved from Liwa to the town of Abu Dhabi, as it had become such an important pearling centre. Early in the nineteenth century, the Maktoum rule in Dubai was established by members of the Al Bu Falasah, a branch of the Bani Yas tribe, who chose to settle by the creek in Dubai.

During the 19th and early 20th centuries, the pearling industry flourished due to the agreements made with the British and the ensuing safety at sea. For the people of the Arabian Gulf Coast, this provided them with both employment and income. Many of those living in the area focused their employment on the seasons by diving for pearls in the summer months and farming dates in the winter, providing a semi-nomadic existence. At the beginning of the 20th century, Abu Dhabi was one of the poorest emirates, whereas Sharjah had the largest population and was a powerful emirate. Abu Dhabi was an unimportant grouping of fishing villages, pearling, camel herding and farming in the oases.

With the discovery of oil, a huge change in Abu Dhabi occurred. The first oil concessions were granted in 1939 by Sheikh Shakhbut bin Sultan Al Nahyan, but it took another 14 years for oil to be found. Initially, there was little impact on Abu Dhabi from the money created from oil. The first paved road was completed in 1961 and a few concrete buildings were built. However, Sheikh Shakhbut was cautious and chose to save the income from the oil sales rather than spending it on growth and expansion as he was hesitant whether the oil revenues would last. In contrast, his brother, Sheikh Zayed bin Sultan Al Nahyan saw the potential from the oil wealth and believed it could transform Abu Dhabi.

Sheikh Zayed was born around 1918 in Abu Dhabi and was the youngest of four sons of Sheikh Sultan bin Zayed bin Khalifa Al Nahyan, Ruler of Abu Dhabi from 1922 to 1926. Sheikh Zayed grew up in Al Ain, an oasis city in the desert on the border of modern-day Oman. He travelled considerably throughout the country as a young man and gained a deep understanding of the people and the land they inhabited. In 1946, Sheikh Zayed became the Ruler's Representative in Abu Dhabi's Eastern Region and was based in the Muwaiji Fort in Al Ain. In this new role, he established a firm belief in the use of consultation and agreement amongst his staff and people, and become known for his wisdom, fairness and insightful judgements.

In 1962, the first exports of oil left Abu Dhabi. This was the turning point for Abu Dhabi, transforming it from the poorest emirate to the richest. On 6 August 1966, Sheikh Zayed succeeded his brother as the Ruler of Abu Dhabi. With the increase in oil revenue, Sheikh Zayed raised the contributions to the Trucial States Development Fund and commenced a significant development programme with the construction of schools, houses, hospitals and roads.

In 1968, it was declared that the British intended to leave the Arabian Gulf by 1971. Sheikh Zayed immediately commenced negotiations with the ruling families of the other six emirates (Dubai, Sharjah, Ajman, Um Al Quwain, Ras Al Khaimah, and Fujairah) and also with Qatar and Bahrain with the intention of becoming a federation. Whilst this was unsuccessful due to differing interests, an agreement amongst six of the emirates was possible, with Qatar and Bahrain choosing independence. The federation, to be known as the United Arab Emirates (UAE), was formed on 2 December 1971, with Sheikh Zayed (Abu Dhabi) as the President, and Sheikh Rashid (Dubai) as the Vice President and Prime Minister. The seventh emirate, Ras Al Khaimah, formally joined the federation on 10 February 1972. Up until his death in November 2004, Sheikh Zayed was re-elected as President at five-year intervals. He was succeeded by his eldest son Sheikh Khalifa bin Zayed Al Nahyan who continues to be president today.

1.2.2 The Education System in the UAE

The first schools in the UAE were informal classes taught by a Mutawwa, an elder in the village, who would help students to memorise the Holy Quran. There would sometimes also be lessons in the art of calligraphy.

Formal education was not introduced until the 1950s, when a Kuwaiti group opened a school in Sharjah. Subsequently, schools were created across the emirates with funding from a number of Arab nations, such as; Kuwait, Qatar, Bahrain, Egypt, and Saudi Arabia. These schools had differing curricula and resources, including teaching staff, depending on the country that had established the school. As a result, the system was disjointed and lacked cohesion (Al Qasimi Foundation for Policy Research, 2014).

Soon after the United Arab Emirates was formed, the Ministry of Education (MoE) was established with a need to develop a consistent approach to schooling in the public sector. The education system and schools have since seen a huge change and growth from approximately 20 schools in 1962 and less than 4000 students to 750,000 students learning a full range of subjects in 2013 (UNESCO Institute for Statistics, 2015). Currently the MoE oversees all K-12 public education in all emirates except Abu Dhabi where the Abu Dhabi Education Council (ADEC) governs these schools instead. ADEC works under the direction of HH Sheikh Mohammed Bin Zayed, Crown Prince of Abu Dhabi.

In Abu Dhabi, the public system of education is predominantly for Emirati students with most schools being separated into boys' and girls' schools. The language of instruction for the majority of subjects is Arabic. The structure contains four levels of schooling: kindergarten (KG1 and KG2) which caters for students aged three to five years, Cycle 1 (grades 1 to 5) for students aged six to eleven years, Cycle 2 (grades 6 to 9) for students aged eleven to fifteen years and Cycle 3 (grades 10 to 12) where the students are generally fifteen to eighteen years (Al Qasimi Foundation for Policy Research, 2014; Gaad, Arif, & Scott, 2006). The Cycle system of schools is similar to the American system with Cycle 1 being equivalent to an elementary school, Cycle 2 being like a middle school, and Cycle 3 similar to a high school. Often schools contain one cycle, however in smaller communities, schools tend to be common cycle and may encompass students from kindergarten to grade 12. The public schools are based on a centralised system where the governing educational body provides the curriculum and resources and appoints the principal and teachers. All aspects of school organisation and structure are directed, including all assessment data which is fed into the main system, and reporting structures for parents are generated centrally.

1.2.3 The Educational Reform in Abu Dhabi

The Abu Dhabi Education Council (ADEC) was established in accordance with law No. 24 of 2005, issued by His Highness Sheikh Khalifa bin Zayed Al Nahyan, the UAE President, the Supreme Commander of the Armed Forces and the Ruler of Abu Dhabi (Abu Dhabi Education Council website, 2016). The objective in founding ADEC was to develop education and educational institutions in the Emirate of Abu Dhabi, apply modern and innovative educational policies, to establish plans and programmes to improve the level of education, and to reach the highest international standards through the support of educational institutions and staff. In order to achieve the vision of transforming the Emirate of Abu Dhabi into an innovation-based, knowledge producing society, the leadership implemented policy agendas and frameworks. These policy agendas and frameworks were used to guide the development of strategic and operational plans in all sectors of the Government. As well as the Emirate's Policy Agenda 2007-2008 (Abu Dhabi Government, 2007), individual policies such as Plan Abu Dhabi 2030, Urban Structure Framework (Abu Dhabi Urban Planning Council, 2007), and Abu Dhabi Economic Vision 2030 (Abu Dhabi Government, 2008), set long-term goals for the development of the Emirate, especially concerning physical and economic development. Education was identified as the number one priority for the Abu Dhabi Government (Abu Dhabi Education Council website, 2016).

In 2008, the Abu Dhabi Education Council (ADEC) launched the development of an education policy agenda that described the guiding values and standards for the education system in the emirate. The education policy agenda was developed with participation from stakeholders, including representatives from K-12 (kindergarten to grade 12), higher education, and technical and professional education, as well as from government and industry.

The first education reform for the public schools in the Emirate of Abu Dhabi, implemented by ADEC, commenced in the 2007/08 academic year with a change in curriculum (called the Abu Dhabi Curriculum Standards), resources, pedagogical approaches, professional development support and mentoring, and assessment framework for a group of schools. The changes affected students from kindergarten to grade 9 in schools directly under ADEC's mentoring (then called Model Schools), and for groups of schools being mentored by partnership companies as part of the Public Private Partnership (PPP) programme. While the efforts began with a group of schools and not all grade levels, the plan was to gradually implement in all schools and all grade levels over time. In the 2008/09 academic year, the implementation moved to grade 10 for some subjects, including mathematics, and extended the programme to include more schools in the PPP. In the following academic year, reform efforts were expanded to include further public schools and also moved to Grade 11 for mathematics. The students and teachers involved in this study are part of this initial reform effort.

In 2009, ADEC launched a 10-year strategic plan to address challenges facing public education. The two key challenges that the plan was generated to address were, first, making sure that the performance of students was at a level at or above expected grade level and, second, ensuring that high school graduates were suitably prepared for higher education and for career opportunities that would support the economic and future demands of the Abu Dhabi Emirate. At the centre of the K-12 Strategic Plan, was the design and implementation of the New School Model (NSM) in all public schools. It should be noted that, prior to any reform efforts, the textbook was the main resource for student learning, and rote learning was the main pedagogical approach.

The new model focused on all aspects of the wellbeing of the students and other stakeholders, and included the curriculum, assessment, school leadership, and community involvement. The need for the New School Model (NSM) to supersede the prior reform efforts was because not all schools were involved in the initial strategy, and introducing the new curriculum, assessment, and pedagogy from kindergarten to grade 9 at once was extremely swift, making it difficult to develop consistency. The New School Model (NSM) was implemented initially for kindergarten to grade 3 in the 2010/11 academic year and then rolled out to a new grade level each year thereafter. At the heart of both of the reform efforts, was new curriculum and pedagogical methodologies intended to enhance student performance by promoting the development and use of the 21st century skills of collaboration, communication, creativity and critical thinking.

In the context of the Abu Dhabi Education Council (ADEC) schools, the educational reform required teachers and students to change from a teacher-directed didactic approach to teaching and learning, to that of a constructivist student-centred approach. Dr. M. K. Al Khaili, Director General of the Abu Dhabi Education Council (Abu Dhabi Education Council, 2012b, p. 2) stated:

> In order to be at the forefront of global innovation and development, we must have an education system that can support a community of life-long learners and innovators. At the core of our education reform is the goal to develop students with strong problem-solving and analytical abilities and to equip them with the skills that they need to succeed in their higher education and future careers. Our graduates should be independent thinkers with the ability to create, innovate, and support the economic and social progression of Abu Dhabi.

It is widely acknowledged that teachers tend to teach in the same way that they were taught when they attended school (White-Clark, DiCarlo, & Gilchriest, 2008). For Abu Dhabi teachers, this involved a rote-learning, textbook-based system which encourages memorisation. To ensure a more constructivist approach, the reform required teachers to change the emphasis from textbooks to a more student-centred approach with students exploring questions and topics (Wu & Hsieh, 2006). As a result, the educational reform required teachers to change significantly in terms of what they understand best practice to be and what this looks like in their classrooms.

The education reform efforts impacted a number of subjects, including mathematics. While there was a shift in the mathematical content in the curriculum, the biggest changes involved those made to the pedagogical approaches and assessment tasks and techniques. The focus pedagogically was to shift to a constructivist model where students would be given more ownership in the classroom, more opportunities to interact, collaborate and construct their own knowledge and understanding of concepts. The teachers had to learn to adopt a student-centred model of teaching and learning rather than the didactic traditional lecturing model with which they were familiar. The new pedagogical approach encouraged inquiry-based learning as a vehicle for constructivism.

In my experience as an Education Advisor and Curriculum Specialist, the teachers tended to separate into three groups: those teachers who were extremely positive about the changes and immediately implemented teaching techniques taught in professional development sessions; teachers who were unwilling to consider any change and remained teacher-centred; and teachers who could be persuaded to change but wanted a good reason as to why they should. One reason to apply the changes came through the implementation of a new continuous assessment model that incorporated new assessment techniques and tools. The new continuous assessment techniques were focused on skills, investigative and exploratory, and applications of mathematics. The use of the techniques utilising an inquiry approach is reported in Section 1.2.5, with constructivism, the theoretical foundation for inquiry-based learning, described in the next section.

1.2.4 Constructivism

In the context of this study, inquiry-based learning is the practical application of the theory of constructivism. Constructivist perspectives share two basic precepts. One is that learners actively construct their own knowledge rather than receive preformed information transmitted by others and the other is that for the principles of constructivism to be utilised, the focus in curriculum documentation, strategies for teaching and learning, and dynamics and interactions within the classroom must change. Green and Gredler (2002) proposed four forms of constructivism: developmental, social-cultural, social, and holistic.

Developmental constructivism is based on the idea that students learn by doing (Piaget, 1963). Students develop understanding of concepts by relating them to their personal experience and reinforcement of ideas occurs where the learning experiences are meaningful for them (Piaget, 1971). Students develop logical thinking through spontaneous student-directed experimentation (Green & Gredler, 2002). The role of the teacher is to ‘create and organise challenging experiences; ask probing questions to facilitate learner rethinking of ideas’ (Green & Gredler, 2002, p. 55). The role of the student is to ‘manipulate objects and ideas; experience cognitive conflict between one’s ideas, experimental results, and teacher questions; re-organize one’s thinking’

(Green & Gredler, 2002, p. 55). This form of constructivism is focused on the individual rather than on interactions between students in group contexts. Piaget (1973) realised that the process involved with developmental constructivism is difficult for the teacher, however he believed that the intellectual development depends on the constructive activity of learners with all its issues and mistakes and the additional time this takes.

The second form of constructivism is social-cultural and is based on the work by Vygotsky (1962). The students are not working alone as in the case of Piagetian thinking, but rather they interact with the teacher to reinforce their own understanding of concepts. The primary mechanism for this approach is teacher-student interactions within the classroom. The process of learning to think about varying concepts is developed by the learner in collaboration with the teacher in instruction (Vygotsky, 1934/1978). Specifically, "the teacher, working with the child, explains, informs, inquires, corrects, and forces the child himself to explain" (Vygotsky, 1934/1987, p. 216). Later on when the child solves a problem on their own, they "must make independent use of the earlier collaboration" (Vygotsky, 1934/1987, p. 216).

Social constructivism is the third type of constructivism and is based on communities of students who discuss ideas and re-create knowledge together through interaction (Bredo, 1994; John-Steiner & Mahn, 1996; Perkins, 1999). This form of constructivism differs to both the Piagetian perspective and Vygotsky's description in three areas: the definition of knowledge; the definition of learning; and the locus of learning (Green & Gredler, 2002).

The final form of constructivism is holistic constructivism. The goal of holistic constructivism is for students to have ownership of the learning process and outcomes of the learning. Holistic constructivism is based on the premise that students 'are more motivated to learn narrow skills (the parts) when they see the larger context into which these skills fit' (Green & Gredler, 2002, p. 58). The focus of the classroom environment is to support real-world communication tasks that build on student's strengths and interests.

The theory of constructivism is enacted in the classroom through practical applications of the concepts. In the context of this study, constructivism is portrayed through the use of inquiry-based learning, where students have opportunities to realise all four forms of constructivism. When students are constructing knowledge through research and linking content to real-life on an individual basis, they are experiencing developing constructivism. When a student interacts with the teacher and is asked probing questions, the student is constructing knowledge through the social-cultural form. The use of groups of students working collaboratively together on an inquiry-based learning task allows them to incorporate social constructivism in their learning and finally, when students follow an inquiry approach, they are learning within a context and seeing 'the bigger picture' that each individual skill sits within allowing for holistic constructivism. Within the Abu Dhabi educational reform, inquiry-based learning and its application is described in the next section.

1.2.5 Inquiry Mathematics as Part of the Reform Efforts

A new pedagogical model through the use of inquiry-based learning was viewed as the key to shifting students away from a rote-learning approach and allowing them to develop the 21st Century Skills (4Cs) of critical thinking, collaboration, communication, and creativity. Inquiry-based learning is a practical expression of the theory of constructivism. Constructivism describes how students learn rather than being a method for teaching. That is, students construct their own knowledge of concepts through experiencing them in real-life contexts, by collaborating with other students, and having the teacher act as a facilitator. Inquiry-based learning takes the theory of constructivism and applies it to classroom practice to provide teachers with a pedagogical approach that allows students to construct their knowledge.

For the purpose of this study inquiry-based learning was defined as "a student-centered pedagogy that uses purposeful, extended investigations set in the context of real-life problems as both a means for increasing student capacities and as a feedback loop for increasing teachers' insights into student thought processes" (Supovitz, Mayer, & Kahle, 2000, p. 332). Inquiry-based learning involves a cycle of learning in which students: engage with the concept and start asking questions; explore aspects of the topic, including self-directed research; explain what is occurring, or seek explanations from the teacher to clarify missed or misunderstood key aspects; elaborate on the findings; and evaluate or answer the questions in preparation for new questions that start the cycle again (see Figure 1.1).

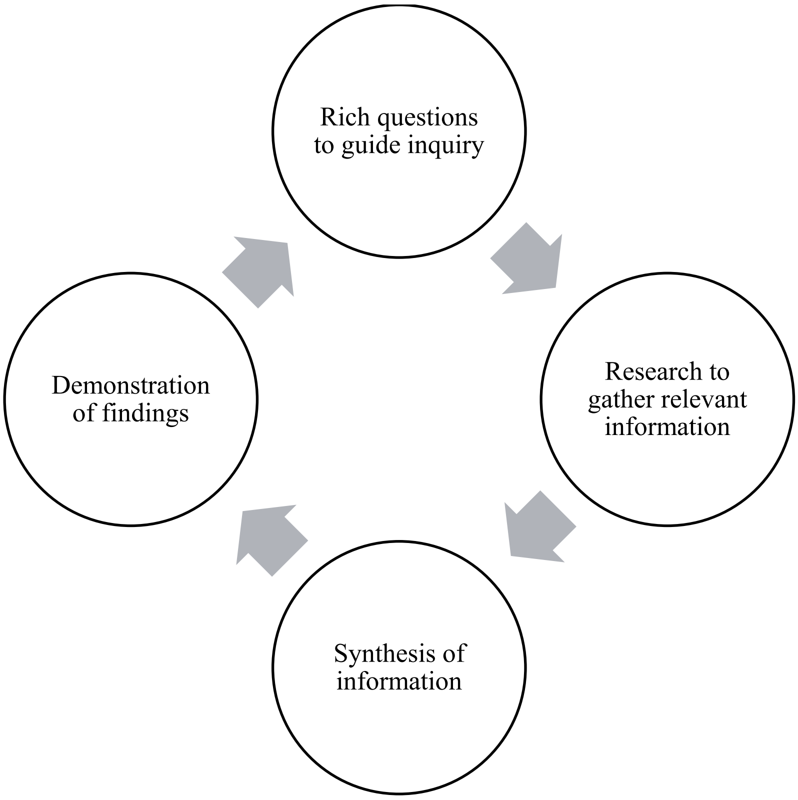

Figure 1.1 Inquiry Cycle

At the time of this study, Abu Dhabi mathematics teachers were encouraged to use inquiry-based learning techniques in classes to help to prepare students for the types of assessments that they would meet. The two new techniques were called investigations and explorations. Investigations are tasks that either allow students to investigate/discover a new relationship or give students an opportunity to apply their knowledge in a real-world context. They are done either individually or in pairs. Investigations contain a sequential list of instructions that allow students to investigate a question and progress to making a decision while displaying proficiency in mathematical skills in the process. The expectation in an investigation is that all students in the class will come to the same conclusion. There is a 'right' answer. The tool used to assess an investigation is a rubric that has criteria for skill outcomes and learning outcomes for content.

As part of the ADEC Mathematics Assessment Framework (Abu Dhabi Education Council, 2012a), teachers were required to use the second technique, that is, explorations. It is these explorations that were the focus of this study. Explorations are completed in groups of between two and four students and are open-ended tasks in which students can explore in different directions. The students follow an inquiry-based learning cycle where they have a question, conduct research to collect information, synthesise the data, and make conclusions including answering the original question. In explorations, students are given a 'big question' by the teacher which is open-ended and gives students the general theme for the task (e.g. How high are the cables on a suspension bridge?). Using a big question, in each group, students then define a more specific question, still open-ended, for their group to answer (e.g. How high are the cables on the Golden Gate Bridge in San Francisco?) This allows students within the same class to start exploring different aspects of the topic using different methods. As with investigations, explorations are assessed using a rubric with criteria for skills and content. A significant percentage of the mark in the continuous assessment is made up with investigations and exploration tasks. Throughout the exploration, the teacher provides guidance regarding the appropriateness of the students' process, through questioning. The tasks are assessed using the following criteria: defining realistic problems; gathering and recording information; generating solutions; suggesting conclusions; and collaborating with other students (for a copy of the Mathematics Explorations Rubric see Appendix A).

The expectations and role of the teacher during an exploration is quite different to that of a more traditional classroom teacher. The role of the teacher is to provide guidance about the appropriateness of the students' process through questioning (Abu Dhabi Education Council, 2012a). The teacher is required to facilitate the inquiry-based learning process, rather than to teach in a traditional lecture style. Teachers need to move between groups asking probing questions to guide students. The intent is not to answer student questions directly but to return with another question that encourages the group to discuss the concept and attempt to solve the problems themselves. The teacher may suggest a book to read or a website to visit or an external expert to discuss their questions with. If the group has submitted their specific question after the first sessions on planning and the teacher feels it is not a question that can be answered or doesn't relate appropriately to the big question, the teacher can give the students a previously prepared specific question and the group will be marked accordingly on the planning section of the rubric.

Once groups have their specific question, they begin the task of gathering and recording information from a number of sources. This may involve research on the internet, reading books available within the classroom or in the library, developing and administering a survey, collecting data from a tool such as GIS (Geographic Information Systems), or interviewing an expert such as a professor from a university or another teacher within the school. Students within the group may choose to split the data collection amongst members of the group (e.g., one student researches background information from books and the internet, one student designs a survey and administers it, another student meets with a physics teacher and discusses the topic they are researching). Some of the information collected may simply be to add background information and knowledge to their topic, while other data will be collected to be analysed to answer their specific question.

After students have collected their data, they are required to analyse what they have collected, perform calculations appropriate to the topic, develop data displays if it supports their data, and then actually answer the specific question they developed at the beginning of the task. Some of the data analysis, calculations and data displays will be dependent on the type of data collected. This is a very useful teaching point for teachers on the type of data collected and how it can be analysed. Many students intend to collect numerical data so that they can perform calculations, but often choose poor questions and data collection methods that do not allow this. Good guidance from the teacher during the planning stages should encourage groups to consider what they intend to get at the end of the process.

An important aspect of explorations is the opportunity for students to present their work to the class and their teacher. Students are required to explain their questions, the process they went through, their analysis and finally their answer. Each group has the freedom to present their work in a manner that is suitable for the topic e.g. PowerPoint, poster, role-play, brochure etc.

In Abu Dhabi, exploration exemplars were provided for teachers at all grade levels from grade 6 to grade 12 (as well as bilingual teacher notes and student frameworks for how to work). The implementation process for this new style of exploration began in the final trimester of the 2011/12 academic year with many teachers beginning to understand the purpose and process. In the 2012/13 academic year, the requirement, in terms of explorations increased, and teachers were required to create the most significant changes in mathematics education since the beginning of the educational reform in the 2007/08 academic year. At the time of this study, individual teachers were implementing explorations to differing degrees and standards depending on many factors, such as, their willingness to change, their understanding of inquiry-based learning, whether they believe students can cope with the demands of the tasks. Some teachers made rapid progress in terms of implementation while others were yet to fully accept the changes.

For many of the teachers, the use of explorations was a significant shift from their traditional rote-learning methods of teaching. By making explorations a compulsory assessment task, teachers were required to adopt the new pedagogy, some more successfully than others. One of the greatest difficulties for teachers was the 'loss of control' that they felt. In the past, students sat quietly in their seats all solving the same problem which the teacher had the answer to. With the inquiry-based learning approach, teachers had groups investigating different ideas using different methods, leaving the class to collect data, discussing their work within their group and between groups, and, in some cases, the teacher no longer had all of the answers.

In the study described in this thesis, the use of inquiry-based learning was investigated, with comparisons made between students' perceptions of the learning environment and attitudes towards mathematics for teachers effectively implementing explorations and those who were not. In the next section, the research objectives for the study are introduced.

1.3 Research Objectives

The aims of the present study were two-fold. First, in this study I examined whether students' perceptions of the learning environment and their attitudes towards mathematics differed for those in classes with teachers exemplary in their use of explorations versus those in classes who were not. Second, it was examined in this study whether, for students in the UAE, there were relationships between students' perceptions of their learning environment and their attitudes towards mathematics. The objectives used to achieve the overall aims are outlined in this section.

To ensure that the results of the study could be relied upon, it was necessary to examine the reliability and validity of the instruments utilised. "Reliability in quantitative research is essentially a synonym for dependability, consistency and replicability over time, over instruments and over groups of respondents" (L. Cohen et al., 2007, p. 146). The validity of an instrument ensures that individual's scores make sense, are meaningful, and enable useful conclusions to be drawn from the sample to the population (Creswell, 2008). Therefore, the first research objective was:

Research Objective 1

To develop and validate instruments suited for use with middle school students in the UAE to assess students' perceptions of the learning environment in exploration classes and their attitudes.

Researchers have claimed that more positive student perceptions of their learning environment also mean that attitudes towards mathematics are also positive (Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). Given this theoretical background, in this study I sought to examine whether associations exist between perceptions of the learning environment and attitudes towards mathematics for students in Abu Dhabi. In this study it was examined whether situations where students experienced positive learning environments, and those that were not positive, produced students with differing attitudes towards mathematics. Given the focus of the UAE towards Science, Technology, Engineering and Mathematics (STEM) education and the intent to encourage more students into the science and mathematics fields, it was considered appropriate to examine students' attitudes and perceptions of the learning environment with a view to adding insights into ways to engage and increase retention in these areas. Therefore, the second research objective was:

Research Objective 2

To investigate whether associations exist between students' perceptions of their learning environment and attitudes towards mathematics.

As part of ADEC's education reform agenda, a focus has been on a shift from traditional teaching methods to those that are student-centred and formed from a discovery or inquiry approach (Abu Dhabi Education Council, 2012b). With such a large-scale and fast-paced reform, the need for research as to the success of the model was considered to be essential. It was important to assess whether the experiences ad attitudes of students exposed to exemplary use of explorations differed when compared to classes where use of the approach was not exemplary. Research that informs the efficacy of the changes expected of the education reform in Abu Dhabi is not prevalent, and so the third research objective, sought:

Research Objective 3

To investigate how mathematics students taught by teachers exemplary in the use of explorations and those who were not differ in terms of students':

a. *Perceived learning environment;*
b. *Attitudes towards an inquiry-based exploration approach in their mathematics classes.*

To ensure the relevance of my study to a range of stakeholders, it was important to investigate potential reasons for the differences observed in the results between student perceptions of the learning environment and attitudes towards mathematics for teachers exemplary and non-exemplary in the use of explorations. Therefore, the fourth research objective was:

Research Objective 4

To investigate reasons for differences of the perceived learning environment and attitudes towards mathematics for students taught by teachers exemplary in the use of explorations and those who were not.

1.4 Significance of the Study

In this section the significance of the study is outlined; however, these points are expanded further in Chapter 5. The results of this study are significant for a number of reasons.

First, the development of two instruments is reported: one to assess the unique learning environments created in mathematics classes using an exploration inquiry approach; and another to assess attitudes towards the mathematics learning in these classes. The scales in the instruments have been brought together as they are suitable for the reform efforts in mathematics in Abu Dhabi.

Second, the validation of the two newly developed instruments in the Arabic language make available tools for educators and researchers in the Middle Eastern context to assess students' learning environment perceptions and attitudes. Further, through the use of these instruments means to monitor the reform efforts currently underway in the UAE has been provided.

Third, the results of the study provide information on inquiry-based learning, which has not been used in mathematics classrooms systematically in Abu Dhabi public schools before this time. The use of inquiry has been documented in other countries, most commonly in science, but also in mathematics, however there is a paucity of research in mathematics classes in the UAE. In particular, the use of inquiry and the impact on the learning environment and student attitudes towards mathematics in the context of Abu Dhabi public schools. Therefore, the findings of this study will play an important role in filling this research gap and adding to the limited literature.

Fourth, due to the current educational reform in Abu Dhabi, research is required to inform next steps for further implementation. The results of the study provide concrete information about the efficacy of inquiry-based learning in mathematics classrooms through the medium of explorations in terms of improving students' attitudes. As such, the findings will inform policymakers within ADEC and also school administrators and teachers.

Fifth, the results of the study may provide some insight into what teachers who are exemplary in the use of explorations are doing to support implementation. This may assist ADEC to better support their teachers in terms of implementation. At this stage of the reform, when the system is moving from a poor to fair situation, it is necessary to define clearly what teachers should be doing to ensure consistency across schools.

Finally, previous research, focusing on the implementation of inquiry-based learning, have been carried out predominantly in Western settings. This study decreases this research void by providing research in an Arab context on inquiry-based learning.

1.5 Overview of the Thesis

In my study I sought to investigate the effectiveness of an inquiry-based exploration approach towards the teaching, learning and assessing of mathematics and whether this has affected students' learning environment perceptions and attitudes towards mathematics. The five chapters contain the rationale, literature, methods, findings and discussion for this study. In this first chapter the conceptualisation of the study has been explained. I have discussed the context of the study in the United Arab Emirates, including the history of Abu Dhabi and the education system, the educational reform undertaken by the Abu Dhabi Education Council, the theory of constructivism and the resulting use of inquiry-based learning as a pedagogical approach as part of the reform efforts. In this chapter the research objectives that were investigated for the study has been outlined. The final component of the first chapter included the significance of my study in mathematics, Abu Dhabi, and the wider field of research.

In Chapter 2 a review of the literature concerning inquiry-based learning, learning environment research, and attitude research, which are all topics pertinent to the study has been presented. Inquiry-based learning literature features a focus on definitions of inquiry, benefits of using inquiry techniques, and a review of effective implementation of inquiry-based learning. The learning environments section focuses on history of learning environments, a multitude of learning environment instruments developed for differing purposes, and past studies implementing learning environments research. The review of attitudes literature concentrates on definitions, attitudes in mathematics research, focusing specifically on enjoyment of mathematics, self-efficacy, and task value.

The theoretical framework for the study and the methods used to gather data are outlined in Chapter 3. These mixed methods include both quantitative and qualitative phases and provided are details concerning the sampling process. The two new instruments developed to assess the learning environment and to assess student attitudes towards mathematics in the quantitative phase for this study, are also detailed. The instruments utilised in the qualitative phase are described, and the data analysis process is presented. Finally, ethical issues associated with the study are detailed.

In Chapter 4 the results of the analysis of the data have been reported. The results pertaining to the research objectives (described in Section 1.3 above) are reported, including: the reliability and validity of the instruments used to collect the data; the differences in learning environment and student attitudes towards mathematics for classes with teachers exemplary in the use of explorations and those who were not; and associations between the learning environment and student attitudes.

In the final chapter, detailed discussion and conclusions of the study's results and includes educational implications and limitations have been given. Additionally, recommendations for further research are incorporated.

CHAPTER 2

Review of Literature

2.1 Introduction

The overarching aim of the present study was to examine whether the learning environment perceptions and attitudes of students differed for those in classes taught by teachers exemplary in the use of explorations and those who were not. In this chapter I have reviewed literature pertinent to the present study and have organised using the following headings:

- Inquiry-based learning (Section 2.2);
- Field of learning environments (Section 2.3);
- Students' attitudes towards mathematics (Section 2.4);
- Chapter summary (Section 2.5).

2.2 Inquiry-based Learning

In this study I sought to examine whether students exposed to exemplary use of explorations in mathematics classes held more positive attitudes towards mathematics and perceived the learning environment differently than those who were not. Therefore, in this section literature related to inquiry-based learning, including a definition of what inquiry-based learning is, and the background to its current use in curriculum documentation internationally and research related to its use in classrooms is reviewed. The review of literature related to inquiry-based learning is organised into two sections: definitions of inquiry-based learning (Section 2.2.1), and empirical studies related to inquiry (Section 2.2.2).

2.2.1 Definitions of Inquiry-based Learning

Inquiry-based learning is viewed as an authentic approach to the teaching and learning of mathematics (Amaral, Garrison, & Klentschy, 2002; Cobb, 2002). Although definitions of inquiry-based learning can differ (Bruder & Prescott, 2013), for the purpose of this study, inquiry-based learning is defined as a “student-centered pedagogy that uses purposeful, extended investigations, set in the context of real-life problems, as both a means for increasing student capacities and as a feedback loop for increasing teachers’ insights into student thought processes” (Supovitz et al., 2000, p. 332).

The process of an inquiry has general steps which are not normally performed in a linear fashion but, rather, follow a cyclic process that involves: questioning, planning, researching, analysis, concluding and reflecting (Chapman & Heater, 2010; Jansen, 2011; Jarrett, 1997; Singer & Moscovici, 2008). Students are required to solve authentic or ‘real’ problems (Makar, 2007) by beginning with a question and ending with an answer that generates more questions to explore. Collaboratively, students plan their process and spend time in research through multiple sources, which may include print, electronic and people sources (Chapman & Heater, 2010). An important aspect of an investigation is the development of the ability for students to filter information and to analyse what has been discovered. Students are required to demonstrate their findings by suggesting a conclusion and then reflecting on their work (Wu & Hsieh, 2006). Makar (2007, p. 48) states that “the goal of inquiry is both knowledge-building and building understanding of the processes of knowledge-building, that is, learning how to learn.”

One exemplar of inquiry-based learning that is widely used, is the 5Es model, developed by the Biological Science Curriculum Study (BSCS), which proposes a five-step model for inquiry (Layman, Ochoa, & Heikkinen, 1996). See Figure 2.1 for a pictorial representation of the 5Es model. “The goal of the first step, ‘engage’, of the 5E model is to give students an opportunity to become motivated or excited about the information they will learn” (Orgill & Thomas, 2007, p. 41). Students begin the inquiry process by engaging with a big question or idea that they wish to investigate. The next step ‘explore’, requires the students to gather information through research, experiments, surveys etc. to support their investigation into the big question. The third step of the cycle allows teachers to explain content and information that students may not have had the opportunity to gather or understand for themselves. In the fourth step, students are required to use mathematics to explain their discoveries and to apply this new knowledge in unfamiliar contexts. This step supports students in forming conclusions to answer their 'big' question. The final step of the cycle is when students present their findings, reflect on their conclusions, and seek to consider where the inquiry goes next. This then informs the engagement in the next big questions and the cycle continues. The teacher has the opportunity to evaluate the understanding that the students have concerning the topic.

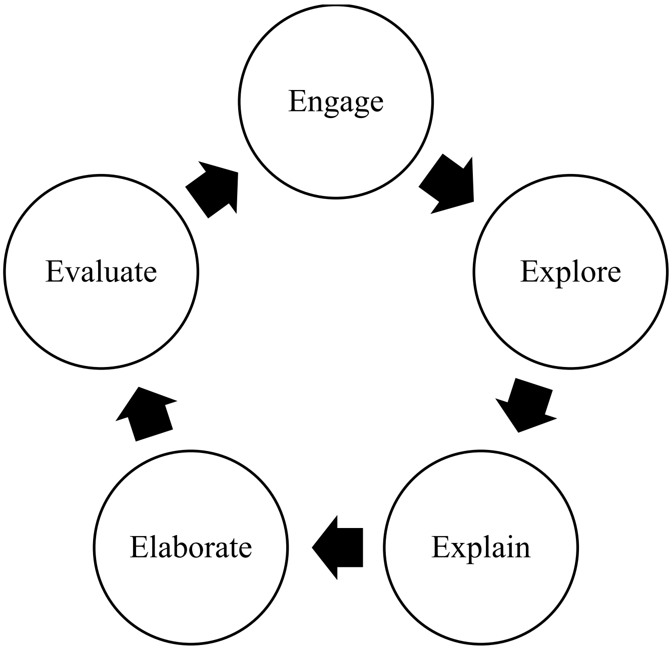

Figure 2.1 Representation of the 5 Es model for inquiry

2.2.2 Empirical Studies Related to Inquiry

Past research related to inquiry-based learning has been carried out in many countries, subjects and contexts. Its use is well documented, with studies reporting the benefits (described in Section 2.2.2.1); and the processes involved in effective implementation (described in Section 2.2.2.2).

2.2.2.1 Benefits of Inquiry-based Learning

Much of the success in any education reform comes from students being genuinely interested in their work and their natural curiosity (Jarrett, 1997), which then leads to meaningful inquiry. It stands to reason then, that meaningful inquiry, implemented effectively, would perpetuate students' interest and curiosity. Indeed, as a teaching approach, research has suggested that inquiry-based learning can have a number of advantages. Inquiry-based learning has been shown to generate positive attitudes in students (Jarrett, 1997), and increase enthusiasm and an enjoyment for learning (Makar, 2007; Sheppard, 2008). Students engaging in inquiry-based learning tend to develop positive identities with regards to mathematics (Staples, 2007), while experiencing opportunities to delve into topics that link to their real lives (Boaler, 1997; Bransford, Brown, & Cocking, 2000; Diezmann, Watters, & English, 2001; Makar, 2007). It is these affective outcomes that are of significance to the current study, however a number of other benefits of inquiry-based learning have also been reported. According to (Jarrett, 1997, p. 6):

> Students develop critical thinking skills by learning through inquiry activities. They learn to work collaboratively, to articulate their own ideas, and to respect the opinions and expertise of others. They learn inquiry skills that they can use in other aspects of their lives and intellectual pursuits.

In a meta-analysis of 205 studies on inquiry-based learning it was asserted that, "overall, inquiry-based instruction was shown to produce transferable critical thinking skills as well as significant domain benefits, improved achievement, and improved attitude towards the subject" (Hattie, 2009, pp. 209-210). Previous research and commission inquiries have revealed that teaching and learning that focuses on the STEM (science, technology, engineering and mathematics) subjects has been shown to be improved through the use of inquiry (Bransford et al., 2000; Bybee et al., 2006; Donovan & Bransford, 2005; Llewellyn, 2001; National Commission on Excellence in Education, 1983; National Commission on Mathematics and Science Teaching, 2000; National Council of Teachers of Mathematics, 2000).

Furthermore, according to the results of past research, using an inquiry approach can: encourage students to think critically (Jansen, 2011; J. C. Marshall, Smart, & Horton, 2010); reason (Staples, 2007); develop deep understanding (Makar, 2007; Oliver, 2007; Staples, 2007); and reduce reliance on memorising facts (Goos, 2004; J. C. Marshall & Horton, 2011). Through the use of an inquiry approach, students have the opportunity to critically reflect on their products and processes (Leikin & Rota, 2006) and to be intellectually engaged in the task (Oliver, 2007). In her reflection on inquiry-based learning, Manouchehri (2007, p. 299) states, "…students made conjectures, formed questions, and collaborated with their peers in constructing mathematical arguments. These skills are far more important than memorising solutions and answers, which students quickly forget once they leave the classroom."

An important aspect of inquiry-based learning is the development of students' abilities to collaborate. According to Staples (2007, pp. 162-163):

> … joint production of ideas, where students offer their thoughts, attend and respond to each other's ideas, and generate shared meaning or understanding through their joint efforts. Collaboration is distinct from cooperation which only implies sharing. Students can cooperate to accomplish a task, by sharing answers or creating a poster or other product together but may not engage in collaboration with respect to the joint production of mathematical ideas.

Stonewater (2005, p. 36) goes further to suggest that true inquiry-based learning in the classroom fosters the development of collaboration and that inquiry-based learning "…teaches students not only what to learn but how to learn.". Collaboration is utilised when students are involved in their lessons and interacting with their peers. Collaboration is a key element in the development of positive learning environments (see Section 2.3.2 for more information regarding learning environments).

2.2.2.2 Effective Implementation of Inquiry-based Learning

Inquiry-based learning cannot occur without thoughtful and careful planning of student tasks, learning environment, teaching methodologies and facilitation, and appropriate resourcing (Barron & Darling-Hammond, 2010). Effective implementation strategies within both small groups and larger-scale reform are essential for the success of any programme involving inquiry-based learning (Puntambekar & Kolodner, 2005). For changes to pedagogies associated with inquiry, often also associated with reform efforts, teachers need to learn to guide behaviour in classrooms where students are not completing traditional activities, design activities and tasks involving the development of both content and skills for the students, and assess outcomes for students (Bakkenes, Vermunt, & Wubbels, 2010; Hoekstra, Brekelmans, Beijaard, & Korthagen, 2009; Hoekstra & Korthagen, 2011). For implementation of inquiry-based learning to be effective, the role of teachers and students within the classroom needs to be clear and established. These roles differ from traditional classes and so there needs to be an adjustment period for all stakeholders in order to establish classrooms and norms and behaviours that allow for successful inquiry to be accomplished (Bruder & Prescott, 2013). Teachers play a pivotal role in supporting and implementing student inquiry through "establishing a radically different set of social norms and values in the classroom as well as finding ways to invite students into the inquiry process, and support them as they engage in the process" (Siegel & Borasi, 1994, p. 210).

The role of teachers in implementing a successful inquiry classroom is important and ensuring that teachers are well supported throughout the process is essential. Makar (2007) realised the importance of identifying support mechanisms that teachers viewed as critical in developing their skills in implementing an inquiry-based methodology. These included: "inquiry experiences as a learner, multiple iterations, validation, resources, sustained support and feedback, collegiality, development of deep disciplinary knowledge, time and support for reflection, relevance, and accountability" (p. 58). As part of the implementation process in a year-long study, Makar (2007) noted that some of the success of the project was due to the teachers already having a positive view and belief towards inquiry and constructivism. It would appear that, if teachers are not committed to this pedagogy, progress is less likely to occur. Similarly, work by Pendergast et al. (2005) indicates that, if an individual teacher's philosophy of education is not consistent with the reform efforts, that initial change of practices is unlikely to be sustainable. For inquiry-based learning to be effectively implemented, the role of the teacher must be considered as in a traditional classroom, the teacher is able to plan and control the entire lesson, however in an inquiry classroom, the teaching and learning relationship can be complex allowing for flexibility and a level of uncertainty within the process (Leikin & Rota, 2006; Phelan, 2005).

The effective implementation of inquiry-based learning, even at the higher-grade levels, can engage students in the mathematics that they are learning (Sheppard, 2008).

According to Sheppard (2008), using a constructivist pedagogy, even in an examination-focused year, can better prepare students for further study, improve students' attitudes towards themselves as learners, and give students the ability to make possible career or higher education study choices. The structured implementation approach of inquiry-based learning encouraged high school students to think freely about the mathematics within a guided process about how to record, think about and discuss observations and outcomes. These factors allowed the students to be more successful than their counterparts in traditional classes (Sheppard, 2008). Students in higher grade levels studying academically challenging subjects, such as chemistry, benefit from the use of inquiry-based learning (Chairam, Klahan, & Coll, 2015). Through the effective implementation of inquiry-based learning in practical laboratory classes, results showed that students made significant progress in developing concept lists, expressing and wording scientific hypotheses, identifying variables, devising experiments, analysing their results and presenting data (Chairam et al., 2015). These findings suggest that inquiry-based learning can be effectively implemented in classes with students of higher grades.

An important aspect of effective implementation is defining the roles of both the students and the teacher within the inquiry process (Kidman & Casinader, 2017). Traditionally, teachers have been the experts at the front of the classroom while students passively acquire the knowledge sitting in their chairs. With the use of effective inquiry-based learning, the roles change significantly (Mills, O'Keefe, & Jennings, 2004). The teacher is seen as a facilitator of learning in student-centred inquiry classrooms (Spronken-Smith, Bullard, Ray, Roberts, & Keiffer, 2008). That is, the teacher employs an inductive approach to teaching, in which the learning is guided by the students' need for information to support their inquiry. This is in contrast to a deductive approach; in which the teacher commences with the content knowledge, including theories and principles, and then the application of the topic thereafter (Prince & Felder, 2006). As such, during an inquiry approach, the role of the teacher changes from a transmitter of content knowledge to a facilitator of the processes associated with learning (Maass, Swan, & Aldorf, 2017; Swan, 2007).

The overall findings of the empirical studies concerning inquiry-based learning indicate that, formally or informally, when implemented effectively, the use of inquiry as a pedagogical tool promotes: positive experiences for students in terms of their engagement (Bruder & Prescott, 2013; J. Murray & Summerlee, 2007; Sheppard, 2008); improved attitudes towards students' learning (Barron & Darling-Hammond, 2010; Sheppard, 2008); and, a higher quality of teaching and learning (Deignan, 2009; J. C. Marshall & Horton, 2011).

Through my study I added to the body of research investigating inquiry-based learning approaches. The research reviewed within this section focuses on the use of inquiry as a teaching and learning technique. In my study I extended this past research as the use of inquiry-based learning in the form of explorations includes both teaching and learning as well as a student assessment tool. In particular, my study focuses on the inquiry-based learning in mathematics classes, extending past research that has been predominantly carried out in science classrooms. My study builds on, and extends, other studies that have compared classes utilising inquiry-based learning techniques and those that have not (see for example, Geier et al., 2008; Summerlee & Murray, 2010; Wolf & Fraser, 2008), by examining differences between students' perceptions of the learning environment and attitudes towards mathematics for students taught by teachers exemplary in the use of explorations and those that were not. The research reviewed within this section focuses on the use of inquiry as a teaching and learning technique. In my study I extended this past research as the use of inquiry-based learning in the form of explorations includes both teaching and learning as well as a student assessment tool. My study also involves the investigation of inquiry-based learning within an Arabic-medium environment in the UAE, which fills a research gap.

2.3 Field of Learning Environments

In my study I sought to examine differences in perceptions of the learning environment for students in mathematics classes with teachers exemplary in the use of explorations and those who were not. The premise was that students with teachers exemplary in the use of explorations would have more positive perceptions of their learning environment as a consequence of the pedagogical approaches that they experienced compared with their peers with teachers who were not. For this reason, a review of literature related to the field of learning environments was carried out.

Students spend a considerable amount of time in classrooms and much attention is paid to their achievement scores. While this is an important aspect of what occurs within the classroom walls, it does not give us a full understanding of the experiences of the students (Fraser, 2007; OECD, 2017). There are two distinct aspects of the learning environment, namely, the human and the physical environment. The human aspect includes the students and teachers and the interactions between them, while the physical environment incorporates the furniture, equipment, resources, classroom displays and lighting (Fraser, 2015). For the purpose of my study, the learning environment involved the psychosocial climate, which takes into consideration the culture, ambience or atmosphere where learning takes place (Fraser, 2012).

With students spending more than 20,000 hours in classroom spaces by the time that they graduate from university, it is essential that the environment they are experiencing is one that promotes and supports positive attitudes towards their learning (Fraser, 2001). In this section literature related to the field of learning environments is reviewed in terms of: the history of the field of learning environments (Section 2.3.1); the instruments used to assess the learning environment (Section 2.3.2); and, learning environment research (Section 2.3.3).

2.3.1 History of Learning Environment Research

Research in the field of learning environments has been carried out for more than 50 years. However, the first formal research studies that were applicable to learning environment research, drew on the work of Lewin (1936), a distinguished psychologist, who commenced work in the 1930s. Lewin found that individual's interactions with the environment could be considered to be strong determinants of human behaviour. Lewin's formula, $B = f(P, E)$, represented the environment as a determinant of human behaviour, with behaviour (B) being a function (f) of the person (P) and the environment (E). The ground-breaking work of Lewin, that utilised scientific methods and experimentation to look at social behaviour, is why he is considered to be the 'founder of modern social psychology' (Marrow, 1977).

Murray (1938) was interested in the concept of the internal determinants of behaviour, however he believed that previous research, such as that of Lewin, neglected this and had not considered the development of a drive or need. Murray corrected the omission by developing the *needs-press* model. The model incorporates the situational variables found in the environment, which seek to explain a degree of behavioural difference. Murray (1938, p. 124) explained that the difference between ‘needs’ and ‘press’, by defining *needs* as “... a force … which organises perception, apperception, intellection, conation, and action in such a way as to transform in a certain direction an existing, unsatisfying situation”. Further, Murray used his *needs-press* model to explain the difference between *alpha press* (the environment as observed by an external observer) and *beta press* (the environment as perceived by individuals themselves). Through Murray’s work with the needs-press model, Lewin’s formula was supported in that personality characteristics and environmental characteristics were further defined. Personality characteristics were considered to be goal oriented whereas, environmental characteristics were external to the individual, determined as either positive or negative, dependent on the personality needs of the individual. Therefore, both Lewin and Murray are widely attributed with having established the basis for fundamental research with respect to classroom learning environments.

Stern’s (1970) work and approach followed on from the needs-press model originally suggested by Murray (1938). Stern looked beyond the academic setting and included industrial environments in his study. His approach, termed ‘environmental taxonomy’, was derived from “the premise that the psychological significance of both the person and the environment can be inferred only from the analysis of overt behaviour” (Zentner, 1971, p. 1156). Stern translated the need-press model into an operational framework through an activities index (AI) and a related environmental index (EI), so that "the AI scales parallel those of the EI, one corresponding to behavioral manifestations of the various needs variables, the other to environmental press conditions likely to facilitate or impede their expression” (Stern, 1970, p. 15). Stern (1970) suggested that, when there is a fit between the environment and what the individual perceives to be their preferred environment, the individual is more likely to perform better on a range of outcomes.

The field of learning environments also draws on the work of Moos (1976), which had a threefold purpose: firstly, to sketch the broad outlines of a social ecological approach to environment and behaviour, secondly to survey the major perspectives from which environments have been conceptualised and measured, and, finally, to summarise existing knowledge about environmental impact on behaviour (Stokols, 1979). Social ecology is defined as "the multidisciplinary study of the impacts of physical and social environments on human beings" (Moos, 1976). He proposed that there are three dimensions into which the different characteristics of all human environments can be classified: 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). The final dimension that Moos describes, 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 have provided the foundation on which many learning environment instruments have been based and have allowed researchers to classify scales within new instruments (Fraser, 1998, 2007, 2012).

The foundation of learning environment research began with work by Walberg and Moos, who independently implemented programmes of research forming the basis for the development of numerous learning environment instruments. Walberg developed the Learning Environment Inventory (LEI) as part of his work with the Harvard Project Physics (Walberg & Anderson, 1968). Alongside Trickett, Moos began developing scales for use in assessing social climate, which culminated in the development of the Classroom Environment Scale (CES; Moos, 1974; Trickett & Moos, 1973). The work of Walberg and Moos is considered to be pioneering in this field and was the beginning of the creation of many historically important as well as contemporary learning environment instruments.

2.3.2 Learning Environments Instruments

The field of learning environments has grown over the last 50 years. There are now many instruments that have been validated for use in many contexts and countries

(Fraser, 2002, 2007, 2012). For my study, it was important to review the available instruments, critique them according to reliability, validity and use in non-English speaking contexts, before assessing what scales would be appropriate to measure student perceptions of the unique learning environment established in an inquiry setting in Arabic-speaking mathematics classrooms in Abu Dhabi. Therefore, in this section, nine historically relevant and current instruments are reviewed. In Table 2.1 these nine instruments are summarised and their scales classified according to Moos' (1979) dimensions (explained in the previous section). The table also includes information on the author of each of the instruments, the number of items per scale the level at which the survey should be used (primary, secondary, higher education), and an example item from one of the scales. The learning environment instruments are described in the following sections:

- Learning Environment Inventory (LEI) (Section 2.3.2.1);
- Classroom Environment Scale (CES) (Section 2.3.2.2);
- Individualised Classroom Environment Questionnaire (ICEQ) (Section 2.3.2.3);
- My Class Inventory (MCI) (Section 2.3.2.4);
- College and University Classroom Environment Inventory (CUCEI) (Section 2.3.2.5);
- Questionnaire on Teacher Interaction (QTI) (Section 2.3.2.6);
- Science Laboratory Environment Inventory (SLEI) (Section 2.3.2.7);
- Constructivist Learning Environment Survey (CLES) (Section 2.3.2.8); and
- What Is Happening In this Class? (WIHIC) questionnaire (Section 2.3.2.9).

2.3.2.1 Learning Environment Inventory (LEI)

The Learning Environment Inventory (LEI) has been used extensively in junior and senior high schools seeking to measure students' perceptions of the social climate of classrooms (Walberg & Greenburg, 1997). The LEI was developed and validated in the late 1960s in a research project with the Harvard Project Physics (Walberg & Anderson, 1968). In the inventory, 15 features of the learning environment are

Table 2.1 Author, level, sample item and items per scale for nine learning environment instruments classified according to Moos' scheme

Instrument	Author/s	Level	Example item	Items per scale	Scales classified according to Moos' scheme: Relationship dimension	Personal development dimension	System maintenance and system change dimension
Learning Environment Inventory (LEI)	Walberg & Anderson (1968)	Secondary	Every student enjoys the same privileges. (Favouritism)	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material environment Goal direction Disorganisation Democracy
Classroom Environment Scale (CES)	Moos (1974)	Secondary	The teacher takes a personal interest in the students. (Teacher Support)	10	Involvement Affiliation Teacher support	Task orientation Competition	Order and organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Rentoul & Fraser (1979) Fraser 1990	Secondary	The teacher takes a personal interest in the students. (Personalisation)	10	Personalisation Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)	Fraser, Anderson & Walberg (1982)	Upper Primary	Children seem to like the class. (Satisfaction)	6-9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College & University Classroom Environment (CUCEI)	Fraser & Treagust (1986)	Higher Education	Activities in this class are clearly and carefully planned. (Task Orientation)	7	Personalisation Involvement Student cohesiveness Satisfaction	Task orientation	Innovation Individualisation

Instrument	Author/s	Level	Example item	Items per scale	Scales classified according to Moos' scheme		
					Relationship dimension	Personal development dimension	System maintenance and system change dimension
Questionnaire on Teacher Interaction (QTI)	Creton, Hermans & Wubbels (1990)	Primary & Secondary	She/he gets angry. (Admonishing Behaviour)	8-10	Helpful/friendly Understanding Dissatisfied Admonishing		Leadership Student responsibility and freedom Uncertain Strict
Science Laboratory Environment Survey (SLEI)	Fraser, McRobbie & Giddings (1993)	Upper Secondary/ Higher Education	I use the theory from my regular science class sessions during laboratory activities. (Integration)	7	Student cohesiveness	Open-endedness Integration	Rule clarity Material environment
Constructivist Learning Environment Survey (CLES)	Taylor, Fraser & Fisher (1997)	Secondary	I learn about the world outside of school. (Personal Relevance)	7	Personal relevance Uncertainty	Critical voice Shared control	Student negotiation
What Is Happening In this Class? Questionnaire (WIHIC)	Fraser, Fisher & McRobbie (1996)	Secondary	I know other students in this class. (Student Cohesiveness)	8	Student cohesiveness Teacher support	Investigation Task orientation Cooperation	Equity

Adapted from Fraser (2012) with permission (see Appendix B).

measured (Walberg & Greenburg, 1997) including, Cohesiveness, Friction, Favouritism, Cliqueness, Satisfaction, Apathy, Speed, Difficulty, Competitiveness, Diversity, Formality, Material, Environment, Goal Direction, and Disorganisation. An example of a statement for Favouritism is “Every student enjoys the same privileges” (Walberg & Greenburg, 1997). Students respond to items using a five-point likert scale of strongly agree, agree, unsure, disagree and strongly disagree to rate the statements.

Although the LEI is an historically important instrument and the forerunner for many other instruments, its factorial validity was never established. The LEI is made up of 105 items, making it an onerous and time-consuming survey to complete. Although the intention of the LEI was to be used with high school students, the language utilised in many of the items of the instrument is somewhat complex for students of this age group to comprehend. Given these shortcomings, and that the LEI is now considered to be an instrument more suitable for teacher-centred contexts, rather than modern classrooms where the focus is on a student-centred environment, this instrument was not considered suitable for the present study.

2.3.2.2 Classroom Environment Scale (CES)

The Classroom Environment Scale (CES), developed by Moos and Trickett (Moos, 1974), “grew out of a comprehensive programme of research involving perpetual measures of a variety of human environments, including psychiatric hospitals, prisons, university residences and work milieus” (Fraser, 2012, p. 1191). The CES is designed for use with secondary schools (Fisher & Fraser, 1983a, 1983b; Fraser & Fisher, 1983; Moos, 1979) and is made up of nine scales with 10 items in each. The nine scales are: Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organisation, Rule Clarity, Teacher Control, and Innovation. Items are responded to using a True or False scale, and as almost half of the items were negative, the scoring was reversed. A typical item in the CES for the Teacher Support scale is “The teacher takes a personal interest in the students”.

One of the benefits of the CES is that it has a preferred form to assess perceptions of the environment ideally liked or preferred. Like the LEI however, factorial validity was never established, and the instrument is suited to a more teacher-centred classroom than to a constructivist model of teaching. A further issue with the CES is whether it has the ability to discriminate sufficiently utilising a two-point scale (true/false) and whether this provides an accurate picture of the perceptions of students. For these reasons, the CES was not selected for use in this study.

2.3.2.3 Individualised Classroom Environment Questionnaire (ICEQ)

The Individualised Classroom Environment Questionnaire (ICEQ) was originally developed by Rentoul and Fraser in 1979 and later published as a final version by Fraser in 1990 (Fraser, 1990). The purpose of the ICEQ is to assess classroom environments in individualised classroom settings rather than those using traditional teaching and learning methodology. Like the CES, the ICEQ was developed to measure teachers' and high school students' preferred and actual perceptions of the learning environment. The ICEQ has five scales with 10 items in each, these being: Personalisation, Participation, Independence, Investigation, and Differentiation. A sample item is "The teacher considers students' feelings" (from the Personalisation scale). The questionnaire uses a five-point frequency response format of almost never, seldom, sometimes, often and very often. Many of the items are reverse scored.

The ICEQ filled a void created by previous instruments, such as the LEI and the CES (which were better suited to more traditional classrooms), in that it included dimensions that were important to open or individualised classrooms (Wheldall, Beaman, & Mok, 1999). Another useful aspect of the ICEQ is the inclusion of both actual and preferred forms with information concerning perceptions of the learning environment of both teachers and students (the actual form measures student perceptions of their current classroom environment and the preferred version measures what they would prefer their classroom to be like). The ICEQ was developed to be economical and to reduce answering and scoring time. This is particularly true for the short form of the questionnaire; however, the long form was considered more reliable (Wheldall et al., 1999). Although the ICEQ was developed to be used in open or inquiry-based situations, its factorial validity was not well established and it did not have sufficient emphasis on the use of inquiry, therefore, a decision was made to not use it in this study.

2.3.2.4 My Class Inventory (MCI)

The MCI was developed as a simplification of the LEI by Fraser, Anderson and Walberg in 1982 (Fraser, Anderson, & Walberg, 1982); to be used with younger children, aged eight to 12 years, whereas the LEI was for secondary aged students. The MCI was altered in four ways to ensure suitability when used with younger children. First, the total number of scales and items were reduced so that it would not be overwhelming for younger students. Second, for younger reading levels, the wording was simplified. Third, the response style was altered to a Yes/No format and, finally, rather than students answering the survey on a separate sheet, they answer directly on the questionnaire. The MCI includes five scales: Cohesiveness, Friction, Satisfaction, Difficulty, and Competitiveness. A typical item is "Children seem to like the class" (from the Satisfaction scale).

When considering use of the MCI, the following points were taken into consideration. First, the factorial validity of the instrument was not confirmed until a study in Brunei Darussalam established a revised factor structure that could be used in subsequent research (Majeed, Fraser, & Aldridge, 2002). Another issue was the yes-no rating scale that suggested a correct answer to some students. This was remedied by a study in Singapore where the yes-no format was changed to a three-point format (seldom, sometimes and most of the time) (Goh, Young, & Fraser, 1995). Finally, the Satisfaction dimension was used as an environment dimension rather than an outcome. Given that the MCI was developed for use in primary schools, rather than in middle schools, where this research was based, the MCI was not chosen as a suitable instrument for this study.

2.3.2.5 College and University Classroom Environment Inventory (CUCEI)

Although this study was based in middle schools, the development of the CUCEI is worth mentioning as, historically, it was the first instrument to be developed for use in assessing the learning environment in colleges and universities. The College and University Classroom Environment Inventory (CUCEI) was developed to assess learning environments in the higher education context because "…surprisingly little work has been undertaken in higher education classrooms which is parallel to the traditions of classroom environment research at the secondary- and primary-school levels." (Fraser, 2012, p. 78). It was developed by Fraser and Treagust (Fraser & Treagust, 1986; Fraser, Treagust, & Dennis, 1986), for use in small classes. The CUCEI has seven scales with seven items in each scale: Personalisation, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation, and Individualisation. In the Task Orientation construct, a sample item is "Activities in this class are clearly and carefully planned". The possible responses to each item are made on a four-point scale of: strongly agree, agree, disagree, and strongly disagree). The response scoring is reversed on a number of the items.

The CUCEI has had mixed success in studies where it has been utilised. In a study of 536 students in 45 classes in Australia, Fraser, Williamson and Tobin (1987) found positive results for involvement, satisfaction, innovation and individualisation. However, in the New Zealand context of two independent studies in computing classes, the statistical performance of the CUCEI was not completely satisfactory and revealed issues common to both studies (Logan, Crump, & Rennie, 2006). Given the mixed success of its use in previous studies, and that the current study was carried out in middle school classes, the CUCEI was not considered for use in this study.

2.3.2.6 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) is used to investigate the interpersonal relationships between students and teachers. It focuses on student perceptions of eight areas of teacher behaviour: Leadership, Helpful/Friendly, Understanding, Student Responsibility and Freedom, Uncertain, Dissatisfied, Admonishing, and Strict. The QTI has a response format incorporating a five-point scale with the options ranging from never to always. A sample item is "She/he gets angry" in the Admonishing scale. It was originally developed in the Netherlands (Creton, Hermans, & Wubbels, 1990; Wubbels & Brekelmans, 2005; Wubbels & Levy, 1993), but an English version was developed for use in the USA to evaluate teacher-student relationships in secondary schools (Wubbels & Levy, 1993).

The QTI has been used in a number of countries including Brunei Darussalam (Scott & Fisher, 2004), Korea (H.-B. Kim, Fisher, & Fraser, 2000; S. S. U. Lee, Fraser, &

Fisher, 2003), Australia (Fisher, Henderson, & Fraser, 1995a), Singapore (Goh & Fraser, 1996; Quek, Wong, & Fraser, 2005) and Indonesia (Fraser, Aldridge, & Soerjaningsih, 2010).

Use of the QTI focuses on evaluating relationships within the learning environment primarily those between teachers and students. While this is extremely valuable, the need to focus on more aspects of the learning environment was required in this study and so the QTI was not considered useful.

2.3.2.7 Science Laboratory Environment Inventory (SLEI)

In the context of teaching science, the laboratory setting is unique and requires a distinctive instrument to assess its learning environment. The Science Laboratory Environment Inventory (SLEI) was developed by Fraser, Giddings and McRobbie to assess the learning environments in laboratory in senior secondary and tertiary institutions (Fraser, McRobbie, & Giddings, 1993; McRobbie & Fraser, 1995). The SLEI has five scales with seven items in each, these being: Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment. A typical item for the Integration scale is "I use the theory from my regular science class sessions during laboratory activities". The items are responded to using a five-point frequency scale of almost never, seldom, sometimes, often and very often.

The SLEI has been used in many studies internationally and has been translated for use in other languages. The SLEI has been cross-nationally validated in six countries (Australia, United States, Canada, England, Israel, Nigeria; Fraser et al., 1993), and validated in Singapore (Wong & Fraser, 1994), Australia (Fraser & McRobbie, 1995), Korea (Fraser & Lee, 2009), and the United States (Lightburn & Fraser, 2007). In Spain, the short Spanish form of the SLEI was found to be a valid, reliable instrument (De Juan et al., 2016).

Whilst the validity and reliability of the SLEI has been established in several countries, its focus on the learning environment in science laboratories made the scales unsuitable for use in this study.

2.3.2.8 Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) was developed by Taylor, Fraser and Fisher (1997) “to assist researchers and teachers to assess the degree to which a particular classroom’s environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and reshape their teaching practice” (Fraser, 2012, p. 1202). The CLES has five scales with six items in each. The scales include Personal Relevance, Critical Voice, Student Negotiation, Uncertainty, and Shared Control (Nix, Fraser, & Ledbetter, 2005). The students can respond to the survey on a five-point response format with options including almost never, seldom, sometimes, often and almost always. An example item for the Personal Relevance scale is “I learn about the world outside of school”.

The validity and reliability of the CLES has been reported in a number of studies including: the US (Beck, Czerniak, & Lumpe, 2000; Cannon, 1995; Harwell, Gunter, Montgomery, Shelton, & West, 2001; Johnson & McClure, 2004; Nix et al., 2005; Peiro & Fraser, 2009; Spinner & Fraser, 2005); Palestine (Zeidan, 2015); and Iran (Ebrahimi, 2015); and a cross-national validation of the CLES was undertaken in mathematics classes in Australia, Canada and the United Kingdom (Dorman, Adams, & Ferguson, 2001). Further, the CLES has been translated and used successfully in several languages including: Mandarin (Aldridge, Fraser, Taylor, & Chen, 2000); Korean (Cho, Yager, Park, & Seo, 1997; H.-B. Kim, Fisher, & Fraser, 1999; Oh & Yager, 2004); and Spanish (Peiro & Fraser, 2009). Of interest to this study, is that the CLES has been modified for use in past research to assess effectiveness of a pedagogical model and used to make comparisons between a control group and a study group in Singapore (Koh & Fraser, 2014).

Given the pertinence of the CLES scales to the present study, as well as the strength of the CLES in terms of its reliability and validity when used in a range of settings and countries, it was drawn on in the development of one of the instruments used in the study reported in this thesis. The four scales that were drawn on were Personal Relevance, Critical Voice, Student Negotiation, and Shared Control. (See Chapter 3 for more information regarding the development of a new survey to assess students’ perceptions of their mathematics inquiry classes.)

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) by combining the most significant and relevant scales from a number of existing instruments with scales that reflect modern teaching methodology and practice. The WIHIC was refined to include seven scales with eight items in each, these being: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity (Aldridge, Fraser, & Huang, 1999; Fraser, 2012). A sample item for the Student Cohesiveness construct is "I know other students in this class". The items are responded to using a five-point frequency response format of: almost never, seldom, sometimes, often, and almost always (Dorman, 2003).

The WIHIC questionnaire has become widely used in many countries, languages and contexts and "the WIHIC has achieved almost bandwagon status in the assessment of classroom environments" (Dorman, 2008, p. 181). The WIHIC has been validated in studies in Australia and Taiwan (Aldridge & Fraser, 2000; Aldridge et al., 1999), Australia, UK and Canada (Dorman, 2003), Australia and Indonesia (Fraser, Aldridge, & Adolphe, 2010), Australia and Canada (Zandvliet & Fraser, 2004, 2005), Singapore (Chionh & Fraser, 2009), India (R. B. Koul & Fisher, 2005), Australia (Dorman, 2008), South Africa (Aldridge, Fraser, & Ntuli, 2009), Korea (H.-B. Kim et al., 2000), Indonesia (Wahyudi & Treagust, 2004b), UAE (Afari, Aldridge, & Fraser, 2012; MacLeod & Fraser, 2010), and the USA (Allen & Fraser, 2007; den Brok, Fisher, Rickards, & Bull, 2006; Helding & Fraser, 2013; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; Pickett & Fraser, 2009; Robinson & Fraser, 2013; Wolf & Fraser, 2008). The WIHIC has also been shown to be reliable in many contexts, including mathematics (Chipangura & Aldridge, 2017), making it a suitable choice for inclusion in the development of a survey for my study.

Given the strong reliability of the WIHIC and the pertinence of a number of scales for the purpose of the study described in this thesis, two scales were drawn from the WIHIC for the development of the new instrument developed for the purpose of the study reported in this thesis: Investigation, and Involvement. (See Chapter 3 for more information regarding the development of a new survey to assess students' perceptions of their mathematics inquiry classes.)

2.3.3 Past Learning Environments Research

The field of learning environments is vast and varied. Fraser (2007, 2012) outlined six applications of learning environment instruments: a) associations between student outcomes and environment; b) evaluations of educational innovations; c) differences between student and teacher perceptions of actual and preferred environments; d) determinants of classroom environment; e) use of qualitative research methods and; f) cross-national studies. Of these six lines of research, two were particularly relevant to my study. In the following sections literature related to these two lines of research are reviewed: associations between student outcomes and environment (Section 2.3.3.1); and evaluation of educational innovations (Section 2.3.3.2).

2.3.3.1 Associations between Student Outcomes and Environment

In much past learning environment research, the assessment of associations between student outcomes and the learning environment has been prevalent (Fraser, 2007, 2012). The examination of relationships has involved a range of "cognitive and affective outcome measures, a variety of classroom environment instruments and a variety of samples (ranging across numerous countries and grade levels)" (Fraser, 2012, p. 1218). A vast majority of studies have reported positive associations between student perceptions of the learning environment and student outcomes, particularly for attitudes or affective outcomes.

Attitudes and enjoyment towards mathematics do not remain in fixed parameters. Instead attitudes can be formed and changed, both directly and indirectly, through experiences within the learning environment (Simonson & Maushak, 2001; Vandecandelaere, Speybroeck, Vanlaar, De Fraine, & Van Damme, 2012). By altering the teaching methodology and climate within the classroom, through such things as giving feedback, coaching and supporting students in self-regulation, students' enjoyment of mathematics can be improved (Vandecandelaere et al., 2012).

Perceptions of the learning environment have been shown to be related to students' attitudes and enjoyment of the subject (Aldridge, Fraser, Bell, & Dorman, 2012; Trinidad, Aldridge, & Fraser, 2005; Walker & Fraser, 2005; Wolf & Fraser, 2008). Through the assessment of the classroom learning environment, a means of monitoring, evaluating and improving teaching and learning can be established. "A key to improving student achievement and attitudes is to create learning environments that emphasise those characteristics that have been found to be linked empirically with student outcomes" (Fisher, Waldrip, & den Brok, 2005, p. 26).

If students have a lack of enjoyment in their classes, through learning environment research, it has been shown that this can lead to feelings of boredom, resulting in a lack of engagement in the educational tasks (Hamilton, 1983). For example, Sakiz, Pape and Hoy (2012), in their study with 317 seventh- and eighth-grade students found a strong correlation between a positive learning environment and students' enjoyment, thus showing the importance of students' perceptions of the learning environment and how they can promote academic enjoyment in mathematics.

Students' perceptions of the learning environment have been shown to be related to academic achievement (Anderson, Hamilton, & Hattie, 2004; Chionh & Fraser, 2009; Wolf & Fraser, 2008). In the past, a lack of academic achievement for students was seen as a deficit on their part, but with a recent shift in thinking, this deficiency in achievement is instead considered in the frame of the learning environment (Anderson et al., 2004). Fraser and Kahle (2007) found that the classroom environment was a statistically significant predictor of students' academic achievement. Through the investigation of which features of the learning environment, from the perspective of the students, impacted academic achievement, Wang and Holcombe (2010) found that a focus on comparison, competition and student ability resulted in a decrease in achievement. When making comparisons between students' perceptions of actual versus preferred learning environments, teachers can use this information to develop strategies for intervention and this can lead to higher student achievement (Fraser & Fisher, 1983, 1986).

When considering the mathematical beliefs of students, two aspects are central, the classroom environment and the students' perceptions of their ability or self-efficacy in the subject (Op't Eynde, De Corte, & Verschaffel, 2007). Much past research suggests that students' perceptions of the learning environment is related to students' beliefs that they can succeed with many studies finding positive classroom environments to impact students' academic- or self-efficacy (Cheng, 1994; Dorman & Adams, 2004; R. B. Koul, Fisher, & Shaw, 2011; Sakiz et al., 2012). Further, Dorman (2001) questioned the legitimacy of self-efficacy theory that does not take the importance and influence of the learning environment into consideration. Studies that have found positive associations between students' perceptions of the learning environment and their self-efficacy have been carried out in a range of countries including: India (Gupta & Fisher, 2012); New Zealand (R. B. Koul et al., 2011); the United States (Sakiz et al., 2012); and Australia (Dorman, 2009).

An important aspect of the research surrounding students' perceptions of the learning environment is the associated impact on student engagement. Positive perceptions of classroom environments have been found to support students' engagement (Cavanagh, 2015; Chipangura & Aldridge, 2017; Patrick, Ryan, & Kaplan, 2007). Given that disengagement in the classroom has become an issue on a global scale (Willms, 2003), these findings are important. It is believed, however, that educators have some control over this (Shernoff, Ruzek, & Sinha, 2017) and that, through the quality of the learning environment, engagement can be influenced (Khalil, 2015; Shernoff et al., 2016). That is, student engagement is not fixed, but can be flexible depending on influences from the learning and the learning environment (Fredricks, Blumenfeld, & Paris, 2004; Inda-Caro et al., 2019).

In past research it has been found that, to improve student engagement, specific focus can be made on features of the learning environment that stimulate learning which, in turn, improve student outcomes (Khalil & Aldridge, 2019; Prendergast & Kaplan, 2015). Students' perceptions of the learning environment can impact the engagement or students' propensity to learn (Khalil, 2015; National Research Council, 2004; Tshewang, Chandra, & Yeh, 2017; Velayutham, Aldridge, & Fraser, 2012), not just procedural engagement, linked to behaviour (Nystrand & Gamoran, 1991); but engagement associated with student experiences and classroom learning (Shernoff, 2013; Shernoff & Bempechat, 2014).

Associated with engagement is students' motivation towards their subjects. Where students experience positive perceptions of the learning environment, this is related to their motivation within the classroom (Anderson et al., 2004; J. C. Lee, Yin, & Zhang, 2009; Patrick et al., 2007). The learning environment influences students' views about the "nature and purpose of learning" (R. Koul, Roy, & Lerdpornkulrat, 2012, p. 218), or their motivation towards the subject (Ames & Archer, 1988; Tapola & Niemivirta, 2008; Urdan, 2004). Motivational beliefs are "the opinions, judgements and values that students hold about objects, events or subject-matter domains" (Boekaerts, 2002, p. 8). These motivational beliefs often result from learning experiences and therefore can be changed when perceiving a positive learning environment (Opolot-Okurut, 2010); therefore, teachers wishing to improve the motivation of their students need to consider the classroom learning environment (Opolot-Okurut, 2010).

My study adds to the body of research that assesses associations between the learning environment and attitudes. Although there are some studies where the relationships between the learning environment and student attitudes in the UAE have been examined (Afari et al., 2012), to my knowledge, none have been carried out in middle school mathematics classes, therefore my study fills this gap.

2.3.3.2 Evaluation of Educational Innovations

Many studies have used learning environment instruments to evaluate the effectiveness of educational innovations. According to Fraser (2018), classroom learning environment instruments can be used as a source of process criteria when evaluating educational innovations. These innovations have ranged from new teaching methods to new teaching tools.

Traditionally, when evaluating educational changes and reform efforts, research has tended to focus on the assessment of academic achievement. While this does provide valuable information, it does not give the full picture (Fraser, 2012). "Research findings have consistently shown that students' and teachers' perceptions of important social and psychological aspects of the learning environments really matter in terms of educational outcomes" (Koh & Fraser, 2014, pp. 158-159).

While past research has focussed on educational innovations in a variety of contexts, I have narrowed my review of the literature to three areas: employment of innovative pedagogical approaches; implementation of new curricula; and innovation in professional development for educators. Of particular interest to my study, is the use of new pedagogies and their impact on student perceptions of their learning environment.

A variety of studies have reported results from research assessing the effectiveness of innovative pedagogies by examining the impact of the new methodologies on students' perceptions of the learning environment (see for example, studies by Afari et al., 2012; Baeten, Dochy, & Struyven, 2013; H.-B. Kim et al., 2000; Spinner & Fraser, 2005; Teh & Fraser, 1994). Of particular interest to this study is research focusing on innovative mathematics programmes (Spinner & Fraser, 2005) and studies involving comparisons between control groups and those being exposed to innovative pedagogical approaches with differences in students' perceptions of the learning environment being assessed (Chipangura & Aldridge, 2017; Koh & Fraser, 2014; Melo, 2018; Schuitema, Peetsma, & van der Veen, 2012; Wolf & Fraser, 2008).

Learning environment research can also be invaluable to educators when assessing the effectiveness of new curricula. Evaluating the impact and effectiveness of new curricula can be done by assessing students' perceptions of the learning environment (H.-B. Kim et al., 2000). For example, when assessing the effectiveness of new curricula, some outcome variables show negligible differences, but learning environment variables can differentiate revealingly and can be an important source of criteria (Fraser, 2012; Joiner, Malone, & Haimes, 2002). For example, when changing from a traditional approach to the teaching of science in a preservice course, to an innovative new curriculum, students perceived the learning environment differently and their attitudes towards science, particularly laboratory work, were more positive (Martin-Dunlop & Fraser, 2008). Learning environment instruments allowed the identification of the elements that led to these positive outcomes, without which such identification could have gone unattended. In current educational reforms and ensuing career readiness, which requires students to acquire the 4Cs of critical thinking, creativity, collaboration and communication, the need to assess more than just the academics of curricula reform is essential (Fraser, 2012). Past research has demonstrated that, through the use of assessing changes in the learning environment, both teachers and policymakers are able to evaluate the impact of changes to curricula (Spinner & Fraser, 2005; Teh & Fraser, 1994; Wahyudi & Treagust, 2004b). This is particularly useful when piloting as part of a larger reform, allowing improvements to be made prior to implementation at a larger scale. Research has shown the usefulness of learning environment dimensions as process criteria in the evaluation of educational programs and curricula (Fraser, 1998; Spinner & Fraser, 2005).

One way to introduce pedagogical innovations and new curricula is through professional development. Learning environment instruments have been used to assess and evaluate whether professional development programmes are effective in making changes for both teachers and students within the environment of the classroom (Fraser, 2012; Soebari & Aldridge, 2016). For innovative professional development programmes to be successful, they need to be ongoing to allow teachers to continually improve and to allow for large-scale reform to be effective (Cho et al., 1997; McChesney & Aldridge, 2018; Von Oppell & Aldridge, 2015). Professional development for teachers is essential when piloting a shift to constructivist teaching and learning principles and in order to scale up beyond the pilot phase, the professional development needs to be consistent, ongoing and needs-based (Cho et al., 1997; McChesney, 2017). Extending beyond initial workshops into ongoing training helps to keep interest alive, allows teachers to use and interpret the reform ideas and allows them to contribute significantly in the process. Evaluation of the effectiveness of professional development models can be completed through the assessment of students' perceptions of the learning environment to investigate whether teaching practices change during the programmes (Soebari & Aldridge, 2015). When evaluating professional development programmes, there is a need to go beyond the outward appearances of teaching, such as the resourcing and content, and to focus on the teacher-student interactions and delivery of the subject matter within the learning environment (Stigler & Hiebert, 2004). This is where the use of learning environment instruments can be very effective.

In my research I have built on and extended this past research involving the evaluation of innovative pedagogies and new curricula, through the use of a learning environment instrument, which allows the identification of key elements within the environment that produce a range of positive outcomes. As such, my study adds to the body of research in this field.

2.4 Students' Attitudes towards Mathematics

An important aspect of this study was the focus on student attitudes towards mathematics and whether students in classes taught by teachers exemplary in the use of explorations reported more positive attitudes (enjoyment, self-efficacy and task value) than those who were not. A review of literature, relevant to student attitudes is provided in two sub-sections: definition of attitudes (Section 2.4.1); and attitude research in mathematics education (Section 2.4.2).

2.4.1 Definition of Attitudes

There have been a large number of definitions of attitudes since the concept of attitude was originally described in 1862 by Herbert Spencer. Researchers have approached the concept of attitude from different points and in different contexts. For example, Thurstone and Chave (1929) defined attitude as "the effect for or against a psychological object", however Likert (1932) provided a less specific definition for attitude as "a certain range within which responses move". Allport (1935) merged both of these ideas when he defined attitude as "a mental and neural state of readiness to respond, organised through experience, exerting a directive and/or dynamic influence on behaviour." Krech (1946) approached the concepts of attitudes from a new angle by suggesting they should be considered as aspects of learning. Other definitions emerged that defined the affective character of attitudes (Katz & Sarnoff, 1954; Rhine, 1958; Triandis, 1971).

Most researchers however agree that attitudes have three parts: the cognitive component that describes the knowledge, beliefs and ideas about an object; the affective component which describes the feeling about an object in terms of like or dislike; and the behavioural component which describes a tendency-towards-action. For the purpose of this study, these three aspects were employed.

2.4.2 Attitude Research in Mathematics Education

Attitude to mathematics has been defined by Neale (1969, p. 632) as "an aggregated measure of a liking or disliking of mathematics, a tendency to engage or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless". For the purpose of this study, the focus was on three aspects of attitude research: enjoyment (reviewed in Section 2.4.2.1); self-efficacy (reviewed in Section 2.4.2.2); and task value (reviewed in Section 2.4.2.3).

2.4.2.1 Enjoyment of Mathematics Classes

"Enjoyment of learning is an activity-related, positive, activating achievement emotion." (Buff, Reusser, & Dinkelmann, 2017, p. 424). This is demonstrated, for example, when a student enjoys learning the subject content, finds the learning stimulating and, due to the pleasure involved in the activity, continues completing more than is necessary. The learner's enjoyment of mathematics is related to their "affective, emotional and behavioural reactions concerning liking, or disliking, mathematics" (Kadijevich, 2008, p. 330). Pekrun, Goetz, Titz and Perry (2002b) stated that students' enjoyment should be studied because it fosters problem solving, promotes resiliency and supports individual self-regulation. Students experience enjoyment when they are interacting with content that is interesting to them (Hidi & Renninger, 2006) and when they experience these positive emotions of interest and enjoyment together, it is associated with creativity and problem solving (Fredrickson, 2001). Fun is generated when interest and enjoyment occur together, suggesting a combination of feelings supporting cognitive engagement and learning (Izard, 1977).

Examining the extent to which students enjoyed their mathematics class was an important attitudinal component employed in the study reported in this thesis. The use of enjoyment of mathematics as a construct in the attitudes instrument administered as part of this study confirms its importance and inclusion. There has been much past research to suggest that enjoyment of a subject is important because it has been shown that pleasant emotions such as enjoyment are positively related with academic motivation (Pekrun, Goetz, Titz, & Perry, 2002a), self-regulation (Pekrun et al., 2002a) and performance (Ashby, Isen, & Turken, 1999; C. Kim, Park, & Cozart, 2014;

Pekrun, 2006). Schiefele (1991) found that enjoyment towards learning and achievement form the basis of interest, and students working in a nominated area of interest gave high ratings of enjoyment (Ely, Ainley, & Pearce, 2013). According to Reiss and Reiss (2006), in the context of mathematics teaching and learning, factors such as enjoyment of learning should be considered, due to the link with achievement. In qualitative research, the most frequently mentioned positive emotion in academic learning and achievement contexts is enjoyment or enjoyment of learning (Pekrun & Stephens, 2012). There have been a number of studies showing a positive relationship between enjoyment of mathematics and achievement (Ahmed, Minnaert, van der Wef, & Kuyper, 2010; Ahmed, van der Wef, Kuyper, & Minnaert, 2013; Goetz et al., 2012).

Enjoyment is also an important factor in the classroom in terms of students' behaviour and engagement. Hidi and Renninger (2006) purport that enjoyment promotes willingness to re-engage in academic subjects over time. Enjoyment relates positively to metacognitive strategies, elaboration, organisation and critical thinking, which suggests that positive academic emotions may in fact facilitate flexible, creative modes of thinking (Pekrun et al., 2002a). Students who experienced enjoyment and interest while working on a science topic were engaged with the topic content and were likely to express a desire to continue their engagement with the topic (Ainley & Ainley, 2011). According to Frenzel, Goetz, Ludtke, Pekrun & Sutton (2009, p. 705), enjoyment is "crucial in today's knowledge-based society, which requires life-long learning. Thus, a desirable goal of teaching is to enhance students' pleasant achievement emotions".

Although limited in number, researchers in a few studies have investigated the use of inquiry-based learning and its promotion of enjoyment of learning (Camenzuli & Buhagiar, 2014; Kreuzer & Dreesmann, 2017). From the findings, it can be suggested that the use of inquiry-based learning, involving a shift away from traditional teaching and learning practices, can introduce a strong element of enjoyment for the students in their mathematics (Camenzuli & Buhagiar, 2014). "The strong link between the IBL [inquiry-based learning] pedagogy and enjoyment of mathematics lessons was one of the most evident and consistent findings of the study." (Camenzuli & Buhagiar, 2014, p. 75). Findings also suggest that the use of inquiry-based learning in mathematics can make the content more interesting, which results in a positive impact on students' attitudes (Bruder & Prescott, 2013), a key variable in my study.

It stands to reason that enjoyment in learning would result in a more positive perception of the learning environment. The opposite has also been found to be true, as there is much past research to suggest that students' perceptions of the learning environment positively impacts their enjoyment of the lessons they attend. The relationship between the learning environment and enjoyment has been studied in a variety of countries and contexts. Associations have been found across differing education levels: middle school (Fisher et al., 2005; Noyes, 2012; Sakiz et al., 2012; Vandecandelaere et al., 2012; Wolf & Fraser, 2008); secondary school (Perlman, 2013); and post-secondary and higher education (Afari, Aldridge, Fraser, & Khine, 2013; Radovan & Makovec, 2015; Walker & Fraser, 2005). Studies where the relationship between the learning environment and enjoyment for differing subjects have been investigated: mathematics (Afari et al., 2013; Noyes, 2012; Sakiz et al., 2012; Vandecandelaere et al., 2012); science (Fisher et al., 2005; Wolf & Fraser, 2008); physical education (Perlman, 2013); and the arts (Radovan & Makovec, 2015). Furthermore, research exploring the learning environment and enjoyment has involved numerous countries: Australia (Fisher et al., 2005); cross-nationally in Australia and Hong Kong (Trinidad et al., 2005); Belgium (Vandecandelaere et al., 2012); England (Noyes, 2012); United States (Sakiz et al., 2012; Wolf & Fraser, 2008); UAE (Afari et al., 2013); and Slovenia (Radovan & Makovec, 2015). Although the studies described were carried out with differing grade levels, in differing subjects and in a variety of countries, results suggest that students' perceptions of the learning environment and the associations with enjoyment of learning were positive.

Given that the enjoyment of learning has been consistently associated with students' attitudes, resilience, self-regulation, motivation, cognitive engagement, behaviour, achievement, creative thinking skills, and the learning environment, it is imperative that enjoyment be a focus for educators. That positive associations have also been found between enjoyment and elements of mathematics and inquiry-based learning specifically, is of significance to my study, and hence enjoyment is a key element of the attitude variable. In my research I built on the studies described above in that I examined relationships between the learning environment and enjoyment of mathematics but also the impact of explorations being utilised in an exemplary manner versus non-exemplary and how this affects the perceptions of students' views concerning the enjoyment they get from the subject. Further, given that few studies have been carried out in the UAE, specifically in the area of examining associations between the learning environment and enjoyment of mathematics, this study extends past research.

2.4.2.2 Self-Efficacy

Self-efficacy is a person's belief in his or her ability to succeed in a particular situation (Bandura, 1977). "Perceived self-efficacy is concerned with judgments of how well one can execute courses of action required to deal with prospective situations." (Bandura, 1982, p. 122). Judgements that individuals make concerning their self-efficacy, whether accurate or faulty, influences the decisions they make concerning their choice of activities and tasks. Often, they then avoid activities that they personally believe may be outside of their achievement or capability and instead participate in those they feel capable of being successful at (Bandura, 1977). Self-efficacy is also a determinant of how long an individual will persevere, expending time and effort, in a task, where they encounter difficulties or obstacles. Those with a strong sense of self-efficacy will apply themselves with determination to overcome and achieve success, whereas those with less self-efficacy will reduce their effort or give up altogether (Choi, 2005; Pintrich, Smith, Garcia, & McKeachie, 1993; Schunk & Pajares, 2002).

Past research provides strong evidence to suggest that self-efficacy is linked to academic performance (Fast et al., 2010; Multon, Brown, & Lent, 1991; F. Pajares, 2006) and can provide powerful information in a reform context. Self-efficacy is defined as an "individuals' confidence in their ability to organize and execute a given course of action to solve a problem or accomplish a task" (Bandura, 1977, p. 3). Self-efficacy can be considered to be a 'can do' attitude that impacts on a student's confidence and willingness to perform and complete learning tasks, the effort involved, persistence, goal setting and achievement (Bandura, 1977; Guthrie et al., 2007; Multon et al., 1991; Schunk, 1995; Solheim, 2011).

The results of past research has provided evidence to suggest that self-efficacy impacts student's achievement in school courses (Balentyne & Varga, 2017; Tempelaar, Niculescu, Rienties, Gijselaers, & Giesbers, 2012) and, specifically, that self-efficacy beliefs towards mathematics is related to student achievements (Hackett & Betz, 1989; F. Pajares, 1996; F. Pajares & Graham, 1999; F. Pajares & Miller, 1995; Pietsch, Walker, & Chapman, 2003; Zimmerman, 2000; Zimmerman, Bandura, & Martinez-Pons, 1992). Unlu, Ertekin and Dilmac (2017) showed that the most important independent variable affecting self-efficacy beliefs towards mathematics is mathematics anxiety. Mathematics anxiety is a complex phenomenon which has been related to decreased mathematics achievement and negative attitudes about mathematics worldwide (Ramirez, Shaw, & Maloney, 2018).

The results of past research have indicated that inquiry-based learning classes can promote students' self-efficacy (Kang & Keinonen, 2017; Laine, Veermans, Lahti, & Veermans, 2017; McElvain & Smith, 2016). In Finland, a study involving inquiry-based learning in the science classroom found a high positive correlation between inquiry and students' self-efficacy (Kang & Keinonen, 2017). Interpretations of these results suggest that students who had opportunities to participate in inquiry classes, had more belief in their ability and this encouraged them to seek study or work in the science context (Kang & Keinonen, 2017).

Researchers have reported a decline in student interest in science over the last twenty years (Rocard et al., 2007), and suggestions to reverse this trend have included introducing active learning techniques, including inquiry-based learning (Laine et al., 2017). As a measure of the effect of inquiry-based learning in the science context, Laine, Veermans, Lahti and Veermans (2017) investigated associations between inquiry and interest, with characteristics such as self-efficacy having been found to influence interest. Similar results were found concerning self-efficacy and interest (Glynn, Bryan, Brickman, & Armstrong, 2015; Tapola, Veermans, & Niemivirta, 2013), indicating that when comparing control and experimental inquiry groups, interest was greater in the inquiry group for physics and chemistry, thus suggesting a positive self-efficacy was held by the students involved (Laine et al., 2017). Similarly, the results of a study comparing a control group with an inquiry-based learning experimental group in the United States, reported a significant mean increase in self-efficacy for the treatment group (McElvain & Smith, 2016).

The investigation of relationships between inquiry-based learning and self-efficacy has been reported in a study in Qatar, and supports previous studies showing an increase in students' self-efficacy through the use of inquiry techniques (Qureshi, Vishnumolakala, Southam, & Treagust, 2017). The research suggested that the students' improved self-efficacy levels were prevalent where students were consistently engaged and motivated to participate in pedagogies involving active and inquiry-based learning (Qureshi et al., 2017). This supported previous research suggesting any increase in self-efficacy in chemistry could be due to the implementation of inquiry techniques (Chase, Pakhira, & Stains, 2013). Given that self-efficacy is a key element of attitudes, and the positive association found between self-efficacy and inquiry-based learning in the literature reviewed above, self-efficacy was a key construct investigated in the current study.

Past research has examined whether students' perceptions of the learning environment is related to students' self-efficacy. Strong and consistent evidence suggests that perceptions of the learning environment is indeed related to self-efficacy for studies carried out in a variety of countries and contexts. Relationships have been shown for differing academic levels, including higher education (Aldridge, Afari, & Fraser, 2012; Qureshi et al., 2017) and secondary school (Dorman, 2001; Dorman & Fraser, 2009; R. B. Koul et al., 2011; Velayutham & Aldridge, 2013). Further, these studies have found positive relationships between the learning environment and self-efficacy across different subjects, including: mathematics (Aldridge, Afari, et al., 2012; Dorman, 2001) and science (Gupta & Fisher, 2012; R. B. Koul et al., 2011; Qureshi et al., 2017; Velayutham & Aldridge, 2013). These studies have included different countries and cultural contexts, including: Australia (Dorman, 2001; Dorman & Fraser, 2009; Velayutham & Aldridge, 2013); New Zealand (R. B. Koul et al., 2011); India (Gupta & Fisher, 2012); Qatar (Qureshi et al., 2017) and the UAE (Aldridge, Afari, et al., 2012). Although the studies described above were carried out with differing grade levels, in differing subjects and in a variety of countries, results suggest that students' perceptions of the learning environment and associations with self-efficacy were positive.

Given the importance of self-efficacy, in my study I sought to examine the differences between students' self-efficacy or 'can do attitude' in their mathematics classes and whether their different pedagogical approaches (exposure to teachers exemplary in the use of explorations and those who were not) affected students' beliefs about their ability in the subject. While there has been much research in the field of self-efficacy, there has been very little investigating this aspect within mathematics classes in the Middle East. While Qureshi et al. (2017) investigated relationships between the use of inquiry-based learning and self-efficacy, the study focused on the science classroom and was based in a neighbouring country, Qatar. In my study I extended this field of research by investigating inquiry-based learning in mathematics and endeavouring to ascertain whether similar relationships between inquiry and self-efficacy were evident in the UAE.

2.4.2.3 Task Value

Task value refers to the student's evaluation of how important, useful and interesting a task is and can be considered to be a belief about how valuable a task is. Studies have shown that students' task values tend to be strong predictors of positive attitudes and prolonged interest in academic disciplines (Acee, Weinstein, Hoang, & Flaggs, 2018; Wigfield & Eccles, 2000). The value that is placed on the task impacts the decision to continue and persist with the specific task and with the area of learning (Eccles et al., 1983). Students show whether they believe a task has value through persistence and effort or the lack thereof (Wigfield & Eccles, 2000). "An individual who has high task value for an activity is more likely to participate in that activity, persist in that activity longer, and exert more effort than someone who has lower value for that same activity" (Cole, Bergin, & Whittaker, 2008, p. 613).

Expectancy-value motivation theory (Eccles & Wigfield, 2002) identifies two main aspects of students' attitudes concerning achievement and academic behaviours, "the degree to which they are confident in accomplishing an academic task (self-efficacy) and the degree to which they believe that the academic task is worth pursuing (task value)" (Liem, Lau, & Nie, 2008, p. 487). In this model, task value can be separated into several components where tasks are important because they are fun and enjoyable (intrinsic value), are useful and relevant to other tasks or aspects of life (utility value), are important to the person's sense of self (attainment value) and they require certain amounts of time, energy and resources (cost value) (Eccles et al., 1983).

Task value has been established as a strong predictor of achievement-related outcomes (Durik, Vida, & Eccles, 2006; Simpkins, Davis-Kean, & Eccles, 2006). Task value has been found to be able to reliably predict students' intention and final decision making concerning continuing education and course selection (Eccles et al., 1983; Eccles & Wigfield, 2002), which would indicate students' attitudes towards these. Miller and Brickman (2004) suggest that when students perceive a task as being useful for future goals and aspirations, they are willing to exert their best effort and expend extended amounts of time in pursuit of attaining their goals through focusing on tasks.

The use of inquiry-based learning techniques in the classroom has been found to increase students' perceptions of the value of the tasks that they complete (Heindl & Nader, 2018). Fielding-Wells, O'Brien and Makar (2017) investigated the effectiveness of inquiry-based learning in a primary mathematics class, through the lens of expectancy-value theory focusing on self-efficacy and task value. Findings suggested that the contextual nature of inquiry-based learning piqued students' interest and the opportunities to solve authentic problems, tapped into students' sense of value in the task and intrinsic desire to learn. Students found value in the increased autonomy that they experienced and the opportunities to extend their learning. Student choice, an important aspect of task value, was a pivotal feature of the inquiry-based learning experience (Fielding-Wells et al., 2017).

Associations have been found between students' perceptions of their learning environment and task value (Ahmed et al., 2010; Eccles, 2007; Wigfield & Cambria, 2010). Findings suggest that students' perceptions of the learning environment influence their attitudes including task value (Khalil & Aldridge, 2019). Research indicates that students' perceptions of the learning environment play an important role in their motivation towards their schoolwork, valuing of academic tasks as well as behaviour leading to academic achievement (Meece, Anderman, & Anderman, 2006; Patrick, Kaplan, & Ryan, 2011; Polychroni, Hatzichristou, & Sideridis, 2012). By improving the classroom climate to establish an environment suitable for the development of creativity, results showed that students improved significantly with regard to task value (Liu, Lin, Jian, & Liou, 2012). Interestingly, Bong (2005) suggested that, as students grew older, the emphasis within the classroom learning environment shifted to one focusing on comparison of students and competition between them with respect to high stakes testing, producing a reduction in task value for students.

While there is much research focusing on task value as an important aspect of motivation in student learning, research that focuses on associations between students' perceptions of the learning environment and task value is limited. My research extends the studies described above in that I am looking at relationships between the learning environment and task value, but also the effect of inquiry-based learning when utilised in an exemplary manner versus non-exemplary and how this affects the perceptions of students' views concerning whether they value the mathematical tasks allocated to them. Similarly, there have been few studies where associations between inquiry-based learning and task value have been explored and while interesting findings from the research have been found, the samples have not been sufficient to make generalisations. My study adds to this body of research by relating inquiry-based learning with task value and has extended the research by exploring this within middle school mathematics in the UAE. Research examining relationships between students' perceptions of the learning environment and task value are scarce and while a study focused on the education reform in Abu Dhabi has been carried out (Khalil & Aldridge, 2019), its focus on science means that my study, which was carried out in the mathematics context, extends this work.

2.5 Chapter Summary

In this chapter I have reviewed literature in three areas: inquiry-based learning; learning environments research; and student attitudes towards mathematics. Each of these is summarised in this section.

The review of literature related to inquiry-based learning was reported in two main areas: definitions of inquiry-based learning; and empirical studies related to inquiry, which incorporated the benefits of inquiry-based learning and effective implementation of inquiry-based learning. In this study inquiry-based learning has been defined as a student-centred pedagogy that uses purposeful, extended investigations, set in the context of real-life problems, as both a means for increasing student capacities and as a feedback loop for increasing teachers' insights into student thought processes. My review of literature highlights many benefits to the use of inquiry-based learning including the development of the 21st Century skills of collaboration, critical thinking, creativity and communication. Research into the effective use and implementation of inquiry-based learning was described, focusing on the importance of careful planning at the system and teacher level, the role of the teacher in content knowledge and facilitation, and the need for professional development for teachers.

The review of learning environment research involved three key areas: history of the learning environment research, various instruments used to assess the learning environment and past learning environments research. In the history of learning environments section, Lewin's (1936) theory that the environment and its interaction with individuals' personal characteristics are strong determinants of human behaviour was discussed. Murray's (1938) *needs-press* model added the theory of a drive or need. Stern's work followed on from Murray's where Stern translated the need-press model into an operational framework and suggested that where a student experiences a fit between preferred and actual learning environment, they perform better on a range of outcomes. Moos proposed three dimensions into which the different characteristics of all human environments can be classified: Relationship Dimension, Personal Development Dimension, and the System Maintenance and System Change Dimension. These dimensions provided the basis for many learning environment instruments.

The field of learning environments has a variety of instruments validated for use. Two instruments have specific relevance to this study as they were the basis for the development of new instruments in this research. The first was the Constructivist Learning Environment Survey (CLES) developed to assess the constructivist nature of classrooms and the What Is Happening In this Class? (WIHIC) questionnaire that reflects modern teaching methodology and practice.

The review of the literature related to the field of learning environments focused on two aspects of past learning environment research: associations between student outcomes and environment; and evaluation of educational innovations. A number of studies have shown that there are associations between student outcomes and environment including cognitive and affective outcome measures, a variety of instruments assessing the learning environment and a range of differing samples. For evaluation of educational innovations, learning environment instruments have been used as part of the process to evaluate success. Innovations have included new teaching methods, new teaching tools and technology and have involved a range of countries including Australia, Singapore, Korea, and the US.

The review of literature for students' attitudes towards mathematics first defined attitudes and then reviewed attitude research in mathematics education. Attitudes are considered to have three parts: cognitive, affective and behavioural. In the mathematics context, attitudes were discussed in four areas, involving, emotions during activities, emotions associated with the subject, evaluations of situations and value of mathematics as part of wider goals. In the study reported in this thesis I focused on three aspects of attitude research: enjoyment of mathematics, self-efficacy and task value. Enjoyment of mathematics is an important aspect to study as it positively related to academic motivation, self-regulation and performance. Self-efficacy is described as a 'can do' attitude and is linked to effort, persistence, goal setting and academic performance. Task value refers to the student's evaluation of how important, useful and interesting a task is and impacts students' willingness to engage with tasks and persist with the area of learning.

In this review of literature, I have identified gaps in the existing literature and acknowledged the importance of the present study in bridging these gaps. The aims presented within this thesis have stemmed from the theoretical basis established in this literature review. In the next chapter, research methods, a detailed description of the sample, quantitative and qualitative data collection methods, data analysis and ethical issues and considerations is provided.

CHAPTER 3

Research Methods

3.1 Introduction

In this chapter the processes and methods used in the collection and analysis of the data are described. The main purpose of the study was to examine whether there were differences in mathematics classrooms in which the teacher was exemplary in the use of explorations when compared to classrooms with teachers who were not. The research methods used in the study are outlined using the following headings:

- Theoretical Framework (Section 3.2);
- Research objectives (Section3.3);
- Sample for the study (Section 3.4);
- Quantitative data collection (Section 3.5);
- Qualitative data collection (Section 3.6);
- Analyses of quantitative data (Section 3.7);
- Analyses of qualitative data (Section 3.8);
- Ethical considerations (Section 3.9); and
- Chapter summary (Section 3.10).

3.2 Theoretical Framework

A paradigm can be described as a ‘worldview’, consisting of a set of common beliefs and agreements, and seeks to guide how problems should be understood or addressed (Creswell, 2009). The following elements: ontology; epistemology; methodology; and methods, make up the components of a paradigm. Ontology is the study of being (Crotty, 1998) and so ontological assumptions are involved with what represents reality, or ‘what is’. Epistemology is concerned with the question ‘how do we know something?’, and the nature and styles of knowledge (L. Cohen, Manion, & Morrison, 2007). The assumptions of epistemology are involved with how information can be generated, obtained and conveyed, in other words, what it means to know.

Epistemology is concerned with the link between what can be known and the would-be knower (Guba & Lincoln, 1994). Every paradigm has its own ontological and epistemological assumptions and views and these differences can be reflected in the methodology and methods.

The study reported in this thesis involved a mixed methods design. Mixed methods designs are “procedures for collecting, analysing, and mixing both quantitative and qualitative data in a single study or in a multiphase series of studies” (Creswell, 2008, p. 62). The use of mixed methods in my study arose from the need to address questions that did not sit completely within either a quantitative or qualitative research approach. The use of mixed methods in this study provided a better understanding of the research problem than the use of either type on its own.

The mixed methods approach used in this study drew on the paradigm of pragmatism. The pragmatic paradigm was first discussed by the classical theorists, Peirce (1878), James (1995, 1907) and Dewey (1948, 1920). The pragmatic method used to determine the meaning of words, concepts, statements, beliefs or ideas suggests we should “consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then our conception of these effects is the whole of our conception of the object” (Ponterotto, 2005). The pragmatic paradigm, by general consensus, focuses on practical applications, rather than on what can be considered unquestionably true or tangible (Weaver, 2018). In this study, the pragmatic paradigm guided the research design, especially when differing approaches appeared to be philosophically inconsistent.

My study consisted of two phases that utilised differing paradigms in each. The first phase involved the collection of quantitative data through the use of surveys. The second phase involved gathering qualitative data through lesson observations and focus group interviews with students. Each phase involved the use of a different paradigm, as discussed below.

The first phase of the research process drew on post-positivism. Researchers who are post-positivists believe that assumptions, previous experiences, understanding and values of the researcher can impact and affect what is observed, unlike positivists who think that the researcher and the person being researched are independent of each other (Robson, 2002). The post-positivist paradigm encourages the confirmation of a variety of facts from qualitative and quantitative methods through a diversity of investigations, while respecting and valuing all findings as the essential components for the development of knowledge (M. Clark, 1998; Fischer, 1998). While post-positivists are not as rigid as positivists in their search for a single tangible reality, they do believe that reality does exist, but that it cannot be known in an absolute way due to the limitations of the researcher and their humanity. In the post-positivist paradigm, the intention of the research is to make predictions about results, to trial a theory, or to discover any cause and effect relationships and to assess the strength of relationships between variables. This paradigm guided the methodology using a quantitative design and the use of surveys as data collection instruments in the first phase of my study. An important aspect of the analysis of the data that was guided by the post-positivist design, was to show that the findings were valid and not based on my judgement, and this was through the use of established procedures (Firestone, 1987). Included in this, was the details of the components within the sample, the methods utilised to collect the quantitative data, the statistical processes used to analyse the data and the findings of the research. The tone of the analysis is scientific and precise, with limited objectivity from myself as the researcher.

The second phase of my study, in which qualitative data was collected, involved an interpretivist approach. This approach intends to understand "the world of human experience" (L. Cohen & Manion, 1994, p. 36), the researcher relies on the "participant's views of the situation being studied" (Creswell, 2009, p. 8), and identifies the influence on the research due to their own beliefs and experiences. The purpose of interpretative research is to understand people's experiences, and so the data collection occurred within the natural setting of the students, the classroom. The research objectives for the qualitative phase were open-ended and aimed to support the findings of the quantitative phase of the study. Due to the subjective nature of the qualitative data collection through the use of lesson observations and focus group interviews, it was essential that I, as the researcher, collected the data. Analysis of the data required the use of rich descriptions of the procedures and resulting findings including quotes and use of the quantitative data to support the findings. The use of the interpretative stance meant that the role of researcher was subjective and so the rhetoric utilised in the description of the findings and was in the first person and personalised, including information on my biases and experiences in the research (Ponterotto, 2005).

An advantage of using a mixed methods approach is that it provides a way to offset the weaknesses of the individual methods of quantitative and qualitative research. Quantitative research does not allow for the context or the voices of the participants to be heard, and qualitative research makes it difficult for generalising findings due to the small sample size, and also can be seen as deficient because of the researcher's personal interpretations (Creswell & Plano Clark, 2017). For these reasons, I chose to utilise mixed methods research for this study, providing both statistical and thematic analysis and personal interpretations to provide insights into the research objectives.

3.3 Research Objectives

The four research objectives, presented earlier, in Chapter 1, are reiterated below.

Research Objective 1

To develop and validate instruments suited for use with middle school students in the UAE to assess students' perceptions of the learning environment in exploration classes and their attitudes.

Research Objective 2

To investigate whether associations exist between students' perceptions of their learning environment and attitudes towards mathematics.

Research Objective 3

To investigate how mathematics students taught by teachers exemplary in the use of explorations and those who were not differ in terms of students':

a. Perceived learning environment;

b. *Attitudes towards an inquiry-based exploration approach in their mathematics classes.*

Research Objective 4

To investigate reasons for differences of the perceived learning environment and attitudes towards mathematics for students taught by teachers exemplary in the use of explorations and those who were not.

3.4 Sample for the Study

In this section I have focused on the selection and composition of the sample. It is separated into two parts: selection of schools and teachers (Section 3.4.1); and, selection of classes and description of the student sample (Section 3.4.2).

3.4.1 Selection of Schools and Teachers

The sample for my study came from four schools in the environs of Abu Dhabi City. For the purpose of my study, students from Cycle 2[1] schools were selected. Cycle 2 schools were chosen because they had been exposed to explorations for some time and the teachers were confident with the teaching and assessment methodology required. Of the four schools, two were Common Cycle schools (grades 6-12) and two were Cycle 2 schools. The schools were chosen based on the selection of the teachers.

Teachers were selected for the study using a purposive sampling strategy. Criteria for teachers exemplary in the use of explorations were developed by the researcher and these were used to select teachers for this study. The criteria were based on the requirements of the inquiry approach as outlined in the ADEC exploration rubric and assessment documentation. The criteria for a teacher to be considered a teacher

[1] Public schools in the Emirate of Abu Dhabi are categorised into Kindergartens (KG1 and KG2), Cycle 1 (grades 1-5), Cycle 2 (grades 6-9) and Cycle 3 (grades 10-12). There are a number of schools that are referred to as Common Cycle Schools and these have more than one cycle within them e.g. a school with grade 1-9 students.

exemplary in the use of explorations were related to six areas. These areas are summarised below, and a full copy of the criteria are provided in Appendix C.

- Demonstration of skills required in the ADEC explorations rubric and framework through teaching and learning experiences as well as assessment opportunities.
- Opportunities for students to explore new concepts.
- Skilful questioning including open-ended questions and those to stimulate thinking.
- Opportunities for students to reflect on processes and products and to discuss limitations and further recommendations.
- Time for collaboration within lessons.
- Use of an extended community of learners and experts outside of the school.

The teachers whose classes were involved in the study were selected through a recommendation process from subject-specific expert mathematics education advisors using the criteria. Mathematics education advisors were employed by ADEC as part of the education reform effort to mentor and coach teachers on matters of curriculum, assessment and pedagogical practice. The education advisors were well placed to make sound recommendations of teachers as they were based in the schools and observed lessons regularly and knew the teachers and their levels of expertise very well. The education advisors were asked to recommend teachers who both met the criteria and were exemplary in the use of explorations in the classroom, as well as teachers who did not meet the criteria. The recommendations were collated, and decisions were made about which teachers were to be included in the study.

In the majority of public schools in the Emirate of Abu Dhabi, female teachers work in schools with all female students for Cycle 2. As a female researcher, a male sample was not available and so only female teachers (and therefore female students) were asked to participate.

Based on the criteria outlined above, two teachers who were considered to be teachers exemplary in the use of explorations and two were chosen because they did not meet any of the criteria and, for the purpose of this study, were referred to as teachers non-exemplary in the use of explorations. All four teachers were UAE nationals and the students in their respective classes were all native Arabic speakers.

3.4.2 Selection of Classes and Description of the Student Sample

Each of the teachers who were selected to participate in the study taught three classes and all three classes were included in the sample. This provided a total of 12 classes taught by the four teachers (see Table 3.1 for a summary of the number of students in each class). For the teachers who were exemplary in the use of explorations, one teacher taught three classes of grade 8 and the other taught three classes of grade 7. For the teachers who were not exemplary in the use of explorations, one taught three classes of grade 9 and the other taught three classes of grade 8. Whilst the grade levels involved in the study differed for the different teachers, the students had all received similar experiences within the reform in that none had been exposed to the New School Model (NSM). The curricula for grades 6 to 9 was similar in style and the topics built from year to year requiring similar pedagogical styles and learning environments. For each teacher, the entire cohort of students taught by that teacher were surveyed. This ensured that, if the school had chosen to band or stream students, a range of student abilities was included in the sample.

Table 3.1 Number of students surveyed from each teacher

Teacher	Classes	Total
1	3	75
2	3	77
3	3	73
4	3	66
Total	12	291

For the administration of the surveys (described below in Section 3.5.3), all of the students in each of the 12 classes were invited to participate in the study. Students who were absent on the day that the survey was administered were not included. This provided a sample of 291 students, with 139 students in classes taught by teachers exemplary in the use of explorations and 152 of the students in classes taught by teachers non-exemplary in the use of explorations. (For a breakdown of the number of students in each class, see Table 3.2.)

Table 3.2 Number of students in each class for the teachers exemplary and non-exemplary in the use of explorations

Teacher	Teacher Type	Class	Total
1	Exemplary	1	28
		2	25
		3	22
2	Exemplary	1	27
		2	25
		3	25
3	Non-exemplary	1	24
		2	24
		3	25
4	Non-exemplary	1	20
		2	22
		3	24
Total		12	291

For the collection of qualitative data, purposive sampling for the focus group interviews was used. To increase the likelihood of students feeling safe and speaking freely, a decision was made to keep the number of adults present to a minimum. Therefore, the first criteria for the selection of students was based on their ability to communicate in English, to ensure that a translator was not required. The second criteria used for selection was to ensure that the sample involved students with a range of abilities and attitudes towards mathematics. With the assistance of the teachers, students with a range of academic results in the subject and a range of effort grades were selected.

Six focus group interviews were held, one after each lesson observation (see Sections 4.5.1 and 4.5.2 for descriptions of the observations). Focus groups were made up of four or five students in each, with three focus groups involving students taught by teachers exemplary in the use of explorations and three made up of students taught by teachers non-exemplary in the use of explorations. There were 27 students interviewed in total.

3.5 Quantitative Data Collection

Given the unique context of the study it was necessary to develop two surveys: one to assess students' perceptions of the learning environment in which explorations were taking place; and another to assess student attitudes towards mathematics. In this section I have described: the instruments (Section 3.5.1); translation of the instruments (Section 3.5.2); and the administration of the instruments (Section 3.5.3).

3.5.1 Instruments Used to Collect Data

Although, within the field of learning environments, there are many established surveys, a review of literature (see Chapter 2) indicated that none of these were suitable for the unique context in which the study took place. Given that the study took place in an education system in which pedagogical change and curriculum development was taking place within a cultural context of the Middle East, the study required instruments that fit the language, pedagogical approaches in mathematics and assessment changes. For these reasons, it was necessary to develop two new instruments.

The development of the instruments involved a number of steps. The first step in the process was an initial focus on research of existing instruments in English in the fields of learning environments and attitudes towards mathematics. It was essential that the existing instruments had validity and reliability research preferably in the context of mathematics and performance in languages other than English as I knew my surveys would have to be developed in Arabic. The second step involved identifying a number of existing instruments and analysing them for the suitability of individual constructs that fitted within the context of the requirements of the ADEC reform and the focus of the inquiry-based exploration approach in mathematics classrooms in Abu Dhabi. Thirdly, once individual constructs had been identified, some items were reworded to fit a mathematics context if they had previously been used in a different subject (e.g., science). The final step in the process of development of the instruments involved the translation of the surveys (detailed in Section 3.5.2).

For both instruments, a description and a justification of the scales is provided in Chapter 4. In this section, however, a brief overview of the two new instruments used to assess the unique learning environment where explorations were being used (described in Section 3.5.1.1) and students' attitudes to mathematics (described in Section 3.5.1.2) are provided.

3.5.1.1 Students' Perceptions of the Learning Environment

The Learning Environment in Inquiry Survey (LEIS) was developed to assess students' perceptions of the learning environment in an inquiry-based setting. It includes six scales that are pertinent to an inquiry-based learning exploration approach (the pedagogical approach is described in Chapter 1). In Table 3.3 a description and sample item for each LEIS scale is provided.

Table 3.3 Description and sample item for each LEIS scale

Scale	No. of items	Description	Sample Item
Personal Relevance	6	The degree to which the learning is relevant to students' lives.	*I learn how mathematics can be part of my out-of-school life.*
Critical Voice	6	The degree to which students are legitimately able to express a critical opinion.	*It's ok for me to express my opinion.*
Student Negotiation	6	The degree to which students are involved with other students in assessing viability of new ideas.	*I talk with other students about how to solve problems.*
Shared Control	6	The degree to which students participate in planning, conducting and assessing of the learning.	*I help the teacher to decide which activities are best for me.*
Involvement	8	The degree to which students have attentive interest, participate in discussions, do additional work and enjoy the class.	*I give my opinions during class discussions.*
Investigation	8	The degree to which skills and processes of inquiry and their use in problem solving and investigation are emphasised.	*I am asked to think about the evidence for statements.*

The newly developed LEIS has a total of 40 items in six scales. Four of the scales, Personal Relevance, Critical Voice, Student Negotiation, and Shared Control were drawn from the Constructivist Learning Environment Survey (CLES). The other two scales Involvement and Investigation were adapted from the What is Happening In this Class? questionnaire (WIHIC). Students responded to the items using a five-point frequency-response scale of almost always, often, sometimes, seldom, and almost never. Using the LEIS provided students with the opportunity to express their opinions about the learning environment in their mathematics classes. A more detailed description, justification, and theoretical basis for the inclusion of individual scales is provided in Chapter 4. A copy of the survey administered to students can be found in Appendix D for the English version and Appendix E for the Arabic version.

3.5.1.2 Students' Attitudes to Mathematics

The second instrument that was developed was the Student Attitudes Towards Mathematics Survey (SATMS). This instrument was developed to assess students' attitudes towards learning in mathematics, particularly in the inquiry-based learning context.

The SATMS is comprised of 23 items in three scales. A description and a sample item for each scale are provided below in Table 3.4. The first scale, containing seven items, assesses students' Enjoyment of Mathematics Classes. The second scale, with eight items was Self-Efficacy, and the third scale, also with eight items was Task Value. A more detailed description of the development of the SATMS and the theoretical basis for the inclusion of individual scales is provided in Chapter 4.

Students responded to each of the items using a five-point frequency-response format of almost always, often, sometimes, seldom and almost never. A copy of the SATMS administered to students can be found in Appendix F for the English version and Appendix G for the Arabic version.

Table 3.4 Description and sample item for each SATMS scale

Scale	No. of items	Description	Sample Item
Enjoyment of Mathematics Classes	7	The degree to which students enjoy their mathematics lessons.	*I look forward to lessons in this subject.*
Self-Efficacy	8	The degree of confidence and beliefs that a student in his/her own ability to successfully perform mathematics-learning tasks.	*I can complete difficult work if I try.*
Task Value	8	The extent that students believe the task they are completing is worthwhile, important and useful.	*What I learn can be used in my daily life.*

3.5.2 Translation of the Instruments

The Learning Environment in Inquiry Survey (LEIS) and the Student Attitudes Towards Mathematics Survey (SATMS) were both translated into Arabic using a process of back translation. The two instruments underwent a translation process, into Arabic, by a translator. The translator specialised in translating documents that required understanding of the ADEC Mathematics context and pedagogical approaches. Once translated, the instruments were then back translated, as recommended by Ercikan (1998) and Warwick and Osherson (1973), into English by an independent specialist in both languages who had not been the translator of the original English versions of the surveys. Both translators involved in this process were my colleagues.

The two English versions were compared by me to ensure that the intent remained the same. Some of the changes were simply grammatical, for example, the original stated "What I learn has nothing to do with my out-of-school life" whereas the back-translated version said, "What I am learning has nothing to do with life outside school". In this case the tense was changed to ensure the meaning translated the same. Another example required a change of wording, the original had "It's ok for me to complain about teaching activities that are confusing", but the back-translation stated, "I am allowed to complain about the misleading activities". Where the English versions differed in the meaning of the statement, I sat with the second translator and together altered the Arabic translation to match the intention of the English statement. Some work was also required with formatting of the questionnaires as Arabic is a right to left language and so tables and the frequency response format had to be reversed appropriately. Given that all students were native Arabic speakers, the Arabic version was administered without the English translation.

3.5.3 Administration of the Instruments

Administration of the two instruments, the LEIS and the SATMS was carried out in a systematic manner at the school level. The surveys were administered by me, personally, to: a) ensure consistency; and b) make it possible for me to clarify any issues related to the items. Administration was carried out over a period of two weeks and, where possible, classes were re-organised to allow for all three classes to be surveyed one after another. On most occasions, the teacher stayed with the class to support the process of administering the surveys. Having the teacher present allowed a verbal explanation of the instructions. In each case, the teacher read the instructions, in Arabic, to the students. As well as written information, students were told in both Arabic and English that the survey was not an exam (this was essential information as I had been introduced to the students as the Senior Specialist for Mathematics Curriculum who wrote the curriculum and the exams they complete) and that the results had nothing to do with their assessment marks.

Students sat separately within the room and worked individually to complete the surveys. Whilst any questions were directed at me, the teacher assisted in translations when required. All student questions were concerning the process for completion, for example “Do I have to complete all the questions on this page as well?” rather than questions about how to answer. Students were instructed to answer with what they felt was the best response for them and their classroom setting in mathematics.

3.6 Qualitative Data Collection

In this section the instruments used to collect qualitative data, these being, lesson observations (Section 3.6.1) and focus group interviews (Section 0) are described. There is also discussion of the trustworthiness of the data (Section 3.6.3).

3.6.1 Lesson Observations

The purpose of the lesson observations was to collect data of a qualitative nature to add richness to the quantitative data and, where pertinent, to provide causal explanations for the survey results. To give the researcher a better understanding of the learning environments created in both groups it was important to observe lessons taught by both teachers categorised as exemplary and non-exemplary in the use of explorations. Of the two teachers exemplary in the use of explorations that were involved in the initial (quantitative) phase of the study, only one was available at the time of the qualitative data collection and so the classes of this teacher were used for observation. This was also the situation with the two teachers non-exemplary in the use of explorations. A total of six lessons were observed, three different classes with the same teacher exemplary in the use of explorations and three different classes with the same teacher non-exemplary in the use of explorations. All classes observed were intended to be lessons where inquiry techniques were used as the main pedagogical approach. The content being taught was at the discretion of the specific teacher according to the scope and sequence. All teachers participating in the study believed they were implementing the requirements of the education reform in mathematics through the use of explorations utilising an inquiry-based learning approach.

All observations were predominantly non-participant and, therefore, I sat at the back of the room. At some points in the lesson (e.g. during activities) I moved about the classes to discuss the lesson with students (where appropriate). Whenever I engaged students in conversation, the questions were open-ended allowing the students to describe what they were doing and how they felt about the work that they were completing. These interactions are further described in the narratives in Chapter 4.

As I observed the lessons, I focused my notes and attention on nine topics that linked with the survey instruments. Each topic had guiding questions to help me to focus on the behaviours and attitudes that would provide explanations and insights into the quantitative results. These nine topics and guiding questions were used as prompts for me, but were not explicitly presented to students during the observations:

1. Personal relevance – How relevant is the work to the students' lives? Are there opportunities to see the link between the topic in-class and real-life?
2. Critical voice – Do students have opportunities to express opinions, ask questions about relevancy?
3. Shared control – Do students have an opportunity to direct the type or pace of teaching, learning or assessment in the classroom?
4. Student negotiation – Do students have opportunities to collaborate, discuss and explain their work to other students in the classroom?
5. Involvement – Are there opportunities for students to participate in the lesson in discussions, problem-solving, asking and answering questions with other students and with the teacher?
6. Investigation – Do students construct knowledge through the use of investigations within the classroom? Are there opportunities to answer questions through a process of investigation? Do students investigate and provide evidence for new ideas/concepts?
7. Enjoyment of mathematics classes – Are students enjoying their time in the classroom? Are they engaged in the subject/activities?
8. Self-efficacy – Are students coping with the work presented to them? Have they got a good attitude towards achieving the work? Do they appear to have a 'can do' attitude?
9. Task value – Are the tasks the students are completing of value to them? Are they relevant, practical to them, interesting, thought-provoking?

(See Appendix H for a copy of the topics and guiding questions).

All observations were recorded as field notes and later typed for analysis. The field notes that were written were later divided into the nine topics mentioned above. By structuring the field notes in this way, a direct link was provided to the topics explored in the quantitative data collection. While I did not force or manufacture comments for each of the sections, I was intentional in observing the class through the lens of each area of focus and sought to write notes for each area.

3.6.2 Focus Group Interviews

Immediately after each lesson observation, I facilitated focus group interviews with students to discuss the lesson that I had observed and to gather information concerning their experiences of their mathematics classes. The purpose of the interviews was to give the students an opportunity to provide additional information about their views of the lesson and for me to investigate and clarify any issues or questions I may have had about what had occurred during the class time. The focus group interviews added an important dimension to the lesson observations as both aimed to provide causal explanations and deeper insight into the quantitative survey data.

Focus group interviews were selected for several reasons. First, using a focus group provided a more relaxed setting for the students, in which they would feel confident to give their opinion. Second, given that students would be speaking in English, and I did not want a teacher present, a group setting allowed students to translate for each other. Focus groups were a useful tool in this context as they are a form of group interview that relies on the discussion and interactions between group members rather than being more formal with the interviewer asking questions of the group and them replying in turn (Morgan, 1988). During the focus group interviews, the students were able to discuss and interact with each other on the use of inquiry in their mathematics classrooms and how they felt about the subject and the learning environment that they were experiencing. This setting allowed me to collect a lot of data during a short space of time and "yield insights that might not otherwise have been available in a straightforward interview" (L. Cohen et al., 2007, p. 376).

The focus group interviews were semi-structured, guided by the nine topics, that were used during observations. Using semi-structured interviews allowed me to ensure that all the topics were covered but provided scope to follow lines of interest that were observed during the lesson. It was also appropriate to use semi-structured interviews to ensure consistency across each of the groups whilst allowing freedom for the discussions to explore topics of interest. The questions used in the lesson observation phase (see Appendix H) created a basis for the discussion in the group interviews. To ensure consistency across the various focus groups, an interview schedule, that included the same nine topics from the observations, was used to guide questions and probes for further discussion. A copy of the interview schedule can be found in Appendix I. The questions were based on the initial prompting questions developed to focus the lesson observation note-taking. The focus group interviews were recorded using field notes during each session.

3.6.3 Trustworthiness of the Data

For my study, triangulation of different data sources was used to enhance the accuracy of the study. "Triangulation is the process of corroborating evidence from different individuals, types of data, or methods of data collection in descriptions and themes in qualitative research" (Creswell, 2008, p. 266). In the context of this study, triangulation was applied through the use of lesson observations and focus groups drawing on multiple sources of information. Respondent validation allows participants to review the data collected and any interpretations of the data made by the researcher. Just as the reliability and validity of quantitative data is examined, ensuring the trustworthiness of the qualitative data is important. Trustworthiness was considered using the four categories recommended by Guba (1981), credibility, transferability, dependability and confirmability.

First, credibility of qualitative data was established through triangulation and respondent validation (as recommended by Cope, 2014). Second, transferability, which can be related to the idea of external validity or generalisability in quantitative research, was considered. Because the findings of qualitative research are limited to a specific group of individuals or situations, it is difficult to demonstrate that the findings are applicable in other environments or with differing individuals (Shenton, 2004). By actioning purposeful sampling that is representative of the population being studied, it is possible to generalise the findings of the qualitative study to a wider audience. In the case of this study, the sampling for the qualitative phase happened after the initial phase involving quantitative data collection occurred. This meant that a combination of two types of purposeful sampling was utilised: critical sampling, which described a case that dramatically illustrated the differences between the classroom and students of the teacher exemplary in the use of explorations and the non-exemplary case, and the second type was confirming sampling, which is intended to confirm the findings of the quantitative phase of research (Creswell, 2008).

The third aspect of trustworthiness of qualitative data collection considered was dependability. This can be likened to reliability in quantitative research where if the work was replicated in the same setting, using the same methods, with the same contributors, the same findings would be attained. This concept of reliability in quantitative research does not fit with the philosophy of qualitative studies (Fidel, 1993; C. Marshall & Rossman, 1999) where "the changing nature of the phenomena scrutinised by qualitative researchers renders such provisions problematic in their work" (Shenton, 2004, p. 71). The nature of using the qualitative data to confirm the findings of the quantitative results, shows that by repeating the data collection albeit via differing methods, the qualitative data can be considered reliable or dependable as required.

The final point considered in terms of discussing the trustworthiness of the qualitative data was confirmability. In qualitative research, confirmability is used in preference to objectivity in quantitative research. To ensure confirmability, steps must be taken to show that the findings of the study represent those of the participants, rather than the opinions and inclinations of the researcher. An important criterion for confirmability is the degree to which the researcher explains their own biases or partialities (Miles & Huberman, 1994). To overcome any biases that may exist in the qualitative phase, the researcher needs to acknowledge within the findings the reasons for favouring one approach over others and any weaknesses within the techniques utilised. To ensure confirmability within my study, I have provided detailed methodological descriptions so that the readers are able to follow the direction of the research step-by-step and determine the extent of the data and results emerging from the study can be accepted.

3.7 Analyses of Quantitative Data

Prior to data entry and analysis, a process of data cleaning, involving three steps, was undertaken. The first was to consider those cases in which data was missing (incomplete survey responses). Those surveys with more than 10% of the data missing, which meant six blanks, were highlighted. The next stage was to record the observations made during the data collection and highlight students who did not complete the surveys with care. The final step was to calculate the standard deviation to determine whether there was sufficient variation in the responses. Cases were omitted if there was a standard deviation less than 0.3. During this process, 11 students (3.6%) were removed from the sample. In some cases, this was because more than 10% of the numbers were missing, in other cases there was little variation in the data collected. Finally, two surveys were removed because the researcher observed, during survey completion, that the student completed surveys without reading items or asked a partner what to write. For those surveys that remained, but had missing numbers, the class mean for that particular item was calculated (rounded to 2dp) and used to fill the gap.

The data, once cleaned, was entered into a database by me to ensure accuracy of data entry. The data was then analysed using the Statistical Package for Social Scientists (SPSS), version 22. The process of data analysis is further described in the following headings:

- Validity and reliability of the learning environment and attitude scales (Section 3.7.1);
- Investigating associations between student perceptions of learning environment and attitudes towards mathematics (Section 3.7.2); and
- Differences between student perceptions for classes with teachers exemplary and non-exemplary in the use of explorations (Section 3.7.3).

3.7.1 Validity and Reliability of the Learning Environment and Attitude Scales

The Learning Environment in Inquiry Survey (LEIS) and the Student Attitudes Towards Mathematics Survey (SATMS) were assessed for reliability and validity using factor analysis, internal consistency reliability analysis, discriminant validity analysis, and its ability to differentiate between the perceptions of students in different classes.

As a first step, factor analysis was used. Factor analysis is a statistical process that collapses a large number of variables into a smaller number of underlying factors that can be interpreted. There could be a situation in which there appears to be variations between a large number of variables, but in actuality it is reflecting the variations between unobserved variables. Factor analysis was used to assess the function of the various scales and items within the two instruments and to identify factors within the instruments that are answered similarly by participants. In this study, principal axis factor analysis with oblique rotation was used. Oblique rotation was considered to be an appropriate technique as it is assumed that the factors in a learning environment are expected to be overlapping (Coakes & Ong, 2010). The two criteria for retaining any item were that it must have a factor loading of at least .4 on its *a priori* scale and less than .4 on any of the other scales (Field, 2005; Stevens, 1992; Thompson, 2004).

To determine the internal consistency reliability, the Cronbach alpha coefficient was used. The purpose of this was to ensure that items within a scale were assessing a common construct. If the items were to behave similarly, the scale is said to have internal consistency. For the purpose of this study, the Cronbach alpha coefficient was calculated for two units of analysis, the individual and the class mean. Alpha coefficients that were .70 or higher were considered to be acceptable and show that the items being measured have a relatively high internal consistency (Nunnaly, 1978).

Within each survey, there were several scales or constructs. The intention was for each scale to assess different areas and that constructs do not overlap or test the same content. Discriminant validity analysis was used to provide information to indicate whether the scales were assessing distinct areas. To do this the mean correlations of each scale with the other scales were calculated. Factor correlations above .8 suggest an overlap of concepts and so scales below this are considered to have an acceptable level of independence (Brown, 2006).

To establish whether the two new instruments were able to differentiate between the opinions of students in the different classes, for each scale, a one-way analysis of variance (ANOVA) was calculated. The eta^2 statistic, which represents the proportion of variance in a scale score between scales, was used.

3.7.2 Investigating Associations Between Student Perceptions of Learning Environment and Attitudes Towards Mathematics

To assess whether there were associations between students' perceptions of the learning environment dimensions and their attitudes towards mathematics, an investigation using simple correlation analyses was performed. The purpose of this was to provide information concerning the bivariate association between each learning environment dimension and each attitude dimension.

An investigation using multiple regression analyses was also performed to examine the combined influence of the LEIS scales as independent variables and the SATMS scales as dependent variables and to lessen the Type I error rate associated with the simple correlation analysis. Beta values were interpreted for each independent variable to estimate the effect of each predictor on the dependent variable.

3.7.3 Differences Between Student Perceptions for Classes with Teachers Exemplary and Non-Exemplary in the use of Explorations

To investigate whether there were differences in student perceptions of the learning environment and attitudes towards inquiry within the mathematics classes for teachers who were exemplary and not exemplary in the use of explorations, a one-way multivariate analysis of variance (MANOVA) was used. For MANOVA, the individual student was used as the unit of analysis with the six learning environment scales and the three attitude scales representing the dependent variables and the type of teacher (exemplary/non-exemplary) representing the independent variable. To assess whether the group differences were statistically significant, a test statistic in MANOVA, Wilks' lambda, was calculated. Wilks' lambda is a measure of the percent variance in independent variables that are not explained by differences in levels of the independent variable (Field, 2016). To interpret the results of the ANOVA, the F statistic was used to measure how much the model improved the prediction of the outcome compared to the level of inaccuracy in the model.

Cohen's effect sizes were calculated to examine the extents of the differences between the student perceptions of the learning environment and attitudes towards mathematics for teachers exemplary in the use of explorations and those who were not. These effect sizes were calculated in terms of the differences in means divided by the pooled standard deviation as suggested by Thompson (1998, 2001).

$$\text{Cohen's } d = \frac{M_1 - M_2}{\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}}$$

3.8 Analyses of Qualitative Data

Analysis of the data collected during the qualitative phase of the research can be time-consuming and overwhelming due to the volume of text collected in the process (L. Cohen et al., 2007). To try to combat this, I followed several steps in the process of analysis in order to analyse my qualitative data. Firstly, narratives were written through the use of impressionistic tales as described in Section 3.8.1 and then the process of analysis of the qualitative data was through the use of thematic analysis, described in Section 3.8.2.

3.8.1 Impressionistic Tales

It was important for my analysis of the lesson observations to tell a story to: a) provide a context to the reader; b) enable easy comparisons between the two cases of data, the lessons observed with the teacher exemplary in the use of explorations and those who were not. The two narratives used within the qualitative data analysis were written as impressionistic tales. Impressionistic tales can be used as a way of describing the observations and providing an insider's view of the classroom allowing readers to feel part of the experience and use the five senses to fully immerse themselves in the story and environment. According to Van Maanen (1988), how research is presented can be as important as what is presented and requires due consideration. The use of impressionistic tales to provide a true cultural description can only be found from:

> … a period of intimate study and residence in a given social setting … [which] ...calls for the language spoken in that setting, first-hand participation in some activities … and most critically, a deep reliance on intensive work with a few instruments drawn from the setting (Van Maanen, 1982, p. 103)

Taylor (1997) describes van Maanen's illustration of impressionistic tales as he likens them to the school of thought of the impressionists, such as Degas, Monet, Renoir, van Gogh, and their preference for earthy un-posed scenes in situ as opposed to formal studio portraits and tangled wheat fields over roses and vases. The painting is not just about the landscape but instead portrays a theme through colours and textures to engage the viewer and encourage them to be a participant in the experience with the artist. This is the intention of the impressionistic tale; to draw in the reader through the use of imagery, phrasing, vivid descriptions and use of all the senses to evoke a reaction.

Two impressionistic tales (one about a class taught by a teacher exemplary in the use of explorations and another about a lesson in which the teacher was non-exemplary in the use of explorations) were written to represent the classrooms. Rather than simply describing one lesson observation, the tales involved extracting themes that were similar across a number of observations. The two impressionistic tales can be considered representative of a number of lesson observations and are written in such a way as the reader can understand and focus on key aspects of the lessons in detail. Each tale describes events and quotations from three lesson observations. Rather than providing three similar tales, pertinent aspects from the three lessons observed of teachers exemplary in the use of inquiry-based learning were extracted and described in one impressionistic tale. This was also the process undertaken for the three lessons observed of teachers non-exemplary in the use of inquiry-based learning, to generate one impressionistic tale.

Following each of the impressionistic tales is an interpretative commentary. The purpose of the commentaries that follow the tales is to put the observations into context and allow for a culturally sensitive basis to explain the similarities and differences between the two impressionistic tales.

3.8.2 Thematic Analysis

Thematic analysis is "a method for identifying and analysing patterns in qualitative data" (Clarke & Braun, 2013, p. 120). In the 1970s, Merton (1975) first named thematic analysis as an approach for the analysis of qualitative data, however many different versions have been proposed since. For the purpose of my study, I have chosen to use the six phases of thematic analysis as described by Braun and Clarke (Braun & Clarke, 2006; Clarke & Braun, 2013).

Phase 1: Familiarisation with the data

During the first stage of the analysis process, the researcher needs to become completely familiar with the data through reading and re-reading all notes. After the data collection process where field notes were written during both the lesson observations and during the focus group interviews, I prepared the data for analysis by converting the shorthand notes into proper cohesive sentences. Then, I read the field notes using preliminary exploratory analysis as recommended by Creswell (2008). This consisted of studying the information to get a general sense of data and included noting ideas down, thinking about the organisation of the data and deciding whether more data was needed. The process involved reading the data in its entirety several times to try to get a sense of the text as a whole before splitting it into parts (Agar, 1980). Throughout the qualitative data analysis process, I read and interpreted the data. This process is termed progressive focusing (Parlett & Hamilton, 1976). I started by focusing using a wide-angle lens and then narrowed the exploration through a process of sifting, sorting, reviewing and reflecting on the data allowing the key ideas to emerge. These were then used as the main concepts for further focusing in a funnelling approach from wide to the narrow (L. Cohen et al., 2007).

Phase 2: Coding

The next stage in the qualitative data analysis process was coding the data. The intention in the coding process was to make sense of all the data that was in text form, to divide it into pieces, label these parts with codes, assess the pieces for overlap or redundancy and then create themes that incorporated a group of related codes (Creswell, 2008). “A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data.” (Saldana, 2013, p. 3). I chose to code the data by hand as I wanted to be close to the data and have a hands-on approach to the analysis. Once a few iterations of coding were complete, where the similar codes were grouped, and redundant codes eliminated, the data was reduced to themes that formed the major ideas of the data.

Phase 3: Searching for themes

"A theme is a coherent and meaningful pattern in the data relevant to the research question." (Clarke & Braun, 2013, p. 121). There are no pre-determined rules about what makes an appropriate theme but instead a theme is characterised by its importance (Maguire & Delahunt, 2017). I examined the codes and tried to fit some together into a theme. During the two stages of coding and identifying preliminary themes, there was some overlap. I completed this stage of the process by collating all of the coded data related to each theme.

Phase 4: Reviewing themes

The next stage in the process involved the reviewing of themes. The themes must work in relation to both the extracts that have been coded and the full data set. It was important that I reflected on "…whether the themes tell a convincing and compelling story about the data…" (Clarke & Braun, 2013, p. 121). It was necessary in this phase to collapse some themes into one.

Phase 5: Defining and naming themes

As the name implies, this step involved defining and naming the themes. The important aspect of this step was to ensure that the name that was created for the theme summarised the key idea and told the story of the theme. I analysed the content of the theme and considered how the theme fitted into the overall picture of the data.

Phase 6: Writing-up

For the purpose of my research, I wrote up the qualitative research using impressionistic tales, commentaries and the individual themes, reported in Chapter 4. "Writing up involves weaving together the analytic narrative and (vivid) data extracts to tell the reader a coherent and persuasive story about the data and contextualising it in relation to existing literature." (Clarke & Braun, 2013, p. 121).

3.9 Ethical Considerations

When completing any research and data collection, consideration of ethical issues is essential to ensure that the rights of participants are respected, research sites are honoured and research is reported honestly and fully (Creswell, 2008). Ethical considerations should not be an afterthought, but rather should be at the forefront of the researcher's mind during the entire research process (Hesse-Bieber & Leavy, 2006). In this section I discuss the various ethical considerations made throughout my research study.

Before it was possible to approach Mathematics Education Advisors and request recommendations for teachers to participate in my study, I obtained ethics approval from Curtin University (a copy of which can be found in Appendix J). I also gained approval from the ADEC Research Office which is a requirement when conducting research concerning teachers and students in ADEC schools (see Appendix K for a copy of the approval). Once recommendations for teachers were made, it was necessary to seek permission from the teachers and principals of the schools where the students I wished to survey attended. Teachers and principals were sent the letter from the ADEC Research Office requesting their support and the appropriate information sheets and participant consent forms generated as part of the approval for ethics process.

Once permission was given, I organised for school visits to occur where I had the opportunity to meet with the principals and teachers and also gain verbal consent for data collection to occur. During the collection of the data and ongoing for the rest of period of the study, I considered the areas of informed consent (see Section 0), consideration (see Section 3.9.2), and confidentiality (see Section 3.9.3).

3.9.1 Informed Consent

All of the students who completed the survey and teachers whose classes were surveyed were given detailed information about the processes required to complete the survey and about the purpose of the survey itself. This information was provided through a number of information sheets (for principals and teachers (Appendix L in English and Appendix M in Arabic), for students (Appendix N in English and Appendix O in Arabic), and for parents (Appendix P in English and Appendix Q in Arabic). It was essential that students with limited English were also informed of the research and so this occurred through the use of Arabic versions of the written instructions on the front of the survey (see Appendix R for the English version and Appendix S for the Arabic version) and verbal instructions at the time of the completion of the survey in both Arabic and English.

The principal from each of the schools provided consent for the surveys to be completed and the teachers agreed to allow their class time to be used and for the students to participate. The teachers also consented to participate in the research and agreed to not having their names used and the option to cease being part of the study at any time. The guidelines for reasonable informed consent, as outlined in L. Cohen, Manion & Morrison (2007), include "An instruction that the person is free to withdraw consent and to discontinue participation in the project at any time without prejudice to the participant" (L. Cohen et al., 2007, p. 53). In this study, students were not obliged to be involved, they were instructed that completion of the survey was voluntary, and they were also informed that they could withdraw from the study at any time. These precautions ensured that the guidelines, as laid out in L. Cohen, Manion & Morrison (2007), were fulfilled.

3.9.2 Consideration

All surveys were completed during class time at the beginning of the respective lessons. Since all students participated in completing the survey, teaching of the curriculum did not occur during those times and students did not miss out while others were taught. In some cases, I used lessons where the students had a relief teacher and so regular classes were not occurring. To allow me to minimise the length of the school visit, classes were re-organised in the timetable to have the three required lessons in a row. Teachers of Arabic and physical education supported this by allowing their class times to be swapped. The survey took approximately 15 to 20 minutes to complete and so the students had the remaining time in their 45-minute periods to continue their normal class work.

It was important that both teachers and the principals from the respective schools were comfortable with the data that was collected and the process for collection, storage and ongoing analysis. Therefore, I ensured that, before I left each school, I met with the teacher concerned and discussed the continuing plans and allowed them to see the surveys. I also met with the principal and generally she requested a copy of the final thesis once it was published. The intention was to alleviate issues related to teacher concerns about the anonymity and confidentiality of the data.

3.9.3 Confidentiality

The promise of confidentiality as defined by L. Cohen, Manion & Morrison (2007) means “that although researchers know who has provided the information or are able to identify participants from the information given, they will in no way make the connection known publicly; the boundaries surrounding the shared secret will be protected.” (L. Cohen et al., 2007, p. 65). At the time of completion of the survey, students were told both verbally and in written form that they did not need to put their name on the survey paper. All papers were numbered, according to the school they attended, their teacher, their class and individually for the students in the class to provide anonymity.

3.10 Chapter Summary

In this chapter the research methods used in the study reported in this thesis have been described. A mixed methods approach involving the use of a sequential design that incorporated two phases was adopted in the study. The first phase focused on the development, validation and administration of two instruments: one to assess the students’ perceptions of the learning environment and the other to assess students’ attitudes towards mathematics. In this stage I utilised quantitative methods of data collection and involved a post-positivist paradigm. In the second phase the collection of qualitative data, including lesson observations and focus group interviews were involved. During this phase, an interpretative paradigm was used.

The sample for the study involved 12 Cycle 2 (grades 6 to 9) classes drawn from four schools in the environs of Abu Dhabi city. The selection of the schools was driven by the selection of the teachers. The selection of teachers involved purposive sampling, using a set of criteria based on teacher skills in the use of explorations. Using this criteria, two teachers that were considered to be teachers exemplary in the use of explorations and two that were not were invited to participate in the study. Each teacher taught three classes, and all were included in the sample, providing a total of 12 intact classes in total, and a total of 291 students. The students were from differing grade levels, however all students had received similar experiences within the reform and by including all the students taught by a particular teacher, this eliminated any issues that may have arisen with the streaming of students and ensured a range of students were surveyed.

The development of the instruments for the quantitative phase involved the selection of constructs from existing instruments that had been validated in non-English speaking environments and rewording to suit the mathematics context in Abu Dhabi. Once the survey was developed, they were translated using the process of back translation. The first instrument, developed to assess students' perceptions of their inquiry classroom, was the Learning Environment in Inquiry Survey (LEIS). This survey contained 40 items used to assess six dimensions of the learning environment that can be considered important to an inquiry classroom. The second instrument, the Student Attitudes Towards Mathematics Survey (SATMS), was developed to assess student attitudes towards mathematics and was made up of 23 items in three scales. Once the instruments had been translated into Arabic, they were administered, by me, over a period of two weeks.

Qualitative data collection involved the observation of six lessons, three classes for each of two teachers, one a teacher exemplary in the use of explorations and one a teacher non-exemplary in the use of explorations. During the observations, field notes were collected and later analysed. After each lesson observation, a semi-structured focus group interview was held with students to provide additional information about their views of the lesson and to allow me to delve deeper into any issues or questions I had encountered during the lesson observations. Every effort was taken to ensure the trustworthiness of the qualitative data through credibility, transferability, dependability and confirmability.

To analyse the data to make conclusions about the four research objectives, various methods were utilised. First, the validity and reliability of the new instruments was assessed using factor analysis, internal consistency reliability analysis, discriminant validity analysis, and its ability to differentiate between the perceptions of students in different classes. Second, to investigate whether associations existed between students' perceptions of their learning environment and their attitudes towards mathematics, simple correlation and multiple regression analyses were used. Third, to examine whether students of teachers who were exemplary and not exemplary in the use of explorations differed in terms of the perceived learning environment and attitudes a one-way multivariate analysis of variance (MANOVA) and effect sizes were calculated. Lastly, to explain the differences between the two cases: the results from the teacher exemplary in the use of explorations and the teacher who was not, impressionistic tales and the ensuing interpretative commentaries were written, after which thematic analysis was used.

There were a number of ethical issues that were considered throughout the study. As well as permission granted from the ADEC research office and ethics approval from Curtin University, ethical considerations regarding informed consent, consideration made to the participants and confidentiality of all information were made. Students, teachers, parents and principals of the schools were informed of the study and the processes utilised to collect and store data. Students were not disadvantaged in any other aspects of their schooling by participating in my study and considerations were put into place to ensure this. Responses to the surveys were anonymous and the identity of participants and their responses through the lesson observations and focus group interviews are known only to me. All participants were provided with written and oral explanations of their rights and responsibilities as part of this research project.

In Chapter 4, the results of the data analysis results for both the quantitative and qualitative data are provided.

CHAPTER 4

Data Analysis and Results

4.1 Introduction

Whereas in the previous chapter the research methods, including the data analyses, were described, in this chapter the results are reported. The results are reported using the following headings:

- Reliability and validity of the instruments (Section 4.2);
- Environment – attitude associations (Section 4.3);
- Teachers exemplary and non-exemplary in the use of explorations: Differences in learning environment and attitudes (Section 4.4);
- Explaining the differences (Section 4.5); and
- Chapter summary (Section 4.6).

4.2 Reliability and Validity of the Instruments

Two surveys were developed for use in this study. As reported in Chapter 3, the development of the surveys involved four steps. First, existing instruments were examined to identify those that reported strong reliability and validity in past research, especially where they had been translated and administered into languages other than English. Second, the instruments were analysed for suitable constructs that fitted the context of the ADEC education reform and inquiry-based learning. Third, rewording items, predominantly to change from a science context to a mathematics context was carried out. Finally, the instruments were translated into Arabic using a process of back-translation. In the first research objective I sought to provide evidence to support the reliability and validity of the two instruments.

Research Objective 1

To develop and validate instruments suited for use with middle school students in the UAE to assess students' perceptions of the learning environment in exploration classes and their attitudes.

The evidence to support the reliability and validity of the instruments is described below. First, in Section 4.2.1, evidence to support the new learning environment instrument, the Learning Environment in Inquiry Survey (LEIS) is reported and, in Section 4.2.2, evidence to support the reliability and validity of the Student Attitudes Towards Mathematics Survey (SATMS) is reported.

4.2.1 Reliability and Validity of the Learning Environment in Inquiry Survey (LEIS)

In this section evidence to support the reliability and validity of the newly- developed Learning Environment in Inquiry Survey (LEIS) is provided. In developing the survey, it was important to ensure the content validity of the scales, that is, whether the scales were theoretically sound and appropriate for inquiry-based learning in the context of explorations in mathematics classes in Abu Dhabi (described in Section 4.2.1.1). To provide evidence to support the construct validity of the newly-developed Learning Environment in Inquiry Survey (LEIS) when used in the UAE, data collected from 291 students in 12 classes was used to examine the: factor structure (Section 4.2.1.2); internal consistency reliability (Section 4.2.1.3); discriminant validity (Section 4.2.1.4); and, the ability to differentiate between classes (Section 4.2.1.5).

4.2.1.1 Content Validity

As described in Chapter 3, the LEIS was based on scales drawn from existing instruments. Four of the six scales of the LEIS were adapted from the Constructivist Learning Environment Survey (CLES; Taylor et al., 1997) and two scales were adapted from the What Is Happening In this Class? questionnaire (WIHIC; Fraser et al., 1996). In the development of the LEIS, it was important to ensure that the scales had a sound theoretical foundation. This information could then be used to determine whether the items within each scale effectively assessed the construct that it was designed to assess. In the following sections I have provided a description of and a theoretical basis for the selection of each of the six scales: Personal Relevance, Critical Voice, Student Negotiation, Shared Control, Investigation and Involvement.

Personal Relevance

It is widely recognised that making students' learning relevant to their lives outside of school is important. Personal relevance can be defined as a personally meaningful connection to the individual (Priniski, Hecht, & Harackiewicz, 2018). In past research, it has been suggested that when lessons are more personally relevant, there is increased engagement and enjoyment in learning (Aldridge, Afari, et al., 2012; Priniski et al., 2018; Taylor et al., 1997; Walker & Fraser, 2005). Teaching and learning experiences and opportunities in the classroom that are relevant to the lives of the students are considered central factors influencing student motivation and engagement, impacting students' abilities to take meaning from the learning opportunities and allowing them to form ideas relating the concepts to their world and understanding (Connell & Wellborn, 1991; Kapon, Laherto, & Levrini, 2018; Ryan, 1995; Ryan & Deci, 2000; Vansteenkiste et al., 2018). According to Cetin-Dindar (2016), when more opportunities for personal relevance are provided for students in the classroom environment, their motivation to learn science is positively affected.

To motivate students during lessons, teachers need to highlight the personal significance or relevance of the learning activity (Vansteenkiste et al., 2018). To make the learning relevant, mathematical concepts need to be introduced to students within a meaningful context that allows them to relate the knowledge to their lives.

The Personal Relevance scale, derived from the CLES (Taylor et al., 1997), was modified to investigate the extent to which students perceived the mathematics learnt in the classroom to be relevant to their life and experiences outside of school. Traditional mathematics classrooms in Abu Dhabi were places where mathematics was taught from a theoretical perspective with little application to real-world experiences and almost no content relevant to the life of a student growing up in a rural or urban context in a desert area in the Middle East. Within the reform effort taking place, the explorations that were required in the mathematics classroom meant that students had to use mathematics in an applied context and for their learning to be linked to a ‘big question’ that they could relate to. Assessing the personal relevance of the educational innovation of exploration approaches to teaching and learning, therefore, was important to determine whether students found them to be relevant to their lives outside of school.

Critical Voice

Critical voice, from a critical theory perspective, is about giving students opportunities to question teacher’s pedagogical methods and activities and empowering students to be able to discuss any restrictions that they encounter in their learning. Teachers should be accountable for their pedagogical actions and students should be involved in decision making processes and putting forward their views, concerns and ideas (Holdsworth, 2016; Taylor et al., 1997). Giving students a voice empowers them and makes them feel that they belong, are valued and that their contributions matter (Bain, 2010). When students find their own voice within a healthy learning environment, they are more likely to develop a confident voice, a capacity to act in the world, and a willingness to lead others (Department of Education and Training, 2018).

Traditionally, mathematics teaching in the UAE has involved the teacher lecturing directly from a government provided textbook and students completing all of the exercises contained within (Gaad et al., 2006). There has been limited freedom for both teachers and students for differing pedagogical methods. With the introduction of the educational reform, teachers have been encouraged to utilise a variety of instructional strategies and students have started expecting lessons that are engaging and interesting. Teachers allowing students to have a critical voice in the classroom is a good indicator of change in pedagogy and lessons that are more student centred and, therefore, this scale was included in the instrument. The Critical Voice scale, which originated in the CLES (Taylor et al., 1997), was adapted to investigate the extent that students feel that they have the opportunity to express opinions, question the teaching on methods and content, and express concern about issues that prevent learning.

Student Negotiation

The use of student negotiation promotes opportunities "for students to explain and justify to other students their newly developing ideas, to listen attentively and reflect on the viability of other students' ideas and, subsequently, to reflect self-critically on the viability of their own ideas." (Taylor et al., 1997, p. 4). Student negotiation encourages student engagement in teaching and learning activities in the classroom as students are provided with some choice about the tasks to be completed (Flutter & Ruddock, 2004; MacBeath, Demetriou, Ruddock, & Myers, 2003; Uztosun, Skinner, & Cadorath, 2018). The use of student negotiation in the classroom indicates a shift in teacher-student roles as students are more actively involved in making decisions, thereby making learning more meaningful (Flutter & Ruddock, 2004; Schoerning & Hand, 2013; Zhang & Head, 2010). Where students feel that their needs and interests are being considered, they are more motivated in the classroom (Doran & Cameron, 1995; Uztosun et al., 2018).

The Student Negotiation scale was adapted from the CLES (Taylor et al., 1997) and modified to assess the viability of ideas as an important aspect of the exploration inquiry process. All explorations are completed in groups of between two to four students, with students being required to present ideas to the other group members and come to a consensus about how to proceed. All aspects of the exploration task need to be completed together and the majority of the components of the task are assessed on a group basis, making student negotiation an important feature of the learning environment.

Shared Control

Shared control in classroom settings is about the "extent to which students are invited to share control of the learning environment with the teacher, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria" (Ozkal, Tekkaya, Cakiroglu, & Sungur, 2009, p. 72). Shared control encourages students to participate and be active in the teaching-learning process, with teachers giving students opportunities to think via discussion and through asking other students questions. The use of shared control in the classroom has led to the use of teaching techniques that employ the social construction of knowledge (Kiany & Shayestefar, 2011; Sultan, Woods, & Ah-Choo, 2011). There is a need for learners to construct their own knowledge through the use of shared control between teachers and students (Sultan et al., 2011; Tharp & Gallimore, 1988) as it makes learning more enjoyable with positive effects on learner motivation (Partin & Haney, 2012; Wolters, 2003; Zimmerman, 2002).

The Shared Control scale, derived from the CLES (Taylor et al., 1997), was modified to investigate whether students felt that they were able to help the teacher to decide what activities were best for them in the context of an exploration inquiry task. This was considered to be important given that, when working on an exploration task, students are required to direct the task with their question, the information they gather, and how they present their findings.

Investigation

The use of investigation in the classroom is the "extent to which skills and processes of inquiry and their use in problem solving and investigation are emphasised." (Dorman, 2008, p. 183). In mathematics, investigation includes finding out about an issue where we do not currently know the answer and using a process of formulating questions and then producing, testing and refining conjectures about those questions. The final step is proving and communicating results (Magen-Nagar & Steinberger, 2017; Ponte, 2001). Mathematical investigation is based on the pedagogical belief that students learn best when they have opportunities to be active learners and to construct personal understandings of mathematical concepts (Alt, 2018; Gadanidis, Sedig, & Liang, 2004). When students are allowed to explore and investigate concepts, they demonstrate deeper mathematical understanding (Heck, Banilower, Weiss, & Rosenberg, 2008; Polly et al., 2014; Smith & Smith, 2006; Tarr, Reys, Reys, Chavez, & Shih, 2008).

The Investigation scale, derived from the WIHIC questionnaire (Fraser et al., 1996), was modified for use in the LEIS to explore the extent to which students believe that they have opportunities to investigate while completing an exploration inquiry task. Given that investigation is essential for effective explorations this scale was selected.

Involvement

Involvement is "the extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class." (Dorman, 2008, p. 183). Involvement is considered to be a distinguishing characteristic of classrooms where students exhibit more positive views towards their subject (Fouts, 1989; Mäkelä, Helfenstein, Lerkkanen, & Poikkeus, 2018). Students who are involved in their lessons exhibit different behaviours to their peers through use of body language, verbal participation and social interactions. They are more willing to attempt mathematical problems, ask questions when clarification is required and are more active in their learning (Nebesniak & Heaton, 2010). In order for students to be encouraged to reach their full potential in their lessons, participation and involvement are essential conditions (Daher & Saifi, 2018).

The Involvement scale, originally from the WIHIC (Fraser et al., 1996), assesses the extent that students feel involved or able to participate within the classroom. In the context of this study, it included discussions about the work or involvement in collaborative activities in which students work together towards a common goal.

4.2.1.2 Factor Structure

To provide evidence to support the reliability and validity of the LEIS, the first step was to examine the *a priori* factor structure of the instrument. Before carrying out the factor analysis, the multivariate normality and sampling adequacy of the data were tested. Bartlett's test of sphericity indicated that $\chi^2 = 4856.45$ and this value was statistically significant ($p<.001$). The Kaiser-Maiyer-Olkin measure of adequacy was high (.918), confirming the appropriateness of the data for further analysis.

As described in Section 3.6.1 of Chapter 3, principal axis factor analysis with oblique rotation was carried out to extract salient factors. The criteria for retaining an item was that it should load at .40 or more on its own scale and less than .40 on any other scale. During factor analysis, three items were found not to meet the criteria (Item 6 for the

Personal Relevance scale, Item 30 for the Involvement scale and Item 37 for the Investigation scale). These items were removed from all further analysis. The remaining 36 items all loaded at least .40 on their *a priori* scale and no other scale. The factor loadings for these items are reported in Table 4.1.

The percentage of variance and the eigenvalue associated with each scale are recorded at the bottom of Table 4.1. The percentage of variance for LEIS scales ranged between 3.77% and 31.33%, with the total percentage of variance being 57.27%. The scale eigenvalues for the LEIS ranged from 1.36 to 11.28, which were all above 1, thereby meeting Kaiser's (1960) criterion for a scale.

4.2.1.3 Internal Consistency Reliability

The Cronbach alpha coefficient was used as an estimate of internal consistency reliability. Alpha coefficients that are .70 or higher were considered to be acceptable and show that the items in a scale have relatively high internal consistency (Nunnaly, 1978). The results, reported in Table 4.2, show that the Cronbach alpha coefficients for each of the six scales ranged from .75 to .88 with the individual as the unit of analysis and from .86 to .95 with the class mean as the unit of analysis. With the exception of Personal Relevance at the individual level of analysis (whose reliability was .75) all alpha coefficients were above .80. These results suggest that the scales of the LEIS have good levels of internal consistency based on L. Cohen, Manion and Morrison's (2000) criteria.

4.2.1.4 Discriminant Validity

Oblique rotation in exploratory factor analysis can be used to provide a realistic representation of how the various factors are interrelated (Brown, 2006; Field, 2009). According to Field (2009), there should be a moderately strong relationship, but factor correlations over .80 can imply an overlap of the concepts and provides an indication

Table 4.1 Factor loadings, eigenvalues and percentages of variance for the LEIS

Item	Factor loading					
	Personal Relevance	Critical Voice	Shared Control	Student Negotiation	Involvement	Investigation
1	.72					
2	.77					
3	.47					
4	.75					
5	.67					
7		.67				
8		.77				
9		.71				
10		.56				
11		.53				
12		.48				
13			.67			
14			.65			
15			.81			
16			.80			
17			.76			
18			.69			
19				.47		
20				.67		
21				.60		
22				.74		
23				.62		
24				.78		
25					.66	
26					.71	
27					.73	
28					.64	
29					.61	
31					.54	
32						.51
33						.48
34						.76
35						.82
36						.75
38						.57
39						.59
Eigenvalue	1.88	2.55	1.95	1.61	11.28	1.36
% Variance	5.24	7.04	5.41	4.47	31.33	3.77

N = 291 students in 12 classes
Factor loadings smaller than 0.40 have been omitted.

Table 4.2 Internal consistency reliability (Cronbach alpha) for the LEIS scales for two units of analysis

Scale	Number of items	Unit of analysis	Cronbach alpha
Personal Relevance	5	Individual	.75
		Class mean	.86
Critical Voice	6	Individual	.83
		Class mean	.88
Shared Control	6	Individual	.88
		Class mean	.95
Student Negotiation	6	Individual	.82
		Class mean	.91
Involvement	6	Individual	.83
		Class mean	.89
Investigation	7	Individual	.86
		Class mean	.91

N = 291 students in 12 classes

of poor discriminant validity. The component correlation matrix, Table 4.3, indicates that the highest correlation was .40, which met the requirements of the threshold of .80 of discriminant validity (L. A. Clark & Watson, 1995; Kline, 2011).

Table 4.3 Component correlation matrix for the scales of the LEIS

Scale	PR	CV	SC	SN	INVO	INVE
Personal Relevance (PR)	–	.30	.36	.30	.33	.33
Critical Voice (CV)		–	.27	.24	.26	.11
Shared Control (SC)			–	.36	.38	.40
Student Negotiation (SN)				–	.32	.27
Involvement (INVO)					–	.20
Investigation (INVE)						–

N = 291 students in 12 classes

4.2.1.5 Ability to Differentiate between Classes

To further support the validity of the LEIS, it was important to ensure that each scale was able to distinguish between those groups for which it was expected to distinguish. Theoretically, students in the same class should have similar perceptions of their learning environment, but these perceptions should be different from students in another class. To examine the ability of each scale in the LEIS to differentiate between the 12 classes in the research, an analysis of variance (ANOVA) was performed. The ANOVA results show a significant difference (p<.05) between classes for all of the six scales of the LEIS (see Table 4.4), thus supporting the ability of each scale to differentiate between classes. The eta² statistic, which represents the proportion of variance attributed to class membership, ranged from .08 to .22 for different scales.

Table 4.4 The ability to differentiate between classes (ANOVA results) for scales of the LEIS

Scale	ANOVA Results (Eta^2)
Personal Relevance	.09**
Critical Voice	.08**
Shared Control	.08*
Student Negotiation	.10**
Involvement	.08*
Investigation	.22**

N = 291 students in 12 classes
* p<.05 ** p<.01

Overall, the results presented in Section 4.2.1, strongly support the validity and reliability of the LEIS when used with Cycle 2 students in mathematics classes in Abu Dhabi. As such, the results derived from the LEIS to address the ensuing research questions, can be interpreted with confidence. Furthermore, teachers using the LEIS as a tool to collect data from their students can be assured of its reliability.

4.2.2 Reliability and Validity of the Student Attitudes Towards Mathematics Survey (SATMS)

In this section evidence to support the reliability and validity of the newly developed Student Attitudes Towards Mathematics Survey (SATMS) is provided. As with the LEIS, it was important to ensure the content validity of the scales, that is, whether the scales were theoretically sound and appropriate for the context of explorations in mathematics classes in Abu Dhabi (described in Section 4.2.2.1). To provide evidence to support the construct validity of the newly-developed Student Attitudes Towards Mathematics Survey (SATMS) when used in the UAE, data collected from 291 students in 12 classes was used to examine the: factor structure (Section 4.2.2.2); internal consistency reliability (Section 4.2.2.3); discriminant validity (Section 4.2.2.4); and, the ability to differentiate between classes (Section 4.2.2.5).

4.2.2.1 Content Validity

The development of the Student Attitudes Towards Mathematics Survey (SATMS) followed the same four steps as the development of the LEIS. As with the LEIS, it was important that the scales were appropriate for assessing the use of inquiry-based learning in mathematics classes in Abu Dhabi. As described in Chapter 3, the SATMS was based on scales drawn from the Test of Mathematics Related Attitudes (TOMRA; Spinner & Fraser, 2005), and the Student Adaptive Learning Engagement in Science questionnaire (SALES; Velayutham, Aldridge, & Fraser, 2011). As a first step, it was important to ensure that the scales included in the survey had a sound theoretical foundation. This information could then be used to determine whether each item within each scale effectively assessed the construct it was designed to assess. In the following sections I have provided a description for each of the scales and a theoretical basis for the selection of each: Enjoyment of Mathematics Classes, Self-Efficacy and Task Value.

Enjoyment of Mathematics Classes

The Enjoyment of Mathematics Classes scale was adapted from the Test of Mathematics Related Attitudes (TOMRA; Spinner & Fraser, 2005) to assess whether students are enjoying and looking forward to attending their mathematics lessons. Student enjoyment is a topic that is worthwhile investigating as it promotes problem solving, increases resiliency and self-regulation and supports behaviour in group work (Fredrickson, 2001; Leavy & Hourigan, 2018; Pekrun et al., 2002b). Studies have also shown that enjoyment is positively related with learning related motivation, self-regulatory efforts, launch of cognitive resources and performance (Ashby et al., 1999; Pekrun, 2006; Pekrun et al., 2002a). Enjoyment towards learning and achievement is also shown to form the basis of interest (Schiefele, 1991; Vansteenkiste et al., 2018) and enjoyment impacts the willingness of students to re-engage in academic content over time (Hidi & Renninger, 2006). Enjoyment is essential in today's knowledge-based society which requires life-long learning; therefore, teachers should consider pleasant emotions to be an important goal in the teaching and learning process (Frenzel et al., 2009). The use of inquiry methods has been shown to increase student enjoyment (Makar, 2007; Sheppard, 2008).

Increasing enjoyment should have an impact on students wanting to participate in mathematics classes and further pursue the subject in high school, higher education and careers. This is an important goal in the Abu Dhabi education reform.

> The goal of this new approach is to improve student learning experiences and to raise the academic outcomes of Abu Dhabi students to the internationally competitive level necessary to achieve the Abu Dhabi Economic Vision 2030. Students will be at the center of an active teaching and learning environment that is supported by schools, families, and the community. Improvements will develop strong literacy, numeracy, critical thinking, problem solving, creativity, and collaboration and communication skills – whilst continuing to emphasize cultural and national identity among Abu Dhabi students. (Abu Dhabi Education Council, 2013, p. 3)

The need for students to choose mathematical and scientific fields for career opportunities is recognised by the Abu Dhabi government and identified in the Abu Dhabi Economic Vision 2030. "The aim of the education sector reform is to ensure that graduates have the skills and qualifications to drive economic growth. To this end, specialised education will be guided to meet the forecast demand of the future growth sectors mainly in the fields of engineering, aerospace, IT, medicine, applied sciences, tourism and business." (Abu Dhabi Government, 2008, p. 94). Students enjoying these areas of education should be an encouragement to pursue them for future careers. This creates a need to assess the enjoyment of mathematics classes. The curriculum documentation for the ADEC education reform states "…teaching through problems that are relevant to students, can encourage improved attitudes to mathematics and an appreciation of its importance to society." (Abu Dhabi Education Council, 2013, p. 8)

Self-Efficacy

According to Bandura (1977), students are more likely to be motivated to learn if they believe that they can succeed. "Self-efficacy beliefs are powerful predictors of the choices that students make, the effort that they expend and their persistence in facing difficulties" (Velayutham et al., 2011, p. 4). Achievement can be impacted by self-efficacy (Eccles & Wigfield, 2002; Geyer, 2018) and student ability to self-regulate their learning in terms of the effort that they put in and their ability to evaluate their progress is linked to their degree of self-efficacy (F. Pajares, 2002; Schunk & Pajares, 2005; Webb-Williams, 2018; You, 2018).

The Self-Efficacy scale, modified from the Students' Adaptive Learning Engagement in Science (SALES) questionnaire (Velayutham et al., 2011), was used in the SATMS to assess students' willingness to persevere and show a 'can do' attitude. With the use of the new teaching, learning and assessing techniques of inquiry-based learning in mathematics explorations, students need to be able to exhibit coping behaviours and extended bouts of effort in the face of obstacles (Geyer, 2018; Stajkovic & Luthans, 1998) as the tasks required students to persist for longer periods of time and use critical thinking, creative, collaborative and communicative skills to be successful.

Task Value

Task value is made up of several components. Interest, which is engaging in a task due to its appeal or enjoyment, attainment, engaging in a task to support one's identity, utility, engaging in a task due to usefulness and cost, and considering sacrifices associated with a task (Linnenbrink-Garcia et al., 2018; Wigfield & Eccles, 2000). The degree to which students value a task is a key component in achievement-related engagement and performance (Eccles, 2005; Wigfield & Eccles, 2000; Wigfield, Tonks, & Eccles, 2004). Miller and Brickman (2004) argue that if students perceive tasks as important, relevant and useful to them in the future and they value the tasks then they are willing to pursue academic goals. Task value is a main determinant of motivation theory (You, 2018).

The Task Value scale, derived from the SALES questionnaire (Velayutham et al., 2011), was modified for use in the SATMS to investigate whether students found value in the work that they were completing in their mathematics classroom. It has been shown that when students see value in the work they are completing in class, there is an increase in motivation (Eccles et al., 1983). Task value and critical thinking skills have been shown to be two dominant predictors of students' performance in mathematical reasoning (Tee, Leong, & Abdul Rahim, 2018). This is one of the reasons that Task Value was chosen as a construct in the SATMS. When mathematical concepts are taught within an applied context through the medium of explorations, the intention is that students will feel that the task is more valuable than when explorations are not implemented successfully. In this study I sought to show whether student attitudes towards mathematics were affected by their perceived value of the assigned tasks from a teacher exemplary in the use of explorations compared with a teacher who was not.

Whereas in the previous section the content validity of the scales was the focus, in the following sections evidence to support the construct validity of the SATMS (factor structure, internal consistency reliability, discriminant validity and ability to differentiate between classes) using the data collected from 291 students in 12 classes has been provided.

4.2.2.2 Factor Structure

To examine the *a priori* factor structure of the SATMS, the factor loadings for each item in the instrument were computed. Principal axis factor analysis with oblique rotation was then carried out to extract salient factors. As a first step, the multivariate normality and sampling adequacy of the data were examined. Bartlett's test of sphericity indicated that $\chi^2 = 5196.54$ and this value was statistically significant ($p<.001$). The Kaiser-Maiyer-Olkin measure of adequacy was high (.957), confirming the appropriateness of the data for further analysis.

The criteria for retaining an item was that it should load .40 or more on its own scale and less than .40 on any other scale. During factor analysis, one item was found not to meet these criteria (Item 17 from the Task Value scale) and was removed from all further analysis. All other items loaded at least .40 on their *a priori* scale and no other scale. The factor loadings for the remaining 22 items are reported in Table 4.5.

The percentage of variance and the eigenvalue associated with each scale are recorded at the bottom of Table 4.5. The percentage of variance for SATMS scales ranged between 6.70% and 54.08%, with the total percentage of variance being 70.59%. The eigenvalues for SATMS scales ranged from 1.47 to 11.90, which all are above 1, thereby meeting Kaiser's (1960) criterion for a scale.

4.2.2.3 Internal Consistency Reliability

The Cronbach alpha coefficient was used as an estimate of internal consistency reliability. Alpha coefficients that were .70 or higher were considered to be acceptable and show that the items in a scale have relatively high internal consistency (Nunnaly, 1978). The results, reported in Table 4.6, show that the Cronbach alpha coefficients for the three scales were high, ranging from .92 to .95 with the individual as the unit of analysis and from .97 to .98 with the class mean as the unit of analysis. All alpha coefficients were above .80, for both units of analysis, suggesting that the scales of the SATMS have good levels of internal consistency based on L. Cohen, Manion and Morrison's criteria (2000).

4.2.2.4 Discriminant Validity

The component correlation matrix, reported in Table 4.7, indicates that the highest correlation was .59 which met the requirements of the threshold of .80 of discriminant validity (L. A. Clark & Watson, 1995; Kline, 2011).

Table 4.5 Factor loadings, eigenvalues and percentages of variance for the SATMS

Item	Factor loading		
	Enjoyment	Self-Efficacy	Task Value
1	0.91		
2	0.88		
3	0.65		
4	0.88		
5	0.82		
6	0.72		
7	0.74		
8		0.79	
9		0.78	
10		0.75	
11		0.78	
12		0.81	
13		0.72	
14		0.78	
15		0.83	
16			0.73
18			0.78
19			0.85
20			0.73
21			0.88
22			0.59
23			0.58
Eigenvalue	11.90	2.16	1.47
% Variance	54.08	9.82	6.70

N = 291 students in 12 classes
Factor loadings smaller than 0.40 have been omitted.
Item 17 has been removed.

Table 4.6 Internal consistency reliability (Cronbach alpha) for the SATMS for two units of analysis

Scale	Number of items	Unit of analysis	Cronbach alpha
Enjoyment	7	Individual	0.95
		Class Mean	0.98
Self-Efficacy	8	Individual	0.92
		Class Mean	0.98
Task Value	7	Individual	0.92
		Class Mean	0.97

N = 291 students in 12 classes

Table 4.7 Component correlation matrix for the SATMS

Scale	Enjoyment	Self-Efficacy	Task Value
Enjoyment	–	.52	.57
Self-Efficacy		–	.59
Task Value			–

N = 291 students in 12 classes

4.2.2.5 Ability to Differentiate between Classes

To ascertain the ability of each scale in the SATMS to differentiate between the 12 classes in the research, an analysis of variance (ANOVA) was performed. The ANOVA results showed a significant difference ($p<.01$) between all classes with the three scales of the SATMS (see Table 4.8), thus supporting the ability of each scale to differentiate between classes. The eta^2 statistic, which represents the proportion of variance attributed to class membership, ranged from .15 to .22 for the scales.

Table 4.8 Ability to differentiate between classes (ANOVA Results) for the SATMS

Scale	ANOVA Results (Eta^2)
Enjoyment	.22**
Self-Efficacy	.15**
Task Value	.17**

N = 291 students in 12 classes
* $p<.05$ ** $p<.01$

Overall, the results presented in Section 4.2.2, strongly support the validity and reliability of the SATMS when used with Cycle 2 students in mathematics classes in Abu Dhabi. As such, the results derived from the SATMS to address the ensuing research questions can be interpreted with confidence. Furthermore, teachers using the SATMS as a tool to collect data from their students can be assured of its reliability.

4.3 Environment – Attitude Associations

In the second research objective I sought to examine the relationships between students' views of the learning environment and their attitudes towards mathematics.

Research Objective 2

To investigate whether associations exist between students' perceptions of their learning environment and attitudes towards mathematics.

Associations between students' perceptions of their learning environment dimensions and their attitudes towards mathematics were investigated using simple correlation and multiple regression analyses. Simple correlations were used to investigate the relationship between two paired data sets. Calculation of the correlation coefficient (r) provides information about the strength of a relationship or degree of association that exists between the variables. If there is a positive correlation then it implies that, as one variable increases, so does the other. Conversely, a negative correlation implies that, as one variable increases, the other decreases.

The use of multiple regression analysis with multivariate data has more than one dependent variable. The purpose was to examine the relationships between all of the variables. Regression calculates a coefficient (β) for each independent variable to estimate the effect of each predictor on the dependent variable. For this analysis, the scales from the LEIS were the independent variables and the scales from the SATMS were the dependent variables.

In Table 4.9 the results of these analyses are shown. The correlation coefficient (r) and the regression coefficient (β) are shown for each of the scales in the LEIS for each SATMS scale. The multiple correlation (R) is also shown for the relationship between the set of LEIS scales and each scale in the SATMS. The results are outlined in the following sections: Enjoyment of Mathematics (Section 4.3.1), Self-Efficacy (Section 4.3.2) and Task Value (Section 4.3.3).

Table 4.9 Simple correlation and multiple regression analyses for associations between students' perceptions of their learning environment and their attitudes

Scale	Enjoyment		Self-Efficacy		Task Value	
	r	*β*	*r*	*β*	*r*	*β*
Personal Relevance	.40**	.11*	.38**	.08	.48**	.21**
Critical Voice	.42**	.14*	.32**	.03	.39**	.06
Shared Control	.51**	.21**	.46**	.06	.53**	.20**
Student Negotiation	.33**	-.08	.42**	.08	.42**	.07
Involvement	.50**	.17**	.54**	.22**	.46**	.03
Investigation	.51**	.23**	.61**	.38**	.54**	.26**
Multiple Correlation (*R*)		.62**		.66**		.65**

N = 291 students in 12 classes
**p*<.05 ***p*<.01

4.3.1 Enjoyment of Mathematics

The first of the attitude scales from the SATMS to be investigated, in terms of whether associations exist with the LEIS scales, was Enjoyment of Mathematics. For the Enjoyment of Mathematics scale, the simple correlations, reported in Table 4.9, were positive and statistically significant ($p<.01$) for all six LEIS scales. The correlations ranged from .33 to .51 for the different scales.

The multiple correlation (R) between the Enjoyment of Mathematics scale and the set of learning environment scales was .62 and was statistically significant ($p<.01$), suggesting that learning environment perceptions accounted for approximately 62% of variance in students' enjoyment of mathematics lessons. The regression coefficients (β) indicated that five of the six LEIS scales (Personal Relevance, Critical Voice, Shared Control, Involvement and Investigation) were positive, independent and statistically significant ($p<.01$) predictors of Enjoyment of Mathematics. The exception was for Student Negotiation, the relationship which was not statistically significant.

4.3.2 Self-Efficacy

The simple correlations for each of the six LEIS scales with the Self-Efficacy scale were positive and statistically significant ($p<.01$). ranging from .32 to .61 for different LEIS scales.

The multiple correlation (*R*) between the Self-Efficacy scale and the set of learning environment scales was .66 and was statistically significant ($p<.01$), suggesting that the students' perceptions of the learning environment accounted for approximately 66% of variance in self-efficacy. The regression coefficients (β) indicated that two of the six LEIS scales were positive and statistically significant ($p<.01$) predictors of Self-Efficacy when the other learning environment scales were mutually controlled, these being, Involvement and Investigation.

4.3.3 Task Value

The correlation for the six LEIS scales with the Task Value scale was positive and statistically significant ($p<.01$). The correlations for the different scales ranged from .39 to .54.

The multiple correlation (*R*) between the Task Value scale and the set of learning environment scales was .65 and was statistically significant ($p<.01$), suggesting that the learning environment accounts for 65% of variance in task value. The regression coefficients (β) indicated that three of the six LEIS scales (Personal Relevance, Shared Control and Investigation) were positive and statistically significantly ($p<.01$) predictors of task value.

Overall, the results presented in Section 4.3, suggest that positive and statistically significant relationships exist between students' perceptions of their learning environment and their attitudes towards mathematics for Cycle 2 students in Abu Dhabi. These findings and their educational implications are discussed in the next chapter.

4.4 Teachers Exemplary and Non-Exemplary in the use of Explorations: Differences in Learning Environment and Attitudes

In the third research objective I sought to investigate the differences between students taught by teachers who were exemplary in their use of explorations and those who were not in terms of their perceptions of the learning environment and attitudes towards mathematics in the context of an inquiry-based exploration approach in their classrooms.

Research Objective 3

To investigate how mathematics students taught by teachers exemplary in the use of explorations and those who were not differ in terms of students':

a. *Perceived learning environment;*
b. *Attitudes towards an inquiry-based exploration approach in their mathematics classes.*

Differences between students exposed to a teacher exemplary in the use of explorations and those exposed to a teacher non-exemplary in the use of explorations in perceptions to the learning environment and their attitudes to mathematics were investigated using a one-way multivariate analysis of variance (MANOVA), see Chapter 3 for information on the selection of teachers and analysis methods. The LEIS scales (used to assess perceptions of the learning environment) and SATMS scales (used to assess students' attitudes) constituted the dependent variables and the teacher group (teachers exemplary and non-exemplary in the use of explorations) constituted the independent variable. Because the multivariate test yielded significant results ($p<.01$) in terms of Wilks' lambda criterion (for the set of criterion variables as a whole) the univariate ANOVA results were interpreted separately for each LEIS and SATMS scale.

Effect sizes were also calculated for each of the six learning environment scales and three attitude scales to provide an indication of the magnitude of the differences in standard deviations, as suggested by Thompson (1998, 2001). As explained in Chapter 3, the effect sizes were calculated using Cohen's d as it is an appropriate effect size for the comparison between means. Effect sizes of .01 were considered to be very small, .20 was considered to be small, .50 as medium, .80 as large, 1.20 as very large and 2.0 as huge (J. Cohen, 1988; Sawilowsky, 2009).

4.4.1 Learning Environment Differences

The differences between students' perceptions of the learning environment for teachers exemplary in the use of explorations and teachers who were not exemplary in the use of explorations are reported in Table 4.10. The results include the average item mean, average item standard deviation, effect size and MANOVA results for each learning environment (LEIS) scale.

Table 4.10 Average item mean, average item standard deviation and difference (effect size and MANOVA with repeated measures) between students with teachers exemplary and non-exemplary in the use of explorations for the LEIS and SATMS

Scale	Average item mean		Average item standard deviation		Difference	
	Exemplary	Non-exemplary	Exemplary	Non-exemplary	Effect size	*F*
LEIS						
Personal Relevance	3.75	3.43	.79	.76	.41	12.14**
Critical Voice	3.80	3.58	.94	.90	.24	3.90**
Shared Control	3.60	3.28	1.03	.97	.32	7.18**
Student Negotiation	3.92	3.71	.78	.85	.26	8.28**
Involvement	3.99	3.71	.78	.85	.34	8.38**
Investigation	4.01	3.69	.74	.83	.41	11.79**
SATMS						
Enjoyment	3.66	3.03	1.27	1.13	.52	20.26**
Self-Efficacy	4.21	3.70	1.27	1.13	.42	25.17**
Task Value	4.01	3.57	.97	1.04	.44	13.80**

N= 139 students in classes with teachers exemplary in the use of explorations and 152 students in classes with teachers who were not

** $p<.01$

Effect size Cohen's d is defined as the difference between the two means (exemplary and non-exemplary) divided by the standard deviation.

An examination of the average item means, reported in the left-hand columns of Table 4.10 and shown in Figure 4.1, indicates that the average item means were higher for students in classes that were taught by teachers exemplary in the use of explorations than their counterparts who were not.

The results reported in Table 4.10, indicate that these differences were statistically significant ($p<.01$) for all six LEIS scales at the 99% significance level. *F* values ranged from 3.90 (for Critical Voice) to 12.14 (for Personal Relevance). That is, for all six LEIS scales, students in classes taught by teachers exemplary in the use of explorations had statistically significantly more positive views of the learning environment when compared to the perceptions of students who were not.

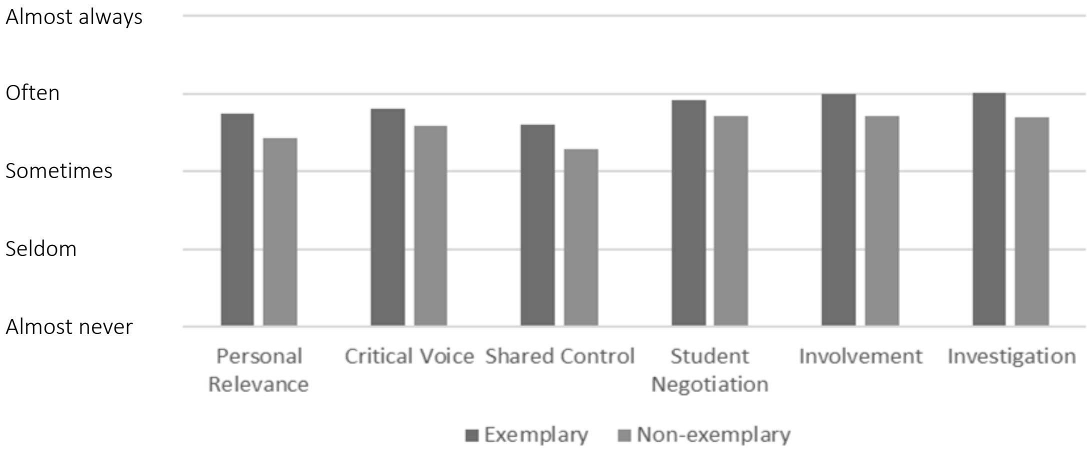

Figure 4.1 Average Item Means for the LEIS

The effect sizes, also reported in Table 4.10, ranged from 0.24 to 0.41 for the different LEIS scales, which are considered to be small to medium in effect (J. Cohen, 1988; Sawilowsky, 2009).

4.4.2 Attitude Differences

The average item means, reported in Table 4.10 and portrayed in Figure 4.2, show that, for the SATMS scales, the average item means were also higher for students in classes taught by teachers exemplary in the use of explorations when compared to those who were not. The univariate ANOVA results, reported in the right-hand column of Table 4.10, were statistically significant (p<.01) for all three SATMS scales. That is, for all three SATMS scales, students in classes taught by teachers exemplary in the use of explorations had statistically significantly more positive attitudes towards mathematics when compared to students in classes who were not.

The effect size for the differences between the two groups ranged from .42 standard deviations, for the Self-Efficacy scale, to over half a standard deviation (.52 standard deviations) for the Enjoyment of Mathematics scale. These results were considered to be medium to large in effect (J. Cohen, 1988; Sawilowsky, 2009).

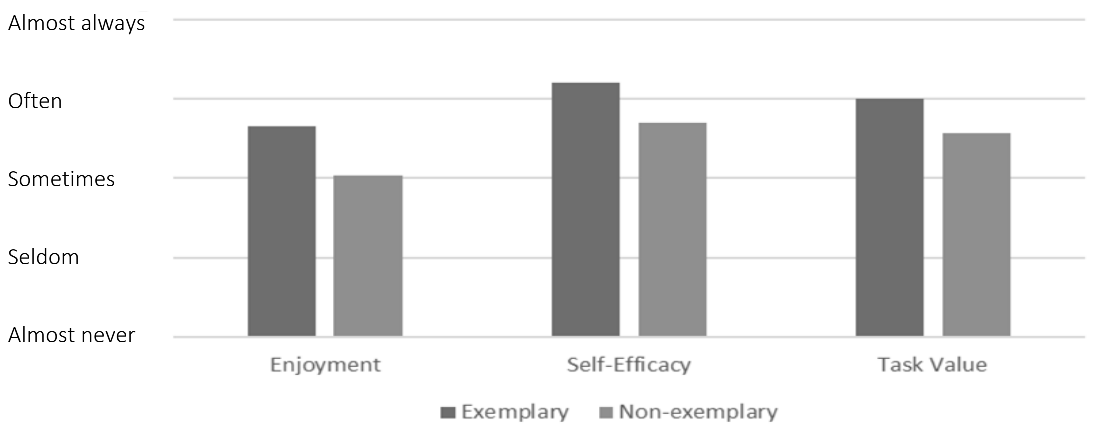

Figure 4.2 Average Item Means for the SATMS

4.5 Explaining the Differences

In the fourth research objective I sought to provide causal explanations for the differences between the learning environment perceptions and attitudes of students taught by teachers exemplary in the use of explorations and those who were not.

Research Objective 4

To investigate reasons for differences of the perceived learning environment and attitudes towards mathematics for students taught by teachers exemplary in the use of explorations and those who were not.

As a first step, to give context to the reader and to portray the observations, two impressionistic tales are provided. The first describes a lesson given by a teacher exemplary in the use of explorations (Section 4.5.1) and the second describes a lesson given by a teacher who was not (Section 4.5.2). The tales were based on a number of lessons as described in Chapter 3, where concepts that were common across the lesson observations were extracted. As such, the lessons portrayed in the tales are not related to any one lesson; rather they are representative of a number of lessons. The impressionistic tales are followed by an interpretative commentary, found in Section 4.5.3, that explains what was observed and compares and contrasts the two tales.

Finally, in Section 4.5.4, the themes that emerged from the analysis of the qualitative data to help to explain the quantitative findings are reported.

4.5.1 Impressionistic Tale –Teacher Exemplary in the use of Explorations

It's winter in Abu Dhabi, which makes it equivalent to a mild summer day in many other countries, and so I enjoy my drive to a school based a short distance outside of Abu Dhabi city. The parking is simple to navigate and I'm early, so I head inside and introduce myself to the receptionist on duty. As is customary, I make a quick detour to the principal's office to say 'hello' before making my way through the school to the mathematics department.

I meet up with the teacher that I am to observe at the mathematics teachers' staffroom. This is the third time that I have visited the school and have observed this teacher's classes. In previous visits, she commented on the usefulness of feedback that I gave to her, suggesting that she is happy to have me visit. I note, however, that she also appears eager to please. While still in the staffroom, we discuss her plans for the lesson, and she explains to me that the students are working on an exploration task in which they are required to complete an inquiry based on the mathematical concept of scientific notation. The exploration is titled 'How long would it take to get to Pluto?' and involves students choosing a slow, medium and fast object, allowing them not to be restricted by what is physically possible but, instead, allowing for creativity and for the mathematical calculations to be accurate according to the object. The investigation involves students making decisions about travelling to Pluto and doing research and performing calculations about their preferred methods. The teacher tells me that the students have been working on the exploration for six lessons and that they are now coming to the end of the task and finalising calculations, drawing conclusions, and developing presentations to share with the class.

As I discuss the topic of the lesson with the teacher, she describes the various questions that the students have posed to shape their explorations and the progress that they are making. She makes a point of emphasising the relevance of the topic to the students in the sense that students have to consider modes of transport and speed/distance/time calculations for their trip to Pluto. We also discuss other topics that she has taught in *this way and how it is a pedagogical approach that she favours because she has found that students are more interested in learning the mathematics when they can relate it to their lives. She explained to me that, for the topic on consumer arithmetic, the students had been required to develop a budget according to a certain employment conditions for a career of their choosing. Through this investigation, students had met learning outcomes related to earning, spending and investing money. She said, "the topic was personal for them as it felt like they were planning for their own money and choosing whether to use a credit card or not and what investments to select".*

After our initial conversation in the mathematics staffroom, the teacher and I head to the classroom so that we are ready to start the lesson at 0855, the second period of the day. We get to the room, which she shares with another mathematics teacher, five minutes early and, soon after, the students begin to arrive. The girls shake my hand which is customary as they enter the room and, when we move inside, two of them help me organise a desk and chair at the back. Many of the students ask me how I am, taking the opportunity to try out their English on a native English speaker. After I am seated at the desk the students prepared for me while the class are settling into their places, I take a chance to look around the room. As with most buildings in the UAE, the walls are constructed from concrete blocks and painted which is suitable for the climate. This tends to make rooms appear cold but, in this classroom, the teacher has made a concerted effort to decorate the room and make it inviting for the students. It is clear that this is a mathematics classroom from the students' work that is displayed on the walls as well as the textbooks and manipulatives that are on view in a storage cupboard at the back of the room. The artificial lighting is bright from overhead fluorescents, but there is also some natural light coming in through the large windows looking out across an empty area to the boundary wall of the school. The room is quite small and does not have a lot of additional furniture besides the teacher's desk, two storage cabinets at the back of the room and the student desks and chairs. All of the individual desks are in groups of between four and six desks. By grouping the desks, there is more room to manoeuvre around from the front to the back of the room and from side to side.

There are 27 grade 9 students in the class, and they are seated in groups with their desks joined together. Each group of desks has a tray with equipment useful for *practical work, such as pens, pencils, rulers, calculators, and coloured pencils. The groups differ in size but there are no more than four girls in any one group. The girls have organised themselves into the groups that were assigned for the exploration. To attract the students' attention, the teacher says good morning, at which point all of the girls stand and respond in Arabic.*

The teacher starts the lesson, in English, by asking each group to summarise where they are up to with the work. Their mathematical topic is scientific notation, but the context and the 'big question' is: 'How long does it take to travel to Pluto?' Each group selects a spokesperson who stands to explain the progress of the group. Some of this presentation is made in Arabic but, where possible, the teacher and the students try to use English so that I can understand. Where Arabic is used, the teacher translates quickly for me. One of the groups report that they have calculated that it will take them 19 years to travel to Pluto. The teacher asks, "How old are you now?" the student responds, "I'm 14, miss". The teacher asks, "How old will you be when you arrive?" "I will be 31". The teacher then asks, "Do you want to go to Pluto? Why? Or why not?" The response from the student was in Arabic, however, when she finished, the teacher translated the response into English. The student had explained that she did not want to go to Pluto because she was worried that she would miss a lot of years of her life when she was young and that it would be boring being stuck in a small space for such a long period of time. After this exchange between the teacher and the student, it seems to encourage the whole class to consider how long the trip would take and how old they would be at the end. The students consider their results in the context of their own lives.

Once each group had an opportunity to explain their progress in the exploration, the teacher reminds them of the next steps they needed to take. The students then commence working on their explorations in their groups. The teacher puts on a PowerPoint that plays quiet classical music and shows interesting photos of planets, stars and space. I like the atmosphere that this creates in the room – interesting and calming. At this point I move around the room to discuss the work with the students. As I move from group to group, the students explain to me that, in prior lessons, they were given the big question, after which they were required to plan what they needed to do to answer it. This involved deciding on a mode of transport, researching *distances and speeds, etc. and planning how they wanted to present their findings to the class at the end of the project. I ask one group what they think of the lesson. The students' responses are all positive, saying "We like this class, it's fun.", "We like to work together." and "We like to learn about the planets and science."*

As I move to the different groups, I note that they have each taken a different approach to the task. One group has decided to fly to Pluto on a commercial plane. They have visited the library in a previous lesson and spent time researching the speed of a typical plane and how far they would have to travel to get to Pluto. They tell me a plane is a good idea because there will be room to move, space to store supplies and the whole group could travel together. One girl in the group explains that they have completed other research on the topic. She says "We researched about NASA on the computer. They went to Pluto in 2006 and got there in 2015. I hope to be an astronaut". I am quite excited to hear this comment from a student as there is extensive government focus on STEM (Science, Technology, Engineering, and Mathematics) and engaging students to consider this field for their future studies.

As I observe the teacher, I note that the class is orderly, and that there appear to be clear routines and expectations for behaviour. The students sit in groups without being told where to sit and they use the resources provided such as scissors and glue, returning it to its place after use. It is rare during the lesson for the teacher to caution a student for behaviour, but when this did occur, the student was told to settle down and she immediately got back on task. I'm surprised to see that there is no evidence of eye-rolling or pursed lips which can be a common feature of teenage girl behaviour when reprimanded. The teacher did not raise her voice considerably but simply used the student's name and asked her to refocus. At the transition times in the lesson, such as changing from the initial full class session to the group-focused work, the process was smooth with students collecting items they required and the teacher moving amongst the desks checking on individuals. Noise levels within the room never got beyond a healthy working volume with the groups interacting discussing their work.

As the groups of students worked together on the exploration, the teacher moved from group to group checking on them and their work. She stopped at each group and asked questions designed to determine whether they were on track and know the next steps.

Rather than giving the students information, she tended to ask questions and allowed them to think the problem through to see if they can find a solution together. In one case she asks the group "what step are you up to?", one student responds by saying "we have completed our calculations and have started to develop our presentation for the class". The teacher asked, "do you think your final answer is sensible?", and the students did not immediately answer. After a few moments of thinking, one student said, "we weren't sure if we were correct, so we talked to another group and they chose a slower plane and got a bigger answer for the time taken so we think our result sounds right". At this point the teacher asked the students about limitations of their process and inquiry design and asked them if there are any problems with their answers and what they would change about the process if they did it again. Again, the students do not immediately answer and so the teacher gives them more time to think. One of the students, who has been quiet until this point, answers in Arabic and this is translated for me afterwards. She says "I think we wasted time and confused ourselves with trying to write numbers out in full and instead we should have used scientific notation earlier and in our calculations. It would have made it easier to compare the distances, times and speeds we were calculating. We made silly mistakes with the number of zeros and it took us some time to correct this." The teacher talked to the girls about the importance of recommendations and making conclusions about not just answers but about the process.

As the teacher continues to move around the room, she pauses to discuss with me about how she enjoys teaching and making relevant, interesting topics for students and that she believes they enjoy being here. She says "it is a lot more work for me in planning lessons like this before I get to the class, but once we are inside the room, my work is less! The students are very focussed on their work and I have less problems with behaviour. They also understand the topics better and can explain to me what they are doing and why."

I walk around the room, observing and talking to the students. I stopped at one group of girls and asked them what they enjoyed about learning this way. Immediately, one of the students responded, "I enjoy learning about math and science together. We get to research and discover new facts and then explain it to our friends in the class." Another student interjected, "We also get to choose how we will learn and how we *will present to the class. We feel like we can choose the way." I was excited to hear that they felt this way but wondered whether they really knew what the teacher was doing to make the class different. When I asked the group about this, one of the students said, "She gives us time to work and think. She lets us ask questions and sometimes makes us find the answers instead of telling us. I didn't used to like this but now I feel like I'm learning more, and I remember better." Another student added, "I think learning this way takes more time for her as we don't just use the textbook but it's fun for us and we are less trouble."*

Another group of students tell me that they particularly enjoy researching topics and learning new and interesting facts. I ask them what type of facts they find fascinating and one student says, "I enjoy learning science facts about things around us, like nature, and also about space." The students appear confident as they discuss the work with each other, the teacher, the class as a whole, or me as a visitor. In my experience, I have found teenage girls can be shy with strangers, but these girls were eager to talk to me when I approached their groups. One group smiled at me as I drew near to their desks and started talking immediately as I arrive. Although the initial banter is generally related to my country of origin, we quickly focus on the topic that they are studying, and I question "How do you feel about presenting your work and your final product to the class?" One student in the group has excellent English and so she becomes the official spokesperson for the others, and replies "We love to talk about what we have learnt and what we have discovered in our research. I find that sometimes it's better to learn from our friends than the teacher as we explain things in a way that makes sense for us. We feel confident and proud to display our work and our calculations".

I watch two students from one group collect the paper that they need for their presentation from the teacher's desk. Once they return to the group, I notice that the girls turning the paper horizontally, and then vertically, and watch them discussing how best to present the work that they have completed. From where I am standing, I observe them divvying up the various tasks between the group, and then commencing the work by collecting coloured paper from a shelf or finding the right marker pens or getting the needed number of pairs of scissors. I note that this is a student-led activity with the teacher currently working with another group.

There is another group of girls who are calculating their results and showing their answers using scientific notation. I move to their group and ask them to explain their work and they are eager to describe their process, results and what it means in terms of the big question. They explain the limitations of their model and what they would do next time to improve the process. The students tell me that 45 minutes at one time is not enough and that they would prefer to have double periods. I ask the girls about working in groups and how they feel about it. One student explains that by working together and pooling their knowledge, they all learn more.

As the time for the lesson to finish draws near, the teacher stops the girls and reminds them of their next tasks. The groups of students immediately commence the tidying process and I note that everything in the classroom has a place where it belongs, making the process of packing up streamlined. The posters that some groups have started developing are rolled up and one student from each group hands them to the teacher where they are stored for the next lesson. The girls thank me for visiting their class and ask me to come back again soon.

In this impressionistic tale I described a classroom where the busyness of students, the work they produced and the conversations occurring between students and between the teacher and students suggested the students were engaged with and enjoying the lesson. The tale suggests that the use of inquiry-based learning as both a teaching and assessment tool provided opportunities for students to relate the mathematical content to their own lives.

The lack of behavioural issues suggested the students were busy with the tasks and engaged in the work they were completing. The students were enjoying the lesson and were willing to talk about how much they liked learning in this way. Throughout the lesson, the students actively discussed the given task and worked together to develop the product.

In the next impressionistic tale, a lesson with a teacher whose use of explorations was not exemplary is described. In this tale, the teacher sought to teach using inquiry-based learning techniques, however she was not successful in effectively planning and implementing an inquiry approach to teaching, learning and assessing. She had received the same level of professional development and support as the teachers exemplary in the use of inquiry, however her lessons were different as shown in the next impressionistic tale.

4.5.2 Impressionistic Tale –Teacher Non-exemplary in the use of Explorations

It is a very foggy morning as I head outside the environs of Abu Dhabi city to a desert school based in a small community within the Emirate of Abu Dhabi. As usual I am early and so I sign in with security, collect my visitor badge and quickly meet with the principal, thanking her for allowing me to visit. I briefly meet with the teacher whose lesson I am to observe, and she explains to me that she is using an inquiry lesson as part of revision for an upcoming unit test on trigonometry. She tells me that the lesson will be based on real-life applications of trigonometry and so the students will be able to inquire and investigate to be able to solve the problems.

The lesson is due to start after the morning break at 10.50 am, but the teacher tells me not to come until 5 minutes into the lesson time, explaining that many girls will be late from their break. I arrive at 10.55 am but, unfortunately, neither the teacher nor the students have arrived yet. The teacher arrives soon after and explains again that the students will be late. I go into the class and organise a desk and chair at the back of the room. The girls start to drift in and take their seats which are set up in groups of four desks.

The lesson commences 10 minutes late. The teacher begins by greeting the students and they reply with the standard response. She quickly introduces me, stating that I am observing the class today. The teacher introduces the lesson by telling the class that they will be learning about applications of trigonometry.

The 25 grade 9 students are seated in groups, with between four and six students in each, in a classroom that is not immediately evident to be a mathematics room. The walls are empty, and the room feels cold, both from the white paint on the walls and the air conditioning blasting a cold breeze. There is storage at the back of the room where books for this class, and the other classes that use this room, are kept. The *teacher shares the classroom with other teachers and so she brings her books with her for each lesson.*

The students collect textbooks from the shelving at the back of the classroom and the teacher tells them what page to turn to. The teacher reiterates that they will be learning about an application of trigonometry involving angles of elevation and depression. She uses one arm to represent the horizontal and then the other going up to show the angle of elevation and then going down to show the angle of depression. On the whiteboard the teacher demonstrates how to solve the first question. The question involves two people on either side of a tower and the students are required to calculate the distance between them. As the teacher demonstrates, she asks the students questions, such as "how do we label the triangle?" "What trig ratio do we use?" "What is the ratio for $\sin\theta$*?" "What units do we need?" Students put up their hands after each of her questions and the teacher chooses one student to answer. After demonstrating the solution to the first question on the board, the teacher instructs the students to work individually on the second question in their textbook. She gives the students approximately one minute to finish the question before setting the question up on the whiteboard. She first labels the sides of the triangle using O for opposite and H for hypotenuse, explaining to the students as she goes how you know what to label each side. At this point, she uses the mnemonic SOHCAHTOA to choose the appropriate ratio and writes the steps of mathematical working on the board. Because most of the students have not started to answer the question yet, they wait until the teacher writes on the board and then copy it into their books. I note that since all of the students have been instructed to complete one question, some finish quickly and wait while others who are slower don't have time to complete the task before they move together to the next question.*

As the students work on question number three which the teacher has allocated to them to complete individually, I look over to see how the group closest to me interact with each other. In one of the groups, I note that, rather than discussing the question together and collaborating, the students appear to be waiting for one girl to complete the task. Once the girl is satisfied with her answer, she turns the page so that they can copy her work into their books. As the teacher has returned to her seat at the front of the classroom, it appears that she has not noticed.

The teacher is situated at the front of the room, so I don't feel it is appropriate for me to walk around the room and discuss the question with the students. Instead, I wait for the next instruction which doesn't take long. The teacher attracts the students' attention and asks who would like to present their answer on the whiteboard. A few girls around the room put their hands up and the teacher selects one of them to come to the board and write the answer to the third question. I note in the groups closest to me that most of the students are either watching the student write on the board and checking their answer against what the student wrote or, writing down the answer if they have not completed it. From my vantage point I can see that one of the groups of girls were not watching but, rather, some were doodling in their textbook and one of these students was taking the cover off the textbook and ripping it into pieces. In another group, two girls commence writing notes and passing them across to another group. Although these students are not outwardly disruptive, it is clear they are not engaged in the lesson.

Once the student has completed her answer on the board and explained it to the class, the teacher confirms that it is correct and the student returns to her seat. The teacher asks the students to complete the next question. She stays at the front of the room, either at her desk or at the whiteboard, and then, when she feels they have finished the question, she chooses a student to come and answer for the class. The questions are all from the textbook and involve towers, bearings and sailing, and cycling.

About 20 minutes before the end of the lesson, one of the students near to me falls to sleep and the three other girls in the group proceed to play with each other's hair. I'm not sure whether the teacher sees this, but one girl sees me looking at the sleeping student and smiles. She keeps glancing at the teacher, but the teacher doesn't catch her eye. The student sleeps soundly until the lesson finishes and is clearly disorientated when woken up by her friend. The bell rings to end the lesson and the girls put their textbooks on the shelves at the back of the room and leave the room. I am struck that there is no conclusion or plenary to the lesson.

The behaviours of the students, as described in this impressionistic tale indicated that they were not engaged in the task. The students did not appear to be listening either to the teacher or to each other and were engaged in off-task behaviour such as drawing on their books and, in one case, falling asleep. The impressionistic tales are interpreted by a commentary in order to compare and contrast the two contexts of classrooms with teachers exemplary in the use of explorations and those who were not.

4.5.3 Interpretative commentary

Although the impressionistic tales, provided above, recount the stories of one lesson, several lessons taught by each of the teachers were observed with similar patterns. I contrasted the lessons using impressionistic tales, by looking for patterns between the lessons and how the students reacted to the teaching and learning experiences in each of the observations.

The first observable difference between the classes described in the two tales was the physical environment of the classrooms. In the classroom of the teacher whose use of explorations was exemplary, the room looked like a mathematics room. That is, there were mathematics books and manipulatives, student-generated wall displays and baskets with provisions for practical activities like scissors, glue and marker pens. The second classroom was a room where the students stayed and the teachers moved to, meaning that all subjects were taught in the room with many different teachers and so it was not equipped with anything mathematical except for the textbooks that were provided by the education department (ADEC). This classroom, therefore, did not look like a mathematics classroom.

There were a number of features related to the teachers' interactions with the students that were also different, such as the movement of the teacher. The teacher exemplary in the use of explorations, described in the first impressionistic tale, moved from group to group throughout the room and also throughout the lesson only returning to the front when the whole class needed to be addressed. Every student in the room had an opportunity to talk to her at some point and all had a chance to ask questions and pursue dialogue with her. This movement allowed the teacher to not only be available as an 'expert' within the exploration process but also provided a useful behavioural management technique as she could easily see who was on task and who needed additional support. In contrast, the teacher described in the second tale remained at the front of the classroom for the entire lesson. Occasionally, the second teacher would sit down while the students were completing the task, but this was only for a couple of minutes before the question was answered and the class moved on. As the tale implies, it appeared that the second teacher was not aware of whether students were completing the set tasks.

Another point of contrast between the two classes was the classroom management and number of incidences of on- and off-task behaviour. In the class taught by the teacher exemplary in the use of explorations, described in the first tale, all of the students appeared to be involved and engaged in the lesson. There was a buzz and working noise in the room, in which students were discussing the calculations they were completing and making the plans for the presentation posters. I observed no obvious behavioural issues or off-task students. Student comments, noted in my field notes, included: "We like this class. It's fun.", "We like to work together." and "We like to learn about the planets and science." The engagement of the students was observable through the interactions of the students with one another as they discussed how to present their work and explored ideas together concerning the calculations and how best to explain this to others. Other students were planning and creating their presentation boards, while a couple of students had engaged the teacher in a discussion about how best to use scientific notation during their calculations.

In contrast, in the second impressionistic tale, an atmosphere that was quite different is described. Throughout the description of the tale, neither the teacher nor the students smiled very much and the chatter that was present in the first tale, as students worked together, was absent. Throughout the tale, students were slow to open books, to write anything down and to volunteer to answer questions that were presented on the board. Added to this, my observations witnessed students defacing books or sleeping during the lesson.

Another difference between the two classes portrayed in the impressionistic tales was students' use of resources within the classroom. In the class taught by the teachers exemplary in the use of explorations, described in the first tale, the students collected and utilised equipment including paper from the teacher's desk and the supplies, such as scissors, marker pens, rulers and staplers, in baskets on each group of desks in the room for their work. This behaviour appeared to be part of the routine, as the students didn't ask permission and the teacher didn't appear to expect them to. In contrast, students described in the second tale, stayed at their desks after they had collected the textbooks and didn't move, nor were they required to. There were no additional supplies available to them within the room, perhaps because this was not a dedicated mathematics classroom, and no opportunity during the lesson to use equipment.

Another difference highlighted by the impressionistic tales was the teacher-student relationships. In the first impressionistic tale, about a teacher exemplary in the use of explorations, I describe the tone of voice and body language used by both the teacher and the students, which indicated that they had a high regard for each other. The students spoke to the teacher in a tone that might be used when addressing an older member of the family, with that of respect and genuine care. For example, as one student spoke to the teacher, she put her hand on the teacher's arm and left it there during their conversation about how best to lay the work out on the large sheet of paper. I noted, however, that the teacher was also tough when she needed to be. That is, if students were off task, the teacher used a stern voice and spoke to them in a respectful manner that brought them back to the work. For example, two girls were chatting noisily in Arabic and it was obvious that it wasn't about their work. The teacher moved to their side so as not to disturb the rest of the girls and spoke quickly to them. They immediately ceased their conversation and refocused on the task at hand. There was evident mutual respect between the teacher and the students which was shown as the students arrived in the classroom and willingly shook the teacher's hand while they had large smiles on their faces and both sides greeted each other warmly. The second tale portrays students who formally greeted the teacher, as expected, followed by limited interaction between the students and teacher. The only exception to this pattern was when individual students were selected to answer the questions posed by the teacher during the explanations of the work. As the teacher remained at the front of the room throughout the lesson, there were no opportunities for less formal conversations with the students.

A point of difference between the two tales was the use of or lack of routines and classroom norms. In the first tale, about the class of the teacher exemplary in the use of explorations, well-established routines and classroom norms were described. From the beginning of the class to the end, students knew where they were expected to sit as they came straight into the room after greeting the teacher and went to their seats without stopping and discussing where they should sit and then rearranging themselves a number of times when others arrived. In the tale I portrayed smooth movement between the start of the lesson and each activity that did not involve teacher direction, indicating that the students knew where they were expected to sit. The noise level was appropriate for working, and that collaboration both within and across groups was encouraged so long as the work was being discussed. The teacher was available for the students if they required to seek clarification on any of the tasks. Students were clear about where the supplies were kept, such as the large paper, and they collected them without causing disruptions to other groups. In contrast, the second tale described students arriving at various times and sitting at desks then moving around before settling. The teacher had to request students to collect textbooks from the back of the room and this was not a quick process with students being slow to move and slow to return to their desks.

Finally, a difference observed between the two tales was that of the value and interest of the work for the students. In the first impressionistic tale, the students were observed to be on task and engaged in their work indicating that the work was valuable and interesting. During the observations, students willingly discussed with me and their peers, aspects related to the task, such as, whether it was an option for them to travel to Pluto within the constraints that they had discovered. When the teacher asked the following questions, they considered the mathematics in the context of their own lives "How old are you now?" "How old will you be when you arrive?" "Do you want to go to Pluto?" "Why? Why not?" The real-life application of the task and students having some say over the direction their investigation took them were some of the reasons that the students gave for why they felt the work in their mathematics class was considered important to them. In contrast, students in the second tale found it difficult to relate to the questions and didn't appear to have any practical understanding of what they were calculating. For example, one student described the content in the mathematics class as being overwhelming in terms of the volume of work and the level of difficulty. Another student said, "I study but I do not remember all the information." The students did not see the content as interesting for them or valuable to learn, but rather as a body of content to be memorised to pass examinations.

4.5.4 *Casual Explanations for the Quantitative Findings*

During the analysis of the qualitative data (the process for which is described in Chapter 3), themes emerged with respect to teacher use of inquiry. The three themes are described below with student engagement and involvement in learning reported in Section 4.5.4.1, task value and real-life application reported in Section 4.5.4.2, and inquiry and investigation reported in Section 4.5.4.3.

4.5.4.1 Student Engagement and Involvement in Learning

A major theme that emerged during my analysis of the data was that of student engagement and involvement in learning. According to Dary, Pickeral, Shumer and Williams (2016, p. 5):

> Student engagement occurs when young people have invested themselves, their energy, and their commitment to the learning environment, both within and outside the classroom. They willingly put forth the required effort to find a level of personal success academically, socially, and emotionally.

Based on the scale of the LEIS, Involvement is described as the degree to which students have attentive interest, participate in discussions, do additional work and enjoy the class. Involvement in learning flows from student engagement where students persist with the given task despite obstacles they may face, that time passes quickly as they become engrossed with the process and product and are working with a purpose without being distracted or exhibiting off-task behaviour. During classroom observations, increased engagement and involvement were observed in a number of ways, including active learning; opportunities to share information and collaborate with peers; and through the use of higher-order thinking. Each of these is described below.

First, students in classes taught by teachers exemplary in the use of explorations were more active in the learning process, than those in classes with teachers that were not exemplary in the use of explorations. The students had opportunities to direct both the content and the process in which they were learning. Petress (2008) explains that active learning:

> …is a process where students take a dynamic and energetic role in their own education, thereby making the student a partner in the learning process… active learning is preferable, as it stimulates pride, increases confidence, stimulates a thirst for broader and deeper understanding in future academic endeavours, and tends to make learning more fun and personally satisfying. (p. 566)

Student involvement in their learning and opportunities to direct the learning in terms of content and process were evident in the lesson observations. This was observed with differing behaviours within the individual groups. For example, one of the groups that were observed, were huddled together, bending over their large piece of paper and discussing where each piece of information should be displayed. The group included three students, and each had an opportunity to suggest how the layout should be completed. Another group of four students had split into pairs with two students working together, one finding solutions using a calculator and the other scribing for her. The second pair were collecting the materials, such as large paper, marker pens, ruler, glue and coloured pencils, required for the next stage of the task. The observations, of the majority of students within the room, were engaged in what appeared to be on-task behaviours. During the observations, I recorded that every student was busy in the room. Due to the variety of tasks that needed to be completed, it meant that, not only was there sufficient work to occupy each student, but that students had some choice over what responsibilities they would take on within the group.

In contrast, students in classes with teachers who were not exemplary in the use of explorations, had less opportunities to be active in the learning process, including the direction of tasks and the content studied. Observations of students in these classes, indicated that they completed tasks more slowly when compared to their counterparts. These students tended to move more slowly to collect their textbooks, and organise their workbooks and writing instruments, further, these students appeared to be more hesitant about starting to solve problems. The tasks completed in these classes were the same for all students, and there were more examples observed of passive rather than active learning. In fact, in most observations, within each group, a number of students did not commence calculating the questions set by the teacher but, rather, waited to copy the answers from the student next to them. In one example, one of the students asked another to tilt her page so that it was easier for her to read her work. Throughout my observations in these classes, I rarely heard dialogues where the mathematical content or process of attaining the answer was discussed.

Secondly, during the focus group interviews, students from classes with a teacher exemplary in the use of explorations described more opportunities to share information with their peers and the teacher and to collaborate in their work. During the interviews, some of the students explained that, by working together and sharing ideas, the learning within the group was increased. For example, one student said "We like to work together to research. She say [says] something, then she say [says] something, then I say something. Then we all learn. We have much information" [Student 1, 05/11/15]. The interviews indicated that students valued the opportunity to be able to share ideas as this helped them to better understand the content. To this end, one of the students said "I didn't understand why we needed to use scientific notation until my friend showed me the answer and the number was so long, we couldn't write it out properly. Then I could see why. She helped me to understand" [Student 2, 08/11/15]. Another said that "In this group we are all good at different things. Mariam likes to speak at the front of the room, Sara can write the math out clearly and I'm good at researching. We use our strengths to help each other to learn and improve" [Student 3, 08/11/15]. The observations indicated that students were eager to share their work and the findings of their research and calculations with their peers and the teacher. For example, in the impressionistic tale with the teacher exemplary in the use of explorations, students willingly explained their answers to me when I joined a group to observe, using scientific notation and the process they had to undergo to get to the final conclusions.

In contrast, the students who were not taught by teachers exemplary in the use of explorations, described less opportunities to share information with other students and their teachers and to collaborate. During the focus group interviews, I asked the students whether they could describe a time when they shared their work with the other students in the class. Initially, the group was quiet. After a couple of minutes, one student explained that, in one of her mathematics lessons, she had been asked to come to the board and write the answer to a question from the textbook. I continued this line of questioning and asked if the students could tell me about a recent time in their mathematics classes when they collaborated to complete a task. There was some confusion over the use of the word collaborate and so, after defining and translating the term, one student gave the example of when the teacher had given their group a worksheet to complete. I asked her to tell me how they worked together, and she explained "the clever girl in our group mostly completed the questions, but we helped sometimes" [Student 7, 02/06/15].

The final way in which students, in classes with teachers exemplary in the use of explorations, were observed to be more engaged and involved in their learning was through opportunities to use higher-order thinking skills including thinking critically and justifying their responses. Observations highlighted how conversations between students within groups involved them questioning each other and providing justifications for the process and the answer. For example, in one of the observations I overheard one student say to another "… but why do you think that? Couldn't it be this instead?" [Student 4, 09/11/15]. The second student then justified her conclusions by responding "It has to be within this range as the rocket must be faster than the plane. This calculation must be wrong as the answer isn't sensible." [Student 5, 09/11/15]. The students also conversed about the limitations within their model and the assumptions that they had made in order to be able to answer the big question. During this process, the students were able to link the results back to their original big question, demonstrating a proficiency in describing the limitations of their model and what it meant for the next topic. The students in classes with teachers exemplary in the use of explorations were able to articulate how they felt about the work that they were completing and the process they underwent to learn their mathematics. For example, the students discussed whether their results using scientific notation were sensible and reasonable.

In contrast, observations of students in classes with teachers who were not exemplary in the use of explorations, had less opportunities to use higher-order thinking skills and to justify their responses. During the lessons, the teachers predominantly stayed at the front of the classroom and tended not to come to individual groups of students to discuss their progress. Throughout the lessons, I did not observe the teachers asking students why they had calculated a particular solution to a question or explain and justify their thinking. Rather, the students were asked to complete questions from the textbook on trigonometry application problems. Although the questions were word problems, they all had the same structure and required the same thinking: draw a diagram, label, choose a trigonometric ratio, substitute and solve. Opportunities to utilise higher-order thinking skills were not widely observed in these classes.

These qualitative findings were reflected in the quantitative results; particularly with respect to the Involvement scale from the LEIS and the Enjoyment of Mathematics and Self-Efficacy scales from the SATMS. In all cases, the students in classes with teachers exemplary in the use of explorations scored higher than their counterparts who were not. Further, these differences were statistically significant ($p<.01$) and with large effect sizes (Involvement = 0.34 standard deviations, Enjoyment of Mathematics = 0.52 standard deviations, Self-Efficacy = 0.42 standard deviations and). Overall, both the quantitative and qualitative results support that students in classes with teachers exemplary in the use of explorations perceived more engagement and involvement in their classes than students in classes with teachers who were not.

4.5.4.2 Task Value and Real-life Application

The second theme that emerged through the data analysis indicated that students in classes with teachers exemplary in the use of explorations expressed more value for the tasks that were provided and had more opportunities to relate their work to their real lives. Past research suggests that, when students value a task, they are more motivated and willing to persevere with more energy than those who don’t (Eccles et al., 1983; Eccles & Wigfield, 2002; Wigfield & Cambria, 2010). These qualitative findings helped to better understand the quantitative results by providing an explanation as to why the scores of the Task Value scale in the SATMS were higher for students in classes with teachers exemplary in the use of explorations than for those who were not. The SATMS scale, Task Value, assesses “the extent that students believe the task they are completing is worthwhile, important and useful.” The two aspects, task value and real-life applications, of the second theme are related. Where students can see the relevance of a task to their personal lives, particularly with reference to their future careers, the students often value it more (Assor, Kaplan, & Roth, 2002).

During classroom observations and focus group interviews, increased task value and applications to real-life were observed in classes with teachers exemplary in the use of explorations, and included: more links to other subjects, in particular science; more opportunities to apply the mathematical content to their own lives; and finding the tasks meaningful and useful. Each of these is described below.

First, students in classes with teachers exemplary in the use of explorations were observed to have more opportunities to relate their mathematics learning to other subjects than students in classes with teachers who were not. For example, in one of the lesson observations with a teacher exemplary in the use of explorations, students were investigating how long it would take them to fly to Pluto using a variety of modes of transport. This activity provided an obvious link to science, as students were required to carry out research involving planets, distances and then scientific calculations to find the solutions. In doing so, the students were learning the mathematical concept of calculations using numbers in scientific notation and, through the teacher allowing for inquiry-based learning and the openness of the task, students had the opportunity to go beyond the algorithm involved in the calculation, to the purpose behind the use of scientific notation. In traditional situations, the topic of scientific notation is taught by completing a large number of questions involving counting decimal places and equating to powers of 10. Instead, here, the teacher allowed the students to explore the purpose of using scientific notation. When performing calculations involving very large or small numbers, the students found the need for a more efficient way of working with and recording these numbers, especially in science where atoms are tiny, and distances can be large. They were able to understand the reason why the use of scientific notation exists, rather than simply learning an algorithmic process. In the focus groups, the students from classes with a teacher exemplary in the use of explorations elaborated on their experiences in the mathematics class. In the ensuing discussions, the students particularly focused on the link with science. They explained how much they enjoyed learning interesting scientific facts and how the mathematics supported their ability to solve and explain scientific issues.

> I had never thought about space travel before this class. Although we are pretending that we could fly to Pluto in an aeroplane, it still makes me think about actual astronauts and their space travel. I'm keen to read and learn more about this as I find it very interesting [Student 3, 08/11/15].

In another example, a student within a focus group setting, explained that they had learnt about navigating, particularly on ships and used trigonometry, compass directions and bearings to calculate distances and destinations for voyages. They used the scenario of a cruise ship and the many ports that they call in on the journey. She explained that the context made the topic more interesting and also helped to link to their science knowledge of boats and the navigation process.

> In the class, we were able to decide where the cruise would go and to find out the distances and directions. We wrote about the places and that was like our English class and we learnt about navigating boats which was like science [Student 4, 09/11/15].

In contrast, students in classes with teachers who were not exemplary in the use of explorations had less opportunities to relate their mathematical learning to other subjects at school. The students that I observed were required to solve problems from a textbook. Because the questions all were application-type problems (such as calculating the hypotenuse in right-angled triangles), the students had few opportunities to relate the mathematics that they were learning to any of their other subjects. Although in one observation, there was a tenuous link to geography when solving problems involving sailing distances and directions, this was not evident in other classes. During the focus group interviews, I asked the students to describe a time when they related the mathematics they were learning in class, to work in their other subjects. After a period of silence, one student shared an experience of solving a word problem and having difficulty understanding some of the text as the question was in English. She explained that she had used a dictionary to understand the words, so then she could solve the problem “Just like we do in English!” [Student 8, 02/06/15]. This was the only anecdote that the students in the focus groups, from classes with teachers who were not exemplary in the use of explorations, were able to share with me.

Second, analyses of the qualitative information indicated that students in classes with teachers exemplary in the use of explorations had more opportunities to relate their mathematics learning to their own lives. For example, in the lesson observations with the teacher exemplary in the use of explorations reported in the first impressionistic tale, the students undertook tasks that allowed them to research distances to planets and speeds of various transport. The students were able to use the content that they had learned in the class to think about their potential future careers and apply the learning to their personal lives. In one case, a student appeared to be excited to be learning about NASA and space as part of the research of her group. She was eager to tell me that she wanted to be an astronaut and expressed interest in the space programmes that the UAE was participating in.

Observations indicated that the students in classes with teachers exemplary in the use of explorations were given opportunities to relate and apply the mathematics to everyday life as they researched and gathered information to answer their inquiry question. The various activities within the lesson were not taken directly from a generic textbook, but instead they had been developed specifically for the students in the class to ensure the work was placed within a context that the students could relate to. For example, in this case, the inquiry involved deciding on a mode of transport that would take them to Pluto and then researching the distances and speeds. Through the exploration, the students saw the benefit of how the mathematical topic could be utilised in real-life calculations which allowed the students to relate the content to their own lives and the world around them. When digging deeper on these topics during the focus group interviews, students were able to articulate how they felt about the work that they were learning and the way they were learning. For example, one student said:

> Most classes at school teach us in a narrow way. We memorise our work for long enough to pass the exam. In this math class, we see the work in a bigger way. How it fits into careers and research into science and the

> whole point of learning the topic. I find this helps me to remember better. I don't need to memorise as I'm experiencing it instead [Student 4, 09/11/15].

In a further example, within one of the lesson observations, students were learning about saving and spending money. The activities involved them in setting up budgets for themselves and using information from their parents as well as what they researched online, to determine the types and amounts of bills they would receive on a monthly basis and how they could determine how much they could save. They also had opportunities to investigate different ways in which they could save their money and possible returns.

In contrast, students in classes with teachers who were not exemplary in the use of explorations found less opportunities to relate the mathematical content to their own lives. In the lesson observations, students completed activities that required them to complete questions from the textbook. Many questions involved contexts related to sailing boats, but the students lived in a small community, a number of hours' drive from the sea. In other questions, the diagrams involved large towers, however in the community in which they lived, all buildings were two storeys or less. In later discussions within the focus groups, students were able to elaborate on their experiences in their mathematics classes.

> The math work doesn't mean much to me. I'm only learning it to pass the exam. We learn from the textbook and most of the questions are about solving triangles and equations. I can't see the point of it [Student 7, 02/06/15].

Finally, based on my observations and interviews with students, it would appear that students in classes with teachers exemplary in the use of explorations found the tasks provided to be more valuable and meaningful than their counterparts. Task value has four components: intrinsic value (how much enjoyment the individual derives from the task); utility value (how the task relates to future goals); attainment value (the perceived importance of doing well); and cost value (what the individual has to give up to engage in a task) (Eccles & Wigfield, 2002). The first two components of task value seemed to be the most prevalent within the lesson observations, with students enjoying the work they were completing and finding the topics and style of learning important for their futures.

Students in classes with teachers exemplary in the use of explorations appeared to experience a variety of valuable opportunities from the exploration tasks they were completing. During one of the lesson observations, while I was moving between groups and discussing the set task with them, one student explained to me that she felt learning through explorations allowed her to develop new skills, outside of the mathematical content, that she believed were beneficial for success in the unit tests, exams, and future life. She stated, "Now that we are learning most of our math with explorations, I have learned to think more about why and how I am working and what the math means for life. It has helped me in questions in exams, that aren't just the normal remembering ones, that have a context" [Student 6, 05/11/15]. She described how in a previous unit of work, the class had completed an inquiry task involving budgeting and understanding the difference between paying with cash, debit cards and credit cards, "We had to set up a scenario where we researched a particular job, a sensible monthly salary and then the expenses we would have to pay. Then we had to discover and calculate payment plans for a new item for our house, like a car or a TV, and the differences with paying using different methods. Even my family didn't know how to do that!" [Student 6, 05/11/15]. In this task, she explained that she had learnt skills that her older brothers and sisters didn't know, and she felt empowered for her financial future. Within the focus groups, when asked about whether the students from classes with teachers exemplary in the use of explorations felt like they completed worthwhile activities, one student explained, "Not only do I enjoy the way we learn in this class, but I also feel like it's useful, for me now, and for me later. Next year, and after I leave school." [Student 1, 05/11/15].

In contrast, observations and interviews suggest that students in classes with teachers who were non-exemplary in the use of explorations had less opportunities to find value in the work they were completing. During the lesson observations, some students chose not to complete the tasks that had been allocated to them. For example, a group of students chose to sit and write notes to one another and did not attempt to complete the questions from the textbook. In another example, I observed four students, sitting at adjoining desks, who chose not to discuss the work they were completing. Instead, one student completed the calculations for the answer and then the others in the group copied this onto their pages once she had finished. During the focus group interviews, to further understand the behaviour I had observed in the lessons, I asked about whether the students found the activities the teacher set, worthwhile and valuable. One student, whose response was representative of others, stated:

> Math is boring. It's always the same. I like subjects that will help me get a good job and they say that I will need math for my career, but I can't see how. It's just numbers that don't relate to anything else [Student 9, 04/06/15].

These qualitative findings were reflected in the quantitative results; particularly with respect to the Personal Relevance scale from the LEIS and the Task Value scale from the SATMS. In all cases, the differences between responses for students in classes with teachers exemplary in the use of explorations and those who were not were statistically significant (p<.01) and with large effect sizes (Personal Relevance = 0.41 standard deviations and Task Value = 0.44 standard deviations). In all cases, the students in classes with teachers exemplary in the use of explorations scored higher than their counterparts who were not.

Overall, the findings suggest that students in classes with teachers exemplary in the use of explorations perceived more task value and real-life application in their classes than students in classes with teachers who were not exemplary in the use of explorations, with both the quantitative and qualitative results supporting this.

4.5.4.3 Inquiry and Investigation

The third theme that emerged from the analysis of the qualitative data was that students in classes with teachers exemplary in the use of explorations experienced a learning environment that had greater inquiry and investigation when compared to students in classes with teachers non-exemplary in the use of explorations. Inquiry in this context involved the use of the inquiry process; that is, the development of rich questions to guide the inquiry, research to gather relevant information, synthesis of the information, and demonstration of the findings (Jansen, 2011). Based on the Investigation scale of the LEIS, investigation is described as “the degree to which skills and processes of inquiry and their use in problem solving and investigation are emphasised.” Investigation, therefore, involves providing students with opportunities to explore and discover mathematics in a student-centred manner rather than a didactic teacher-led situation where memorising facts that are given is the norm. During classroom observations, in classes taught by teachers exemplary in the use of explorations, increased opportunities for inquiry-based learning and investigation were observed in a number of ways, including: opportunities for students to use open-ended tasks; research from multiple sources; and opportunities for students to reflect on their work and think critically. Each of these is expanded upon below.

First, students in classes with teachers exemplary in the use of explorations were given more opportunities to complete open-ended tasks. Open-ended tasks are those that have multiple possible answers, allowing students insights into a range of mathematical opportunities through seeing and discussing (Sullivan, Griffioen, Gray, & Powers, 2009). Such tasks have been found to be influential in supporting student opportunities for exploration, collaboration and mathematical reasoning (Kosyvas, 2016). Analysis of the data collected during the lesson observations and my interviews and discussions with students, indicated that, in classes with teachers exemplary in the use of explorations, lessons involved tasks with an open-ended nature which allowed students to take their group’s investigation in a different direction from other groups in the class. For example, during one lesson, I moved between groups of students and noticed that each group had taken a different approach to the task that had been set. Some students had chosen to use a commercial plane as their mode of transport while others had chosen to focus on using a rocket. Similarly, different groups of students had chosen differing methods of presentation, both for their calculations and mathematical working and for the verbal and written presentations. One student explained to me, “I really like that each group can go in their own direction in solving the problem. It makes it interesting at the end when we present our work. Seeing what everyone has done.” [Student 10, 05/11/15].

In contrast, students in classes with teachers who were not exemplary in the use of explorations experienced less opportunities to explore their learning through open-ended tasks. Instead, students were observed completing closed tasks where every student completed the same steps to attain the same solution. For example, in the impressionistic tale the teacher demonstrating the answer to one of the questions and instructing the students to complete the next question from the textbook was described. In this case, the teacher gave the students time to commence work on the mathematics problem but started to set up the solution on the white board (by labelling the triangle and explaining the next steps) before they had finished. In this example, many of the students waited until the teacher started solving the problem and then wrote the answer from the board into their books. The students then went on to complete the same tasks that had fixed solutions for all. The questions were short problems with one solution, requiring all students to take the same steps to answer. In another example, I observed students writing in their books, rather than investigating either individually or in groups. In this case, the students did not discuss the work together but, rather, they chose to wait for one student to finish her calculations and then they wrote the work into their own books. As one student said:

> In this math class we find it easiest to work together. My friend is very clever so she shows me her answers so I can complete the work. Sometimes the teacher just solves the question on the board so I'm able to write it down [Student 13, 02/06/15].

Throughout my data collection, I did not observe students in classes with teachers who were not implementing explorations in an exemplary way, complete any open-ended tasks that allowed them to follow differing paths with their investigations and inquiry.

Second, students in classes with teachers exemplary in the use of explorations had opportunities to use multiple sources for research as part of their learning process. In traditional mathematics lessons, students tend to receive their information directly from the teacher, often using the textbook to support with examples of model question types. An aspect of inquiry-based learning is enabling students to be able to gather information and data from a number of differing sources. This could be from experts, within and external to the school, from books in the library and using online sources of information. For example, during one of the lesson observations, students explained that, during earlier lessons, they had been given the 'big question' and then, in groups, they had planned how they would answer it. Some of the decisions that they were required to make included how they would plan the research that they would need to complete the inquiry and how they would present their findings to the class at the end of the exploration. During a focus group interview, these students articulated the inquiry process that they were undergoing, including the variety of research they would undertake.

> We follow a process that our teacher has taught us where we start with a question that is quite wide and big and then in our groups, we narrow our question and make it more specific for what we want to investigate. It's then very important for us to decide how to gather our information. When we first started learning this way it was hard for us to be able to work out for ourselves how to answer the big question, but as we did it more, we became better at knowing what to do [Student 3, 08/11/15].

In this example, prior to the lesson, the teacher had explained that the inquiry allowed the students to use various resources for research, including online material, books and people. Here the students were given class time in the library for their investigation and inquiry. When I asked some students in one group how they had gathered their information, they explained to me that they had visited the library during a previous lesson.

> In normal math classes we all do the same work from the textbook. In this class we can use lots of different ways to collect information. I have got [gotten] better at using the library and also searching online. When we started, I found it hard to find the information I needed on the net as the better searches are in English and I find written English very difficult. By working with my friend, she has helped me use better keywords to search and it's become easier for me [Student 11, 08/11/15].

In contrast, students in classes with teachers who were not exemplary in the use of explorations had less opportunities to research or use multiple sources for information. Inquiry-based learning classes require the teacher to be a facilitator rather than an expert lecturer. Observations indicated that, in these classes, predominantly, the teacher was the sole source of information for the students. For example, in one class, the teacher asked the students to complete a question from the textbook and then remained at the front of the classroom, initially standing and then sitting at her desk. From her viewpoint she kept an eye on the students by her desk and when they appeared to be finished, she got up and went to the whiteboard where she requested one student to join her and asked them to solve the problem on the board for all students to see.

> If we put our hand up, the teacher will come and solve the problem in our books for us, but normally we just wait for her to solve it on the board. It is quicker this way [Student 14, 03/06/15].

During the focus group interviews, when discussing the use of inquiry during their mathematics lessons, these students appeared to have little understanding of the meaning of inquiry. That is, for the most part, the students generally agreed that, when they were asked to solve a problem individually after being given an example on the board, this was inquiry. I asked the students in the focus groups to explain a time during their mathematics lessons when they used inquiry to learn. One student stated, "We use inquiry in class a lot. The teacher shows us a question on the board and the steps to solve, and then we try one in our books." [Student 7, 02/06/15]. Another student agreed, "Yes, the teacher gets us to solve the next problem by ourselves, so we have to think. Just like inquiry!" [Student 8, 02/06/15]. One student also stated, in response to a question from me, that new concepts were not investigated by them prior to the theory being given by the teacher. When asked about the activities that they complete in class, the students all agreed that the allocated tasks were all decided upon by the teacher who also determined the amount of time they had to complete them. For example, in one focus group, the students explained about discovering or investigating mathematics and how they believe the teacher allowed them to discover for themselves when solving questions but not when being introduced to new concepts. One student said:

> When we learn about a new topic, the teacher explains the notes in the front of the section in the textbook. This normally has some history about the topic and some examples with answers to show us what to do. Then

> we try some questions for ourselves. That's how we do investigations [Student 15, 04/06/15].

Analysis of the data indicated that, whilst students worked in groups to solve problems, they were not provided with opportunities to do practical tasks or work with applications that were relevant to their lives and personal experiences. Some students misunderstood the idea of inquiry and believed that being seated in a group meant they were using inquiry-based learning. The problems that the students were asked to solve were from the textbook and did not require them to work together to construct a response that did not follow the prescribed steps explained previously by the teacher. When I asked about the different types of tasks and activities that they completed in class, one student explained, "We only do exercises from the book." [Student 7, 02/06/15]. I then probed further by asking about any practical activities they may have completed, but they gave a negative response explaining that they don't do work like that in mathematics. I wanted to establish if they completed tasks that they could relate to, with applications relevant to their personal experiences, but two students explained, one in Arabic with the other translating, "The books have changed the names of people to Ahmed and Fatima, but the problems still have baseball and other things we don't know about." [Students 16 and 17, 03/06/15]. In all of my observations, the work provided to students was drawn from a textbook. Students in classes with teachers who were not exemplary in the use of explorations rarely had opportunities to complete activities and tasks that involved gathering information for themselves and completing research from any sources other than the textbook.

Third, students in classes with teachers exemplary in the use of explorations were provided with more opportunities to think critically and to reflect on their learning processes. An important goal of inquiry-based learning is to foster critical thinking in students (National Research Council, 1996). Critical thinking is defined as something which "involves the use of information, experience, and world knowledge in ways which allow students to seek alternatives, make inferences, pose questions, and solve problems, thereby signalling understanding in a variety of complex ways" (Liaw, 2007, p. 51). For example, in classes taught by teachers exemplary in the use of explorations, students were given opportunities to discuss the limitations of their research model. In one case, I observed students describing their research and findings, and discussing the limitations of their model. As part of this process, the students articulated where they believed they had been successful and what parts of the process they would change for next time. As one student explained:

> The first time we did an exploration task I found it very bad. It was so hard to think in this new way. Before we just memorised the equations and did the questions in the book, but now we had to explain what we were doing and why. I am much better at it now and can even think of better ways to do it next time [Student 12, 09/11/15].

In contrast, students who were in classes with teachers who were not exemplary in the use of explorations rarely had opportunities to think critically and to reflect on their work. Rather, these students completed the same algorithmic process for each trigonometric problem from the textbook involving the steps: draw a diagram, label sides, choose trigonometric ratio, substitute and solve. When students encountered difficulties, they waited for the teacher to write the solution on the board so that they could copy it down, or alternatively asked their friends if they could see their answer. It was not evident that any students had opportunities to think critically about the task they were completing. As part of the questioning in the discussions in the focus group interviews, I asked the students if they could describe a time when they reflected on their work, either the answers they gained or the process they underwent to attain the solution. One student explained that she likes to think about whether her answer is sensible in the context of the question. By probing further, I enquired about why she does this, and she answered "Last year in our math class, our teacher told us to always think about the units and the number and whether they work. This year we don't do that, but I like to." [Student 18, 04/06/15]. This was the only evidence of critical thinking or reflective practice that I observed during the lessons or within the focus group interviews. In general, the students in classes with teachers who were not exemplary in the use of explorations did not have opportunities for reflective or critical thinking.

The qualitative findings indicated that students in classes with teachers exemplary in the use of explorations had more opportunities for inquiry and investigation. These findings were reflected in the quantitative results; particularly with respect to the

Critical Voice, Student Negotiation, Shared Control and Investigation scales from the LEIS. In all cases, the differences between responses for students in classes with teachers exemplary in the use of explorations and those who were not were statistically significant ($p<.01$) and with large effect sizes (Critical Voice = 0.24 standard deviations, Student Negotiation = 0.26 standard deviations, Shared Control = 0.32 standard deviations and Investigation = 0.41 standard deviations). In all cases, the students in classes with teachers exemplary in the use of explorations scored higher than their counterparts who were not.

4.6 Chapter Summary

Reported in Chapter 4 are the results of the analysis of data gathered to address the research objectives raised in the study. Several differing techniques were used to analyse the data collected to address each objective.

Two new instruments were developed for the purpose of this study. First, the Learning Environment in Inquiry Survey (LEIS) was developed to assess students' perceptions of the learning environment in their inquiry-based mathematics classes. The results of principal axis factor analysis with oblique rotation strongly supported the factorial validity of the 36-item, six-scale, Arabic version of the LEIS when used in Cycle 2 (grades 6 to 9) schools in the UAE. Reliability using the Cronbach alpha coefficient was high for all six scales of the LEIS for both units of analysis (individual and class mean). The ANOVA results, used to examine the ability of the scales in the LEIS to differentiate between classes, revealed statistically significant ($p<.05$) differences between classes for all six LEIS scales.

The second instrument, the Student Attitudes Towards Mathematics Survey (SATMS), was developed to assess students' attitudes towards mathematics. The results of principal axis factor analysis with oblique rotation strongly supported the factorial validity of a 22-item, three-scale, Arabic version of the SATMS when used in Cycle 2 (grades 6 to 9) schools in the UAE. The Cronbach alpha coefficient was high for all three scales of the SATMS for both units of analysis (individual and class mean). The ANOVA results, used to examine the ability of the scales in the SATMS to differentiate between the 12 classes in the study, indicated statistically significant (p<.01) differences between classes for all three scales.

To examine whether associations existed between the attitude scales of the SATMS and the learning environment (Research objective 2), simple correlations and multiple regressions were used. The results of the simple correlations indicated that all six LEIS scales were positively and statistically significantly (p<.01) related to all three SATMS scales. The regression coefficients (β) indicated that: five of the six learning environment scales were positive, independent and statistically significant (p<.01) predictors of Enjoyment of Mathematics; two of the six LEIS scales were positive and statistically significant (p<.01) predictors of Self-Efficacy; and three of the six LEIS scales were positively and statistically significantly (p<.01) related to Task Value.

In the third research objective I sought to determine whether differences between students with a teacher exemplary in the use of explorations differed to those with a teacher who was not, in terms of their perceptions of the learning environment and their attitudes. The MANOVA results suggest that there are statistically significant differences (p<.01) for all six learning environment scales and all three attitude scales. Further, the effect sizes indicate that the magnitudes of the differences ranged from medium to large in effect.

In the final research objective, I investigated reasons for the differences of the perceived learning environments and attitudes towards mathematics for students taught by teachers exemplary in the use of explorations and those who were not. Impressionistic tales, based on a number of lessons, helped to identify concepts that were common over a number of lesson observations. An interpretative commentary explained the observations and compared and contrasted the two tales. Analysis of the qualitative data identified three main themes that provided causal explanations for the quantitative data: student engagement and involvement in learning; task value and real-life application; and inquiry and investigation. Overall, students in classes with teachers exemplary in the use of explorations perceived more engagement and involvement in their learning, task value and opportunities for real-life application and inquiry and investigation in their classes than students in classes with teachers who were not. Both the quantitative and qualitative results support this. In the next chapter a discussion of these results is provided.

CHAPTER 5

Discussion and Conclusions

5.1 Introduction

In this study I focused on the use of inquiry-based learning approaches and compared the learning environment perceptions and attitudes of students taught by teachers who were exemplary in their use of explorations and those who were not. The study took place amidst a period of major educational reform in Abu Dhabi, UAE, in which teachers were implementing inquiry-based learning with varying levels of success. In this study a mixed method approach that was carried out in two phases was incorporated. The first phase, guided by a post-positivist paradigm, involved the collection of quantitative data, and the second phase, guided by an interpretivist paradigm involved the gathering of qualitative information. The mixed methods design used in this study was an explanatory sequential design in which the collection and analysis of qualitative data in the second phase helped to explain or expand on the first-phase quantitative results; as defined by Creswell and Plano-Clark (2017). For the study reported in this thesis, the integration of the two phases within the explanatory sequential design occurred in two places. First, integration for mixing occurred after the quantitative data analysis in the first phase of the research and prior to the qualitative data collection in the second phase. This occurred by identifying quantitative results that required further examination within the qualitative phase. Second, integration occurred when the qualitative phase was complete. At this stage, the two sets of connected results allowed for integrated conclusions to be made about how the qualitative results explained and extended the quantitative results.

Data collection for the first phase involved the development of two new instruments: the Learning Environment in Inquiry Survey (LEIS), to assess students' perceptions of the learning environment: and the Student Attitudes Towards Mathematics Survey (SATMS), to assess students' attitudes towards mathematics. The surveys were administered to 291 middle school students in 12 mathematics classes, six of the classes were taught by teachers who were exemplary in the use of explorations and six of the classes were taught by teachers that were not.

For the second phase, data collection involved gathering qualitative information through lesson observations and focus group interviews with students. This included observations in three classes taught by teachers exemplary in the use of explorations and three in classes taught by teachers who were not. In addition, focus group interviews with between four and five students in each group were held after each lesson observation.

This chapter concludes the thesis and is organised under the following headings:

- Summary and discussion of major findings (Section 5.2);
- Limitations of the study (Section 5.3);
- Summary of recommendations (Section 5.4);
- Significance of the study (Section 5.5); and
- Concluding remarks (Section 5.6).

5.2 Summary and Discussion of Major Findings

In this section a summary of the major findings, structured around the four research objectives, followed by a discussion of the findings is included. The section is organised using the following headings: validity and reliability of the instruments (Section 5.2.1); correlations between learning environment perceptions and attitudes (Section 5.2.2); differences in learning environments perceptions and attitudes of students taught by teachers exemplary in their use of explorations and those who were not (Section 5.2.3); and, explanations for the differences (Section 5.2.4).

5.2.1 Validity and Reliability of the Instruments (Research Objective 1)

The first research objective was:

To develop and validate instruments suited for use with middle school students in the UAE to assess students' perceptions of the learning environment in exploration classes and their attitudes.

Data collected from 291 students in 12 intact classes was used to provide evidence to support the reliability and validity of each of the LEIS and SATMS in terms of their factor structure, internal consistency reliability, discriminant validity, and ability to differentiate between scales. In this section I have summarised and discussed the results for each instrument: Learning Environment in Inquiry Survey (LEIS; Section 5.2.1.1); and Student Attitudes Towards Mathematics Survey (SATMS; Section 5.2.1.2).

5.2.1.1 Learning Environment in Inquiry Survey (LEIS)

To assess students' perceptions of the learning environment, the Learning Environment in Inquiry Survey (LEIS) was developed. The instrument included 40-items that have four scales with six items and two scales with eight items. Four of the scales were drawn from the Constructivist Learning Environment Survey (CLES; Taylor et al., 1997) and two scales were drawn from the What Is Happening In this Classroom? Questionnaire (WIHIC;Aldridge et al., 1999). Key findings for the validity and reliability of the LEIS are summarised below.

- The 40-item, six-scale version of the LEIS displayed satisfactory factorial validity after the removal of three items. Factor loadings for the remaining items ranged from 0.47 to 0.82.
- The percentage of variance for different scales ranged from 3.77% to 31.33% with the total proportion of variance accounted for being 57.27%. The eigenvalues for different scales ranged from 1.36 to 11.28, thereby meeting Kaiser's (1960) criterion for a scale.
- The internal consistency reliability for scales of the LEIS ranged from 0.75 to 0.88 with the individual as unit of analysis and from 0.86 to 0.95 with the class mean as the unit of analysis. Given L. Cohen, Manion and Morrison's (2000) criteria, these results were considered to be high.
- The discriminant validity shown in the component correlation matrix indicated the correlations ranged from 0.11 to 0.40, meeting the requirements of the threshold of 0.85 for discriminant validity (L. A. Clark & Watson, 1995; Kline, 2011).

- The ANOVA results indicated that all six LEIS scales were able to differentiate significantly ($p<0.05$) between the perceptions of students in different classrooms.

Given that the LEIS was developed using scales from the CLES and the WIHIC, it was considered appropriate to make comparisons between the reliability and validity of the LEIS with respect to the performance of these instruments in past research. The findings reported for the LEIS are consistent with previous research involving the Personal Relevance, Critical Voice, Shared Control, and Student Negotiation scales adapted from the CLES when translated into Mandarin (Aldridge et al., 2000), Spanish (Peiro & Fraser, 2009) and Korean (Cho et al., 1997; H.-B. Kim et al., 1999; Oh & Yager, 2004). Further, the reliability and validity of the Involvement and Investigation scales, adapted from the WIHIC, also supported past research for versions translated into Arabic (Afari et al., 2012; MacLeod & Fraser, 2010), Mandarin (Aldridge & Fraser, 2000; Aldridge et al., 1999), Korean (H.-B. Kim et al., 2000), Indonesian (Wahyudi & Treagust, 2004b) and Spanish (Allen & Fraser, 2007; Helding & Fraser, 2013; Robinson & Fraser, 2013).

The development of the LEIS adds to the suite of reliable learning environment tools available in the field of learning environments. Further, the LEIS is unique in that it makes available a reliable tool in the Arabic language to examine classes that involve the use of the inquiry-based exploration approach in mathematics.

5.2.1.2 Student Attitudes Towards Mathematics Survey (SATMS)

To assess students' attitudes towards the inquiry-based exploration approach in mathematics, the Student Attitudes Towards Mathematics Survey (SATMS) instrument was developed. The 23-item, three-scale SATMS included one scale that was drawn from the Test of Mathematics-Related Attitudes (TOMRA; Spinner & Fraser, 2005) and the two scales that were drawn from the Student Adaptive Learning Engagement in Science (SALES) questionnaire (Velayutham et al., 2011). Key findings for the validity and reliability of the SATMS are summarised below.

- The SATMS displayed satisfactory factorial validity after the removal of one item. Factor loadings for the remaining 22 items ranged from 0.58 to 0.91.
- The percentage of variance for the SATMS scales ranged from 6.70% to 54.08% while the total proportion of variance accounted for being 70.59%. The eigenvalues ranged from 1.47 to 11.90 for different SATMS scales, thereby meeting Kaiser's (1960) criterion for a scale.
- The internal consistency reliability for the modified 22-item, three-scale SATMS, ranged from 0.92 to 0.95 with the individual as unit of analysis and from 0.97 to 0.98 with the class mean as the unit of analysis. The coefficients are considered to show high reliability for two units of analysis (L. Cohen et al., 2000).
- The discriminant validity, shown in the component correlation matrix, indicated that the correlations ranged from 0.52 to 0.59. This met the requirements of the threshold of 0.85 for discriminant validity (L. A. Clark & Watson, 1995; Kline, 2011).
- The ANOVA results indicated that all three SATMS scales were able to differentiate significantly ($p<0.05$) between the perceptions of students in different classrooms.

The development of the SATMS incorporated scales from each of the SALES and the TOMRA; so, it was considered appropriate to make comparisons between the reliability and validity of the SATMS with respect to the performance of these instruments in past research. The findings summarised above are consistent with previous research involving the Task Value and Self-Efficacy scales adapted from the SALES (Velayutham & Aldridge, 2013; Velayutham et al., 2011) and the Enjoyment of Mathematics scale adapted from the TOMRA (Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005).

Overall, the reliability and validity of the LEIS and SATMS instruments, in terms of the factor analysis, scale internal consistency reliability, component correlation, and ability to differentiate between classes, were supported. These strong results served to establish that the instruments, when used with this sample of middle school students in the UAE, were valid and reliable. These findings suggest that the data could be used with confidence to address subsequent research objectives.

5.2.2 Associations between Learning Environments and Attitudes (Research Objective 2)

The second research objective was:

To investigate whether associations exist between students' perceptions of their learning environment and attitudes towards mathematics.

With the implementation of an innovative technique of teaching and assessing mathematics, it was pertinent to examine whether there was a relationship between how students perceived their learning environment and their attitudes towards mathematics. Simple correlation and multiple regressions were used to examine whether relationships existed between students' perceptions of the learning environment and attitudes towards mathematics, the results for which are summarised below.

- The results of the simple correlation analysis indicate that there were statistically significant (p<.01) relationships between all six LEIS scales and all three SATMS scales.
- The multiple correlation for the set of LEIS scales was positive and statistically significant (p<.01) for all three SATMS scales.
- Interpretation of the beta values suggested that there were statistically significant (p<.01) associations between each attitude scale (Enjoyment of Mathematics, Self-Efficacy, and Task Value) and the set of six learning environment scales. These statistically significant independent predictors, all of which were positive in direction, are outlined below.
    - Shared Control, Involvement, and Investigation contributed uniquely and significantly (p<.01) to the explanation of the variance in the Enjoyment of Mathematics scale.
    - Involvement and Investigation contributed uniquely and significantly (p<.01) to the explanation of the variance in the Self-Efficacy scale.

- Personal Relevance, Shared Control and Investigation contributed uniquely and significantly (p<.01) to the explanation of the variance in the Task Value scale.

The positive and statistically significant (p<.01) relationships found between all six of the learning environment scales and the three attitude scales corroborates much past research that suggests that students' perceptions of the classroom environments are related to attitudes (Fisher, Henderson, & Fraser, 1995b; Wolf & Fraser, 2008; Yang, 2015). First, with respect to enjoyment of mathematics, my findings are comparable to results found in similar studies investigating relationships between learning environment perceptions and enjoyment of learning in mathematics (Afari et al., 2013; Chionh & Fraser, 2009; Sakiz et al., 2012; Vandecandelaere et al., 2012). My results also corroborated studies in differing subjects, such as science (Allen & Fraser, 2007; Wahyudi & Treagust, 2004a) and the arts (Radovan & Makovec, 2015). Second, with respect to self-efficacy, the results supported a growing body of research which also found strong positive relationships between students' perceptions of the learning environment and self-efficacy in mathematics (Afari et al., 2013; Aldridge, Afari, et al., 2012; Dorman, 2001) and those investigating relationships in the science classroom (Gupta & Fisher, 2012; Qureshi et al., 2017; Velayutham & Aldridge, 2013). Of importance, these findings also support studies that are based geographically in the Gulf region, including Qatar (Qureshi et al., 2017) and the UAE (Afari et al., 2013; Aldridge, Afari, et al., 2012). Finally, with respect to task value, the findings are similar to previous research which has found positive relationships with learning environment perceptions (Khalil & Aldridge, 2019; Liu et al., 2012).

The results reported in this study have important implications for teachers, policymakers and curriculum developers when considering the relationship between the learning environment and student outcomes. If students find value in their mathematics tasks in middle school classes, have high self-efficacy with respect to mathematics and are enjoying the subject, they will be more willing to consider a career in this field (Ismail, 2009; Mettas, Karmiotis, & Chirstoforou, 2006; Middleton & Spanias, 1999). Since this study shows strong and positive associations between the learning environment and attitudes towards mathematics, making improvements in the learning environment has the potential to improve student attitudes towards mathematics, which may increase participation numbers. Given these strong correlations, it is recommended that practical strategies and professional development opportunities, both initial training and ongoing mentoring and support, are developed to promote changes in the learning environment throughout the Emirate of Abu Dhabi and the UAE (*Recommendation 1*).

5.2.3 Differences in Learning Environments and Attitudes between Exemplary and Non-Exemplary Classrooms (Research Objective 3)

The third research objective was:

To investigate how mathematics students taught by teachers exemplary in their use of explorations and those who were not differ in terms of students':

a. Perceived learning environment;
b. Attitudes towards an inquiry-based exploration approach in their mathematics classes.

To address this objective, the data collected from 291 students in 12 classes were used. Of this sample, six classes (n = 139 students) were taught by teachers exemplary in the use of explorations and six classes (n = 152 students) were in classes taught by teachers who were not. One-way MANOVA (using the student as the unit of analysis) was used to determine whether statistically significant differences existed between the students' scores on the LEIS and SATMS for these two groups. To examine the magnitudes of the differences, effect sizes were calculated. The set of six LEIS scales (Personal Relevance, Critical Voice, Student Negotiation, Shared Control, Investigation, and Involvement) and three SATMS scales (Enjoyment of Mathematics Classes, Self-Efficacy, and Task Value) constituted the dependent variables whilst the two groups (those taught by teachers exemplary in the use of explorations and those who were not) represented the independent variable. The results of this quantitative analysis are summarised below.

- The average item mean for all six LEIS scales and all three SATMS scales for students in classes that were taught by teachers exemplary in the use of explorations were consistently higher than for students in classes taught by teachers who were not.

- The scores for all six learning environment scales were statistically significantly ($p<.01$) different, with students in classes taught by teachers exemplary in the use of explorations scoring higher than their counterparts who were not.
- The effect sizes ranged from 0.24 standard deviations (for the Critical Voice scale) to 0.41 standard deviations (for the Personal Relevance, and Investigation scales). These differences can be considered medium according to Cohen (J. Cohen, 1988).
- Like the LEIS, the scores for all three SATMS scales were statistically significantly ($p<.01$) different, with students in classes taught by teachers exemplary in the use of explorations scoring higher than their counterparts who were not.
- The effect sizes for the difference are considered medium to large according to Cohen (1988) and ranged from 0.52 standard deviations for Enjoyment of Mathematics Classes to 0.44 standard deviations for Task Value.

The results of my study, which indicate statistically significant differences for all the learning environment scales, supported other studies that have examined the use of inquiry-based learning and found positive impacts on students' perceptions of the learning environment (see for example, Nix et al., 2005; Oh & Yager, 2004; Wolf & Fraser, 2008). There were similarities between the findings of this study and those found in research carried out in Korea investigating the effectiveness of the implementation of constructivist instructional approaches (Oh & Yager, 2004). Both studies found that students' perceptions of the learning environment were more positive with the use of inquiry-based learning techniques than situations where it was not present or was poorly implemented. The findings also corroborated those of Nix, Fraser and Ledbetter (2005) who reported that students, in classes with teachers who had received professional development on the use of inquiry-based learning, perceived their learning environment more favourably than those who had not. Also, the findings reported in this thesis, were similar to a study where comparisons were made between an experimental inquiry-based learning group and a control group with traditional teaching techniques. These results indicated that students who experienced inquiry methodologies perceived a more positive learning environment than their peers (Wolf & Fraser, 2008). My findings corroborated the results of these past studies, indicating that, in classes taught by teachers exemplary in the use of explorations, the teachers promoted a more positive learning environment for students.

There were also statistically significant differences between scores on the SATMS scales for students in classes in which teachers implemented explorations in ways that were exemplary and those in which teachers did not. These findings support numerous other studies that have examined the use of (well-implemented) inquiry-based learning and found positive impacts on a range of student attitudes towards mathematics, including: enthusiasm and enjoyment for learning (Makar, 2007; Sheppard, 2008); positive identities with regards to mathematics, (Boaler, 1997; Bransford et al., 2000; Diezmann et al., 2001; Makar, 2007; Staples, 2007); positive student attitudes to learning (Jarrett, 1997); and positive associations between inquiry and students' self - efficacy (Kang & Keinonen, 2017; McElvain & Smith, 2016; Qureshi et al., 2017).

The results of the study reported in this thesis, as well as past research have shown that where inquiry-based learning has been implemented in an exemplary manner, students have experienced more positive attitudes towards mathematics than their peers who did not (Jarrett, 1997). Given that positive attitudes towards mathematics have been found in previous research to increase the likelihood of students pursuing a career in the field (Ismail, 2009; Middleton & Spanias, 1999), and given that STEM education is at the top of the list of the 2030 UAE Strategic Vision (Abu Dhabi Government, 2008), these results are extremely encouraging. The positive relationship between the learning environment and students' attitudes towards mathematics in classes with teachers exemplary in the use of explorations, justifies this component of the reform efforts in Abu Dhabi. However, the mandate that teachers use inquiry-based learning in the teaching, learning, and assessment of mathematics is not being implemented consistently, with the level and skill of inquiry-based teaching being completed in differing degrees, as highlighted by this research. It is recommended, therefore, that ADEC examine how they can better upskill teachers in the use of inquiry through professional development, exemplars of tasks and student work, model lessons and further in-school support *(Recommendation 2*).

These results, showing statistically significant ($p<.01$) differences in perceptions of the learning environment and attitude scales, provide implications not only for ADEC in terms of the current educational reform, but also for teachers, school leaders, policymakers, and teacher professional development providers with the need for educators to consider and improve the learning environment through the delivery of quality inquiry-based learning. The consideration of teacher professional development to support the implementation of inquiry-based learning is discussed further in Section 5.2.4.3.

5.2.4 Explaining the Differences (Research Objective 4)

The fourth research objective was:

To investigate reasons for differences of the perceived learning environment and attitudes towards mathematics for students taught by teachers exemplary in the use of explorations and those who were not.

To provide insights into the differences in students' perceptions of the learning environment and attitudes towards mathematics, and to add depth to the quantitative data, qualitative information collected using classroom observations and interviews was analysed. Two impressionistic tales were developed, one based on observations of classes that were taught by teachers exemplary in the use of explorations and the other based on observations of classes taught by teachers who were not. The first impressionistic tale, describing a lesson with a teacher exemplary in the use of inquiry, shows behaviours by both students and the teacher reminiscent of the processes involved in the inquiry cycle, however, this is not the case in the lesson described in the second impressionistic tale with a teacher non-exemplary in the use of inquiry. The teacher appears to have misinterpreted the term inquiry and associated terminology and does not present activities and learning opportunities that fit well within the inquiry cycle.

During the analysis of the data, three themes emerged: student engagement and involvement in learning; task value and real-life application; and inquiry and investigation that explained differences in students' scores (quantitative results). These themes are summarised below.

5.2.4.1 Theme 1: Student Engagement and Involvement in Learning

The first theme indicated that:

- Students in classes taught by teachers exemplary in the use of explorations were more active in the learning process than those in classes that were not. Analyses indicated that these students had opportunities to direct both the content and the process in which they were learning.
- There were more opportunities for discussion, both with the teacher and with peers, in the classes with teachers exemplary in the use of explorations than for students in classes with those who were not.
- Student collaboration and the 'pooling of knowledge' was more prevalent in the classes with teachers exemplary in the use of explorations than in the cohort with teachers that were not.

My findings, with respect to the differences reported through lesson observations and focus group interviews with teachers exemplary in the use of explorations and those who were not, generally reflected student responses to the surveys which showed statistically significantly (p<.01) more favourable responses for students who were in classes taught by teachers exemplary in the use of explorations for the Involvement scale of the LEIS and the Enjoyment of Mathematics and Self-Efficacy scales of the SATMS.

The analysis of the qualitative data indicated that students in classes with teachers exemplary in the use of explorations had more opportunities to be active in their learning and to be involved in making decisions as to the content and processes used in tasks. Similar to my findings, past research provides evidence to suggest that the use of exemplary inquiry-based learning in classes afforded many benefits for students, including engaging in authentic conversations and increased involvement in learning (Amaral et al., 2002). My findings corroborated those of Goos (2004), who purported that, in inquiry-based learning classrooms, students are involved with their learning and, "rather than rely[ing] on the teacher as an unquestioned authority, students in [inquiry-based] classrooms are expected to propose and defend mathematical ideas and conjectures and to respond thoughtfully to the mathematical arguments of their peers" (p. 259). My study also supported those of Boaler (1998) who investigated differences between two schools, one using a textbook approach and the other using inquiry-based learning. Like my study, the results showed similar findings, with students in the inquiry classes experiencing more engagement and enjoyment, whereas students in the comparison class found the classes boring and difficult and they "did not think it was appropriate to try to think about what to do; they thought they had to remember a rule or method they had used in a situation that was similar" (Boaler, 1998, p. 47).

As with the students described in the previous studies, the reform in Abu Dhabi is aiming for students to have opportunities to propose and defend ideas and, therefore, experience more engagement and enjoyment (Abu Dhabi Education Council, 2013). The research reported in this thesis indicates that students in Abu Dhabi are experiencing more enjoyment and engagement in classes taught by teachers exemplary in the use of explorations. Therefore, it is recommended that quality inquiry-based learning is continued, and any teachers identified as exhibiting teaching that is not exemplary in inquiry-based teaching methods, should be supported to improve their pedagogical approaches (*Recommendation 3*).

5.2.4.2 Theme 2: Task Value and Real-Life Application

The second theme indicated that:

- Students in classes with teachers exemplary in the use of explorations had opportunities to link their mathematics to other subjects, specifically science. Students who were not in classes with teachers exemplary in the use of explorations tended to have no or few links to other subjects.
- In the classes where explorations were well facilitated, students were provided with opportunities to consider the mathematics they were learning in the context of their own lives. Whereas, in the classes where explorations were not well-facilitated, students did not make any reference to how the content applied to them personally. They tended to complete questions from a textbook that did not link to any aspect of their everyday lives.

- Teachers exemplary in the use of explorations more frequently gave students opportunities to find value in the tasks they were completing and allowed them to find the work meaningful and useful for them. In the comparison classes, students appeared to find no value in the tasks they completed and displayed off task behaviour such as copying from peers, sleeping or occupying themselves with other activities.

My qualitative findings, with respect to the differences for the theme of task value and real-life applications, generally reflected student responses to the surveys. The survey results indicated that there were statistically significant ($p<.01$) differences for students who were in classes taught by teachers exemplary in the use of explorations and those who were not, particularly with respect to the value they placed on tasks and applications to their lives, shown in the Personal Relevance scale of the LEIS and the Task Value scale of the SATMS.

Similar to my findings, past research has reported that the use of exemplary inquiry-based learning can increase students' value they place in the task and allow them more opportunities to apply their learning in real-life contexts. My findings corroborated the results of McCarty, Hadley Lynch, Wallace and Benally (1991) who compared inquiry-based learning with whole-class lectures and found increased student participation levels and greater interest when students connected their mathematics learning to the social, economic and cultural realities of their society.

For the Abu Dhabi context, the findings reported in this thesis are important given that research has shown that the value students place on tasks tend to be strong predictors of positive attitudes and prolonged interest in academic disciplines (Acee et al., 2018; Wigfield & Eccles, 2000). In Abu Dhabi, the findings indicate that inquiry-based learning could be useful in reaching the mandate of the reform efforts. It is recommended, therefore, to further support teachers who are not yet exemplary in the use of explorations, exemplar tasks for teaching and learning, and not just assessment, could be developed specific for the UAE context and in topic areas of particular interest to the age of the target students (*Recommendation 4*).

5.2.4.3 Theme 3: Inquiry and Investigation

The third theme indicated that:

- Students in classes with teachers exemplary in the use of explorations had opportunities within the learning process to inquire and investigate. The teaching process was active, allowing students to research using a variety of sources. Students taught by teachers who were not exemplary in the use of explorations were more likely to complete prescribed questions from the textbook with less opportunities for inquiry or investigation.
- Teachers exemplary in the use of explorations were more likely to give students open-ended tasks whereas the teachers who were not tended to provide traditional closed teaching and learning opportunities. Groups of students in classes taught by teachers exemplary in the use of explorations were able to take the work in differing directions with different process and products to other groups within the class. In the classes with teachers not exemplary in the use of explorations, students tended to all complete the same work using the same processes.
- Teachers exemplary in the use of explorations were more likely to give students the opportunities to reflect on their work and to discuss limitations in both the processes and the final products and conclusions that they made, than their counterparts who were not.

My findings, with respect to the differences reported through lesson observations and focus group interviews with teachers exemplary in the use of explorations and those who were not, generally reflected student responses to the surveys. The survey results indicated statistically significant ($p<.01$) differences for the Critical Voice, Student Negotiation, Shared Control and Investigation scales from the LEIS, that were higher for students in classes taught by teachers exemplary in the use of explorations than those who were not.

Overall, the qualitative results, in terms of inquiry and investigation, supported those of Wolf and Fraser (2008), who found that students who participated in inquiry activities had more freedom to investigate their topic. They stated that, "students in the inquiry class were not confined to specific directions and were often found to explore interactions in greater detail than did students in the non-inquiry group" (Wolf & Fraser, 2008, p. 337). Considering ADEC's move towards inquiry-based learning, which requires students to develop and apply their inquiry and investigation skills, it is important that students be given these opportunities. The students of teachers exemplary in the use of explorations in this study had significantly greater opportunities to do this. Therefore, it is recommended that ADEC support all teachers to deliver quality inquiry-based learning (*Recommendation 5*).

This study supports past research which indicates that, when examining the effectiveness of teacher improvements in new pedagogies, such as inquiry-based learning, instruments assessing the learning environment can be utilised as process criterion. The study reported in this thesis further corroborates the usefulness of using the learning environment as process criterion in the evaluation of the implementation of a pedagogical innovation. It is recommended, therefore, that the continuing impact of the implementation of inquiry-based learning in Abu Dhabi's schools could be monitored through the use of the LEIS or other learning environment instruments (*Recommendation 6*). Further, it is recommended that students' perceptions of the learning environment during the implementation of inquiry-based learning is studied further, particularly when used in education reform *(Recommendation 7).*

Research suggests that the use of inquiry-based learning positively impacts on students' attitudes (Fielding-Wells et al., 2017). In the case of the study reported in this thesis, when students were taught by a teacher exemplary in the use of explorations, they reported more enjoyment of mathematics, greater self-efficacy and higher levels of task value than their peers in classes with teachers who were not. This supports previous research that has shown positive associations between inquiry-based learning and students' enjoyment (Bruder & Prescott, 2013; Camenzuli & Buhagiar, 2014; Kreuzer & Dreesmann, 2017); self-efficacy (Chase et al., 2013; Glynn et al., 2015; Kang & Keinonen, 2017; Laine et al., 2017; McElvain & Smith, 2016; Qureshi et al., 2017; Rocard et al., 2007; Tapola et al., 2013); and task value (Fielding-Wells et al., 2017; Heindl & Nader, 2018). Much of the research identified above took place in Western countries, namely Germany, Finland, US, Australia and Belgium, so the fact that the same holds true for the context of the UAE is an interesting consideration. Given the emphasis on STEM education, and the importance of this to national goals of the UAE (Abu Dhabi Government, 2008), this finding is encouraging and implies the value of inquiry-based learning and the education reform effects in mathematics specifically. It is recommended, therefore, that further studies to investigate whether similar results hold true for inquiry-based learning in other subjects (*Recommendation 8*).

My study highlights that the differences between the ways that teachers are implementing inquiry, despite professional development opportunities for all mathematics teaching staff, impact students' attitudes. The implementation of new pedagogies and practices tends to have difficulties, particularly in large-scale reform, where the aim is to have consistent practices over a large number of schools. These issues of implementation could be due to cultural differences, teacher beliefs and professional development. Although outside the scope of this study, in the context of Middle Eastern educational reform, the issue of culture and cultural differences should not be ignored. Culture influences the way that individuals act, feel and think, and impacts their reactions, interactions with others and interpretation of events (Dahl, 2004; Hall, 1959; Hall & Hall, 1990; Neuliep, 2011). When trying to implement inquiry-based learning, the role of the teacher changed from a source of all knowledge and prestige at the front of the room to a facilitator. This dynamic was very different to traditional roles within teaching and learning and particularly for cultures with a high power distance index as for the UAE (Hofstede, Hofstede, & Minkov, 1991, 2010). It is recommended that further studies examine the role of culture, particularly Middle Eastern cultures, in relation to the implementation of inquiry-based learning *(Recommendation 9).*

Introducing new pedagogies, which for this study was inquiry-based learning, can be inhibited by teacher beliefs, resistant to change and a lack of understanding of what is required for implementation. Research shows that, when teachers are required to make a change, such as introducing new curricula or pedagogical approaches, they often believe that they are implementing what is required of them (Karavas-Doukas, 1996; Kleve, 2004). Teachers may not even be aware that they have misunderstood and misinterpreted the practices required in the education reform and have reverted to their traditional practices (Karavas-Doukas, 1996; Kleve, 2004; M. F. Pajares, 1992). In this study, the teachers of explorations who were not exemplary in their practice, believed that they were implementing the requirements of the education reform as they were meeting ‘content’ stipulations in the curriculum documentation. Their beliefs around pedagogy meant they misunderstood how their teaching practices were also required to change, as well as the content they taught. An educational reform requires not just pockets of excellence but consistent practice across teachers and schools. It is recommended, therefore, that further research investigates the relationship between teacher beliefs about pedagogy and the impact on implementing reform initiatives such as inquiry-based learning in the Middle Eastern context *(Recommendation 10).*

As with any innovation, for the introduction of inquiry-based learning to be effective, teacher professional development must be provided (Oliveira, 2010). Past research indicates that the move from traditional teaching to inquiry-based learning requires teachers to develop a raft of new skills such as the use of questioning techniques and managing student requests for right answers (Furtak, 2006; Keys & Kennedy, 1999; Roehrig & Luft, 2004); managing teacher versus student roles (Hayes, 2002); and managing classroom behaviour (Lotter, 2004). To help to ensure effective implementation of inquiry, it is recommended that ongoing and robust teacher professional development is incorporated in the strategy (*Recommendation 11*).

5.3 Limitations of the Study

Whenever research is undertaken, there are limitations to the study that are characteristic of design or methodology that may have impacted or influenced the interpretation of the findings. In this section possible limitations that should be considered when generalising the data are discussed.

The results of this study add to a multitude of other studies that have developed valid reliable instruments. However, it must be considered that most of these studies, including this one, have used exploratory factor analysis to examine the factor structure rather than the use of confirmatory factor analysis. Whilst this was acceptable for this study, given the modifications made and the unique sample, it is recommended that future studies further establish the validity of the LEIS and SATMS using confirmatory factor analysis (*Recommendation 12*). Further, it is recommended that future use of the LEIS and SATMS involve a larger sample across more schools in the

UAE, including some of each of the other six emirates, to further establish the reliability of the survey throughout the country (*Recommendation 13*).

A further limitation of the study was the restricted number of factors impacted by the use of inquiry-based learning that were included. Although important outcomes were included in the study, it is recommended that further research looks at other factors that may be impacted using inquiry-based learning, such as student achievement (*Recommendation 14*).

Another limitation involved the time period of data collection. The data collected in this study was gathered over a short space of time, thereby creating a 'snapshot' of the situation. Although outside of the scope of the study, a longitudinal study would allow the investigation to determine whether inquiry-based learning is useful for students at different stages of their schooling (*Recommendation 15*).

Concerning the sample used in my study, there were four limitations: locality; grade levels; female student participants; and number of teachers. Whilst most of these factors were outside of the researcher's control, these limitations are discussed below.

The first limitation concerns the locality of where the sample was gathered. The study was based in schools in the area of Abu Dhabi city and in the Emirate of Abu Dhabi and so generalising results to the rest of the UAE should be done with care. It is recommended that future research involve a wider geographical area looking at schools both in other regions of the Emirate of Abu Dhabi, such as Al Ain and Al Dhafra, as well as the other six emirates of the UAE (*Recommendation 16*).

The second limitation regards the selection of students from different grade levels. In public schools in the UAE the usual practice is for a mathematics teacher to teach three classes from one grade level only. This means that, when teachers who met the criteria for a teacher exemplary in the use of explorations were recommended to participate in the study, the surveys were administered to the students who they taught, all of whom were from the same grade. However, this may have been a different grade to other teachers included within the sample. Whilst all students were from Cycle 2 (grades 6 to 9) classes and were, therefore, all in the middle years of schooling, it is noted that, had the sample been larger, it would have been possible to carry out additional analyses for the purpose of investigating whether grade level differences affected students' perceptions of the learning environment and attitudes. The findings of past research indicate that grade levels can impact learning environment perceptions (Wentzel, Battle, Russell, & Looney, 2010), therefore, it is recommended that future studies include a larger sample to investigate grade level differences (*Recommendation 17*).

The third limitation concerns the participants being female only. Although it is acknowledged that, having male students would have made the results more generalisable, only female teachers were classified as using explorations in an exemplary manner (see Chapter 3 for selection details). Given that, in public schools in Abu Dhabi, female teachers can only teach female students, this cohort included only female students. To make a valid comparison between the two teacher types, a decision was made to include only female teachers for both groups. Given that gender differences have been found to impact students' perceptions of the learning environment (Wahyudi & Treagust, 2004b; Wolf & Fraser, 2008) and attitudes towards mathematics (Vandecandelaere et al., 2012), generalising results to include male students should be made with caution. Therefore, it is recommended that future studies researching similar topics should include both male and female samples (*Recommendation 18*).

The final limitation regarding the sample was the number of teachers involved in the study. There were a limited number of teachers identified as being exemplary in the use of explorations and so this impacted the size of the teacher sample. The impact of the small number of teachers also affected the number of students within the total sample thereby creating limitations on the types of data analyses that could be used. Although in-depth qualitative data was collected, the sample limited the analysis of the quantitative data. In particular, although it was possible to use exploratory factor analysis, the data was not sufficient to split to include confirmatory factor analysis. It is recommended, therefore, that future studies involve a larger teacher sample to ensure greater generalisability and a larger student sample *(Recommendation 19).*

5.4 Summary of Recommendations

Recommendation 1: Development of practical strategies and professional development opportunities, both initial training and ongoing mentoring and support, to promote changes in the learning environment throughout the Emirate of Abu Dhabi and the UAE.

Recommendation 2: To upskill teachers in the use of inquiry through professional development, exemplars of tasks and students work, model lessons and in-school support.

Recommendation 3: In the education reform in Abu Dhabi, quality inquiry-based learning is continued, and any teachers identified as exhibiting teaching that is not exemplary be supported to improve their pedagogical approaches.

Recommendation 4: Development of exemplar tasks that are specific to the UAE context and of particular interest to students in middle school.

Recommendation 5: That ADEC support all teachers to deliver quality inquiry-based learning.

Recommendation 6: Further research to monitor the continuing impact of the implementation of inquiry-based learning in Abu Dhabi through the use of the LEIS or other learning environment instruments.

Recommendation 7: The use of inquiry-based learning to improve students' perceptions of their learning environment should be studied further, particularly in reform contexts.

Recommendation 8: Further studies to be conducted to investigate if similar results concerning positive student outcomes hold true for inquiry-based learning in subjects other than mathematics.

Recommendation 9: Further studies should examine the role of culture, particularly Middle Eastern cultures, in relation to the implementation of inquiry-based learning.

Recommendation 10: Further research should investigate the relationship between teacher beliefs and the impact on implementing reform initiatives such as inquiry-based learning in the Middle Eastern context.

Recommendation 11: Teacher professional development is an integral part of any reform effort incorporating inquiry-based learning.

Recommendation 12: Future studies involving the use of confirmatory factor analysis (in addition to exploratory factor analysis) to further establish the validity of the LEIS and the SATMS.

Recommendation 13: Future studies administering the LEIS and the SATMS instruments involving a wider sample, particularly within the emirates of the UAE, to further establish reliability.

Recommendation 14: Further research should examine other factors that may be impacted using inquiry-based learning such as student achievement.

Recommendation 15: Longitudinal studies should be carried out to investigate student engagement with inquiry-based learning over time and at different points in mathematics education for students.

Recommendation 16: Further research should be conducted to improve the external validity of the study by extending the sample to include students in the wider area of the Emirate of Abu Dhabi, in Al Ain and Al Dhafra, and in the other six emirates of the United Arab Emirates.

Recommendation 17: Further research should be conducted with a wider sample to include students in differing age groups e.g. Cycle 1 (grades 1-5) and Cycle 3 (grades 10-12) to investigate whether grade level differences influence students' perceptions of the learning environment and attitudes towards mathematics.

Recommendation 18: Further research should replicate the study but include male and female samples.

Recommendation 19: Future studies to involve a larger teacher sample to enable the use of confirmatory factor analysis.

5.5 Significance of the Study

In the study reported in this thesis I investigated differences between students in classes where exemplary use of explorations was used when compared to students who were not (in terms of learning environment perceptions and student attitudes). The findings indicated that students had differing experiences, perceptions and attitudes in classrooms where the teacher was exemplary in the use of inquiry teaching, learning and assessing methodology compared with teachers who were not considered exemplary. This research is significant for its methodological and practical contributions.

The research is methodologically significant in the development and validation of two instruments, the Learning Environment in Inquiry Survey (LEIS, to assess students' perceptions of an inquiry-based learning environment) and the Student Attitudes Towards Mathematics Survey (SATMS, to assess students' attitudes). These instruments bring together scales that are suitable for the reform efforts in mathematics teaching, learning and assessment in Abu Dhabi. Further, validation of these instruments makes available an economic tool that could be used at the teacher, school and emirate-wide policy level.

Given the dearth of instruments available in the Arabic language that have been validated for use in the UAE, the development and validation of the LEIS and SATMS adds to the tools available to monitor the education reform efforts in the UAE. The validation of these instruments in the Arabic language also contributes to research in Arabic-speaking countries and provide a means for researchers and educators to assess students' perceptions of the learning environment and attitudes towards mathematics.

The results of the study reported in this thesis show positive and statistically significant relationships between the learning environment and students' attitudes. Whilst this replicates the findings of research undertaken in countries around the world, this study is significant because it has been found in mathematics classrooms (as opposed to the more common research in science classes). Further these findings are significant in that they were replicated for classes in the UAE, where learning environment research is still in its infancy.

Importantly, the findings of the study, which suggest that students in classes with teachers exemplary in the use of explorations report more positive attitudes and perceive their learning environment more favourably, are of significance to policymakers within ADEC, and for school administration and teachers. These findings affirm that it could be worthwhile to include explorations as a means of achieving the reform goals in Abu Dhabi. Further, as part of the reform efforts, the findings provide consideration into the importance of the classroom learning environment and how perceptions can impact the implementation of educational innovations and associated student outcomes.

The results of this study are significant for teachers wishing to implement explorations in the teaching and assessment of mathematics. The use of teaching, learning and assessing using explorations is entirely unique to public schools in the UAE and is such being assessed as an educational innovation. The data collected can be utilised at an individual teacher level where they can be encouraged to be a reflective practitioner and change their teaching practices in ways that improve the learning environment. Data can also be utilised as part of school improvement initiatives which are a vital component of the reform efforts in Abu Dhabi, as each school is tasked with developing, implementing and reporting on school improvement plans.

The data and analysis gathered from the use of the instruments could be significant for those employed at a policy level for the Emirate of Abu Dhabi. These results could be used to inform professional development programmes, including coaching and mentoring to improve the quality of teaching and learning through inquiry and can be used as a vehicle for teachers to improve practice, thereby engaging students and improving attitudes towards mathematics. The end-goal of this would be to increase student numbers in mathematical courses at universities and in careers. Professional development services could utilise learning environment and attitude instruments as part of their provision, allowing for data and research-driven responses to the effectiveness of their programmes within the reform agenda.

An important and unique aspect of this study was the assessment of student attitudes towards mathematics and the comparison of the difference when students were taught by teachers exemplary in the use of explorations and those who were not. The findings are of significance for policymakers in education. Given that attitude research in mathematics in the UAE is not prevalent, yet social issues exist within the country due to disengaged students (OECD, 2015), the findings from this study, that indicate that quality inquiry-based learning, can be used to improve students' attitudes towards learning mathematics. Therefore, this thesis adds to the field of study in attitude research, specifically in the UAE.

Research focusing on the implementation of inquiry-based learning have been prevalent in Western settings (Bruder & Prescott, 2013; J. C. Marshall & Horton, 2011; Wolf & Fraser, 2008), however, similar studies within the context of the Middle East are not as common. My study is significant in that it decreases this research void, providing research that focuses on the use of inquiry-based learning within an Arab nation, useful and significant for researchers based in the Middle East.

The results reported in this thesis are significant for policymakers within ADEC. As the UAE continues with its educational reforms in Abu Dhabi through the Abu Dhabi Education Council, the need for research that investigates the changes in the reform is required. Research in education in the Emirate of Abu Dhabi is approved and collected by ADEC from the researchers themselves and disseminated via the website allowing the community access to findings and recommendations. This study adds to the data collected by ADEC, and allows for some much needed, relevant, and distinctive research that will inform further steps in the implementation of mathematics pedagogical approaches assessed through analysis of students' perceptions of learning environments and attitudes.

5.6 Concluding Remarks

The results and findings presented in this thesis suggest that teachers exemplary in the use of explorations promote more favourable perceptions of the learning environment and more positive attitudes towards mathematics. Although the focus of this study was on inquiry-based learning within mathematics classes, the findings could help educators improve their learning environments, and therefore, student attitudes in other subjects. In particular, the findings suggest that students who experience a more positive environment, find more value in the tasks they complete, have greater self-efficacy and experience enjoyment in their mathematics classes. These findings have wide-spread implications for a variety of stakeholders, including, policy makers, researchers, governmental and other educational institutions, school leaders and administrators and teachers focusing on improving learning environment and student attitude outcomes.

The education reform in Abu Dhabi will not be successful until there is consistency across schools in excellent teaching, learning and assessment throughout the emirate. The results presented in this thesis could become the basis of further research and provide the impetus for increased support for teachers to help them to effectively engage students and encourage them to enjoy their mathematics classes.

REFERENCES

Abu Dhabi Education Council. (2012a). *ADEC Mathematics Assessment Framework*. Abu Dhabi: Abu Dhabi Education Council

Abu Dhabi Education Council. (2012b). *The foundation of the New School Model: An introduction for teachers*. Abu Dhabi: Abu Dhabi Education Council

Abu Dhabi Education Council. (2013). *Cycle 2 Mathematics Curriculum - Teacher Guidebook*. Abu Dhabi: Abu Dhabi Education Council

Abu Dhabi Education Council website. (2016). *About ADEC*. Retrieved from https://www.adec.ac.ae/en/AboutADEC/Pages/default.aspx

Abu Dhabi Government. (2007). *Policy Agenda 2007-2008 for the Emirate of Abu Dhabi*. Abu Dhabi: Abu Dhabi Government

Abu Dhabi Government. (2008). *The Abu Dhabi Economic Vision 2030*. Abu Dhabi: Abu Dhabi Government

Abu Dhabi Urban Planning Council. (2007). *Plan Abu Dhabi 2030 urban structure framework plan*. Abu Dhabi: Abu Dhabi Government

Acee, T. W., Weinstein, C. E., Hoang, T. V., & Flaggs, D. A. (2018). Value reappraisal as a conceptual model for task-value interventions. *Journal of Experimental Education, 86*(1), 69-85. doi:http://dx.doi.org/10.1080/00220973.2017.1381830

Afari, E., Aldridge, J. M., & Fraser, B. J. (2012). Effectiveness of using games in tertiary-level mathematics classrooms. *International Journal of Science and Mathematics Education, 10*(6), 1369-1392. doi:http://dx.doi.org/10.1007/s10763-012-9340-5

Afari, E., Aldridge, J. M., Fraser, B. J., & Khine, M. S. (2013). Students' perceptions of the learning environment and attitudes in game-based mathematics classrooms. *Learning Environments Research, 16*(1), 131-150. doi:http://dx.doi.org/10.1007/s10984-012-9122-6

Agar, M. H. (1980). *The professional stranger: An informal introduction to ethnography*. San Diego, CA: Academic Press.

Ahmed, W., Minnaert, A., van der Wef, G., & Kuyper, H. (2010). Perceived social support and early adolescents' achievement: The mediational roles of motivational beliefs and emotions. *Journal of Youth and Adolescence, 39*, 36-46. doi:http://dx.doi.org/10.1007/s10964-008-9367-7

Ahmed, W., van der Wef, G., Kuyper, H., & Minnaert, A. (2013). Emotions, self-regulated learning, and achievement in mathematics: A growth curve analysis. *Journal of Educational Psychology, 105*, 150-161. doi:http://dx.doi.org/10.1037/a0030160

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology, 36*(1), 4-12. doi:http://dx.doi.org/10.1016/j.cedpsych.2010.08.001

Al Qasimi Foundation for Policy Research. (2014). *Education in the United Arab Emirates and Ras Al Khaimah*. Retrieved from http://www.alqasimifoundation.com/en/publication/12/fact-sheet-education-in-the-united-arab-emirates-and-ras-al-khaimah

Aldridge, J. M., Afari, E., & Fraser, B. J. (2012). Influence of teacher support and personal relevance on academic self-efficacy and enjoyment of mathematics lessons: A structural equation modeling approach. *Alberta Journal of Educational Research, 58*(4), 614-633. doi:http://dx.doi.org/10.1037/t38960-000

Aldridge, J. M., & Fraser, B. J. (2000). A cross-cultural study of classroom learning environments in Australia and Taiwan. *Learning Environments Research, 3*(2), 101-134. doi:http://dx.doi.org/10.1023/A:1026599727439

Aldridge, J. M., Fraser, B. J., Bell, L., & Dorman, J. (2012). Using a new learning environment questionnaire for reflection in teacher action research. *Journal of Science Teacher Education, 23*(3), 259-290. doi:http://dx.doi.org/10.1007/s10972-012-9268-1

Aldridge, J. M., Fraser, B. J., & Huang, T.-C. I. (1999). Investigating classroom environments in Taiwan and Australia with multiple research methods. *Journal of Educational Research, 93*(1), 48-62. doi:http://dx.doi.org/10.1080/00220679909597628

Aldridge, J. M., Fraser, B. J., & Ntuli, S. (2009). Utilising learning environment assessments to improve teaching practices among in-service teachers undertaking a distance-education programme. *South African Journal of Education, 29*, 147-170.

Aldridge, J. M., Fraser, B. J., Taylor, P. C., & Chen, C.-C. (2000). Constructivist learning environments in a cross-national study in Taiwan and Australia. *International Journal of Science Education, 22*(1), 37-55. doi:http://dx.doi.org/10.1080/095006900289994

Allen, D., & Fraser, B. J. (2007). Parent and student perceptions of classroom learning environment and its association with student outcomes. *Learning Environments Research, 10*(1), 67-82. doi:http://dx.doi.org/10.1007/s10984-007-9018-z

Allport, G. W. (1935). Attitudes. In C. M. Murchison (Ed.), *Handbook of social psychology* (pp. 798-844). Worcester, MA: Clark University Press.

Alt, D. (2018). Teachers' practices in science learning environments and their use of formative and summative assessment tasks. *Learning Environments Research, 21*(3), 387-406. doi:http://dx.doi.org/10.1007%2Fs10984-018-9259-z

Amaral, O., Garrison, L., & Klentschy, M. (2002). Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal, 26*(2), 213-239. doi:http://dx.doi.org/10.1080/15235882.2002.10668709

Ames, C., & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivational processes. *Journal of Educational Psychology, 80*, 260-267. doi:http://dx.doi.org/10.1037/0022-0663.80.3.260

Anderson, A., Hamilton, R. J., & Hattie, J. A. (2004). Classroom climate and motivated behaviour in secondary schools. *Learning Environments Research, 7*, 211-225. doi:http://dx.doi.org/10.1007/s10984-004-3292-9

Ashby, F. G., Isen, A. M., & Turken, A. U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review, 106*, 529-550. doi:http://dx.doi.org/10.1037/0033-295X.106.3.529

Assor, A., Kaplan, H., & Roth, G. (2002). Choice is good, but relevance is excellent: Autonomy-enhancing and suppressing teacher behaviours in predicting student's engagement in school work. *British Journal of Educational Psychology, 72*, 261-278. doi:http://dx.doi.org/10.1348/000709902158883

Baeten, M., Dochy, F., & Struyven, K. (2013). The effects of different learning environments on students' motivation for learning and their achievement. *British Journal of Educational Psychology, 83*(3), 484-501. doi:http://dx.doi.org/10.1111/j.2044-8279.2012.02076.x

Bain, J. (2010). Integrating student voice: Assessment for empowerment. *Practitioner Research in Higher Education, 4*(1), 14-29. doi:http://dx.doi.org/1755-1382

Bakkenes, I., Vermunt, J. D., & Wubbels, T. (2010). Teacher learning in the context of educational innovation: Learning activities and learning outcomes of experienced teachers. *Learning and Instruction, 20*, 533-548. doi:http://dx.doi.org/10.1016/j.learninstruc.2009.09.001

Balentyne, P., & Varga, M. A. (2017). Attitudes and achievement in a self-paced blended mathematics course. *Journal of Online Learning Research, 3*(1), 55-72.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215. doi:http://dx.doi.org/10.1037/0033-295X.84.2.191

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*(2), 122-147. doi:http://dx.doi.org/10.1037/0003-066X.37.2.122

Barron, B., & Darling-Hammond, L. (2010). Prospects and challenges for inquiry-based approaches to learning. In H. Dumont, D. Istance, & F. Benavides (Eds.), *The nature of learning: Using research to inspire practice* (pp. 199-225). Paris: OECD Publishing.

Beck, J., Czerniak, C. M., & Lumpe, A. T. (2000). An exploratory study of teachers' beliefs regarding the implementation of constructivism in their classroom. *Journal of Science Teacher Education, 11*, 323-343. doi:http://dx.doi.org/10.1023/A:1009481115135

Boaler, J. (1997). *Experiencing school mathematics: Teaching styles, sex and setting*. Buckingham, England: Open University Press.

Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. *Journal for Research in Mathematics Education, 29*(1), 41-62.

Boekaerts, M. (2002). *Motivation to learn*. Paris: UNESCO.

Bong, M. (2005). Within-grade changes in Korean girls' motivation and perceptions of the learning environment across domains and achievement levels. *Journal of Educational Psychology, 97*(4), 656-672. doi:http://dx.doi.org/10.1037/0022-0663.97.4.656

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academies Press.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:http://dx.doi.org/10.1191/1478088706qp063oa

Bredo, E. (1994). Reconstructing educational psychology: Situated cognition and Deweyan pragmatism. *Educational Psychologist, 29*, 23-25.

Brown, T. A. (2006). *Confirmatory factor analysis for applied research*. New York: Guilford Press.

Bruder, R., & Prescott, A. (2013). Research evidence on the benefits of IBL. *ZDM The International Journal on Mathematics Education, 45*(6), 811-822. doi:http://dx.doi.org/10.1007/s11858-013-0542-2

Buff, A., Reusser, K., & Dinkelmann, I. (2017). Parental support and enjoyment of learning in mathematics: Does change in parental support predict change in enjoyment of learning? *ZDM The International Journal on Mathematics Education, 49*(3), 423-434. doi:http://dx.doi.org/10.1007/s11858-016-0823-7

Bybee, R. W., Taylor, J. A., Gardner, A., Scotter, P. V., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins, effectiveness, and applications*. Colorado Springs, CO: BSCS and NIH.

Camenzuli, J., & Buhagiar, M. A. (2014). Using inquiry-based learning to support the mathematical learning of students with SEBD. *International Journal of Emotional Education, 6*(2), 69-85.

Cannon, J. R. (1995). Further validation of the Constructivist Learning Environment Survey: Its use in the elementary science methods course. *Journal of Elementary Science Education, 7*(1), 47-62. doi:http://dx.doi.org/10.1007/BF03173772

Cavanagh, R. F. (2015). A unified model of student engagement in classroom learning and classroom learning environment: One measure and one underlying construct. *Learning Environments Research, 18*(3), 349-361. doi:http://dx.doi.org/10.1007/s10984-015-9188-z

Cetin-Dindar, A. (2016). Student motivation in constructivist learning environment. *EURASIA Journal of Mathematics, Science & Technology Education, 12*(2), 233-247. doi:http://dx.doi.org/10.12973/eurasia.2016.1399a

Chairam, S., Klahan, N., & Coll, R. K. (2015). Exploring secondary students' understanding of chemical kinetics through Inquiry-based learning activities.

EURASIA Journal of Mathematics, Science & Technology Education, 11(5), 937-956. doi:http://dx.doi.org/10.12973/eurasia.2015.1365a

Chapman, O., & Heater, B. (2010). Understanding change through a high school mathematics teacher's journey to inquiry-based teaching. *Journal of Mathematics Teacher Education, 13*(6), 445-458. doi:http://dx.doi.org/10.1007/s10857-010-9164-6

Chase, A., Pakhira, D., & Stains, M. (2013). Implementing process-oriented, guided-inquiry learning for the first time: Adaptations and short-term impacts on students' attitude and performance. *Journal of Chemical Education, 90*(4), 409-416. doi:http://dx.doi.org/10.1021/ed300181t

Cheng, Y. C. (1994). Classroom environment and student affective performance: An effective profile. *Journal of Experimental Education, 62*, 221-239. doi:http://dx.doi.org/10.1080/00220973.1994.9943842

Chionh, Y. H., & Fraser, B. J. (2009). Classroom environment, achievement, attitudes and self-esteem in geography and mathematics in Singapore. *International Research in Geographical and Environmental Education, 18*(1), 29-44. doi:http://dx.doi.org/10.1080/10382040802591530

Chipangura, A., & Aldridge, J. M. (2017). Impact of multimedia on students' perceptions of the learning environment in mathematics classrooms. *Learning Environments Research, 20*(1), 121-138. doi:http://dx.doi.org/10.1007/s10984-016-9224-7

Cho, J.-I., Yager, R. E., Park, D.-Y., & Seo, H.-A. (1997). Changes in high school teachers' constructivist philosophies. *School Science and Mathematics, 97*(8), 400-405. doi:http://dx.doi.org/10.1111/j.1949-8594.1997.tb17384.x

Choi, N. (2005). Self-efficacy and self-concept as predictors of college students' academic performance. *Psychology in the Schools, 42*(2), 197-205. doi:http://dx.doi.org/10.1002/pits.20048

Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological Assessment, 7*(3), 309-319. doi:http://dx.doi.org/10.1037/1040-3590.7.3.309

Clark, M. (1998). The qualitative-quantitative debate: Moving from positivism and confrontation to post-positivism and reconciliation. *Journal of Advanced Nursing, 27*(6), 1242-1249. doi:http://dx.doi.org/10.1046/j.1365-2648.1998.00651.x

Clarke, V., & Braun, V. (2013). Teaching thematic analysis: Overcoming challenges and developing strategies for effective learning. *The Psychologist, 26*(2), 120-123.

Coakes, S., & Ong, C. (2010). *SPSS: Analysis without anguish using SPSS version 18.0 for Windows*. Milton, Queensland: John Wiley.

Cobb, P. (2002). Reasoning with tools and inscriptions. *Journal of the Learning Sciences, 11*(2-3), 187-215. doi:http://dx.doi.org/10.1080/10508406.2002.9672137

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. USA: Lawrence Erlbaum Associates.

Cohen, L., & Manion, L. (1994). *Research methods in education* (4th ed.). London: Routledge.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed.). London: Routledge Falmer.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Oxon, UK: Routledge.

Cole, J. S., Bergin, D. A., & Whittaker, T. A. (2008). Predicting student achievement for low stakes tests with effort and task value. *Contemporary Educational Psychology, 33*(4), 609-624. doi:http://dx.doi.org/10.1016/j.cedpsych.2007.10.002

Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. In M. R. Gunnar & L. A. Sroufe (Eds.), *Self-processes and development* (Vol. 23, pp. 43-77). Hillsdale, NJ: Erlbaum.

Cope, D. (2014). Methods and meanings: Credibility and trustworthiness of qualitative research. *Oncology Nursing Forum, 41*(1), 89-91. doi:http://dx.doi.org/10.1188/14.ONF.89-91

Creswell, J. W. (2008). *Educational research*. Upper Saddle River, New Jersey, USA: Pearson Prentice Hall.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). Los Angeles, CA: Sage.

Creton, H., Hermans, J., & Wubbels, T. (1990). Improving interpersonal teacher behaviour in the classroom: A systems communication perspective. *South Pacific Journal of Teacher Education, 18*, 85-94. doi:http://dx.doi.org/10.1080/0311213900180202

Crotty, M. (1998). *The foundations of social research*. London: Sage.

Daher, W., & Saifi, A.-G. (2018). Democratic practices in a constructivist science classroom. *International Journal of Science and Mathematics Education, 16*(2), 221-236. doi:http://dx.doi.org/10.1007%2Fs10763-016-9772-4

Dahl, S. (2004). *Intercultural research: The current state of knowledge*. London, UK: Middlesex University Business School.

Dary, T., Pickeral, T., Shumer, R., & Williams, A. (2016). *Weaving student engagement into the core practices of schools: A national dropout prevention center/network position paper*. Retrieved from Clemson, SC: www.dropoutprevention.org/resources/major-research-reports/studentengagement/student-engagement-2016-09.pdf

De Juan, J., Pérez-Cañaveras, R. M., Segovia, Y., Girela, J. L., Martínez-Ruiz, N., Romero-Rameta, A., . . . Vizcaya-Moreno, M. F. (2016). Student perceptions of the cell biology laboratory learning environment in four undergraduate science courses in Spain. *Learning Environments Research, 19*(1), 87-106. doi:http://dx.doi.org/10.1007/s10984-015-9201-6

Deignan, T. (2009). Enquiry-based learning: Perspectives on practice. *Teaching in Higher Education, 14*(1), 13-28. doi:http://dx.doi.org/10.1080/13562510802602467

den Brok, P., Fisher, D. L., Rickards, T., & Bull, E. (2006). Californian science students' perceptions of their classroom learning environments. *Educational Research and Evaluation, 12*(1), 3-25. doi:http://dx.doi.org/10.1080/13803610500392053

Department of Education and Training. (2018). *Amplify: Empowering students through voice, agency and leadership*. Melbourne, Australia: Department of Education and Training

Dewey, J. (1948, 1920). *Reconstruction in philosophy*. Boston, MA: Beacon Press.

Diezmann, C., Watters, J., & English, L. (2001). *Difficulties confronting young children undertaking investigations.* Paper presented at the 26th Annual Meeting of the International Group for the Psychology of Mathematics Education, Utrecht, The Netherlands.

Donovan, S. M., & Bransford, J. D. (2005). *How students learn: History, mathematics, and science in the classroom*. Washington, DC: National Academies Press.

Doran, C., & Cameron, R. J. (1995). Learning about learning: Metacognitive approaches in the classroom. *Educational Psychology in Practice, 11*, 15-23. doi:http://dx.doi.org/10.1080/0266736950110203

Dorman, J. P. (2001). Associations between classroom environment and academic efficacy. *Learning Environments Research, 4*(3), 243-257. doi:http://dx,doi.org/10.1023/A:1014490922622

Dorman, J. P. (2003). Cross-national validation of the What is Happening in this Class? (WIHIC) questionnaire using confirmatory factor analysis. *Learning Environments Research, 6*(3), 231-245. doi:http://dx.doi.org/10.1023/A:1027355123577

Dorman, J. P. (2008). Use of multitrait-multimethod modelling to validate actual and preferred forms of the What Is Happening In this Class? (WIHIC) questionnaire. *Learning Environments Research, 11*(3), 179-193. doi:http://dx.doi.org/10.1007/s10984-008-9043-6

Dorman, J. P. (2009). Associations between psychosocial environment and outcomes in technology-rich classrooms in Australian secondary schools. *Research in Education, 82*(1), 69-84. doi:http://dx.doi.org/10.7227/RIE.82.6

Dorman, J. P., & Adams, J. (2004). Associations between students' perceptions of classroom environment and academic efficacy in Australian and British secondary schools. *Westminster Studies in Education, 27*(1), 69-85. doi:http://dx.doi.org/10.1080/0140672040270106

Dorman, J. P., Adams, J., & Ferguson, J. M. (2001). Psychosocial environment and student self-handicapping in secondary school mathematics classes: A cross national study. *Educational Psychology, 22*, 499-511. doi:http://dx.doi.org/10.1080/0144341022000023590

Dorman, J. P., & Fraser, B. J. (2009). Psychosocial environment and affective outcomes in technology rich classrooms: Testing a causal model. *Social Psychology of Education: An International Journal, 12*, 77-99.

Durik, A. M., Vida, M., & Eccles, J. S. (2006). Task values and ability beliefs as predictors of high school literacy choices: A developmental analysis. *Journal of Educational Psychology, 98*, 382-393. doi:http://dx.doi.org/10.1037/0022-0663.98.2.382

Ebrahimi, N. A. (2015). Validation and application of the Constructivist Learning Environment Survey in English language teacher education classrooms in Iran. *Learning Environments Research, 18*(1), 69-93. doi:http://dx.doi.org/10.1007/s10984-015-9176-3

Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement-related choices. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 105-121). New York: The Guildford Press.

Eccles, J. S. (2007). Families, schools, and developing achievement related motivations and engagement. In J. E. Grusec & P. D. Hastings (Eds.), *Handbook of socialization* (pp. 665-691). New York: Guilford Press.

Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., & Meece, J. L. (1983). Expectancies, values, and academic behavior. In J. T. Spencer (Ed.), *Achievement and achievement motivation* (pp. 75-146). San Francisco: W. H. Freeman.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109-132. doi:http://dx.doi.org/10.1146/annurev.psych.53.100901.135153

Ely, R., Ainley, M., & Pearce, J. (2013). More than enjoyment: Identifying the positive affect component of interest that supports student engagement and achievement. *Middle Grades Research Journal, 8*(1), 13-32.

Embassy of the UAE. (2011). *UAE history*. Retrieved from http://www.uaecd.org/uae-history

Ercikan, K. (1998). Translation effects in international assessments. *International Journal of Educational Research, 29*, 543-553. http://dx.doi.org/10.1016/S0883-0355(98)00047-0

Fast, L. A., Lewis, J. L., Bryant, M. J., Bacian, K. A., Cardullo, R. A., Rettig, M., & Hammond, K. A. (2010). Does math self-efficacy mediate the effect of the percieved classroom environment on standardized math test performance. *Journal of Educational Psychology, 102*(3), 729-740. doi:http://dx.doi.org/10.1037/a0018863

Fidel, R. (1993). Qualitative methods in information retrieval research. *Library and Information Science Research, 15*, 219-247.

Field, A. (2005). *Discovering statistics using SPSS* (2nd ed.). London: Sage.

Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). London: Sage.

Field, A. (2016). *Discovering statistics using IBM SPSS statistics* (5th ed.). London: Sage.

Fielding-Wells, J., O'Brien, M., & Makar, K. (2017). Using expectancy-value theory to explore aspects of motivation and engagement in inquiry-based learning in primary mathematics. *Mathematics Education Research Journal, 29*(2), 237-254. doi:http://dx.doi.org/10.1007/s13394-017-0201-y

Firestone, W. A. (1987). Meaning in method: The rhetoric of quantitative and qualitative research. *Educational Researcher, 16*(7), 16-21. doi:http://dx.doi.org/10.3102/0013189X016007016

Fischer, F. (1998). Beyond Empiricism: Policy inquiry in a post-positivist perspective. *Policy Studies Journal, 26*(1), 129-146. doi:http://dx.doi.org/10.1111/j.1541-0072.1998.tb01929.x

Fisher, D. L., & Fraser, B. J. (1983a). A comparison of actual and preferred classroom environment as perceived by science teachers and students. *Journal of Research in Science Teaching, 20*, 55-61. doi:http://dx.doi.org/10.1002/tea.3660200106

Fisher, D. L., & Fraser, B. J. (1983b). Validity and use of Classroom Environment Scale. *Educational Evaluation and Policy Analysis, 5*, 261-271. doi:http://dx.doi.org/10.3102/01623737005003261

Fisher, D. L., Henderson, D., & Fraser, B. J. (1995a). Interpersonal behavior in senior high school biology classes. *Research in Science Education, 25*(2), 125-133. doi:http://dx/doi.org/10.1007/BF02356447

Fisher, D. L., Henderson, D., & Fraser, B. J. (1995b). Interpersonal behaviour in senior high school biology classes. *Research in Science Education, 25*, 125-133. doi:http://dx/doi.org/10.1007/BF02356447

Fisher, D. L., Waldrip, B., & den Brok, P. (2005). Students' perceptions of primary teachers' interpersonal behavior and of cultural dimensions in the classroom environment, chapter 2. *International Journal of Educational Research, 43*(1-2), 25-38. doi:http://dx.doi.org/10.1016/j.ijer.2006.03.004

Flutter, J., & Ruddock, J. (2004). *Consulting pupils: What's in it for schools?* Great Britain: Routledge.

Fouts, J. T. (1989). Classroom environments and student views of social studies: The middle grades. *Theory and Research in Social Education, 17*(2), 136-147. doi:http://dx.doi.org/10.1080/00933104.1989.10505585

Fraser, B. J. (1990). *Individualised Classroom Environment Questionnaire*. Melbourne, Australia: Australian Council for Educational Research.

Fraser, B. J. (1998). Science learning environments: Assessment, effects and determinants. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 527-564). Dordrecht, The Netherlands: Kluwer.

Fraser, B. J. (2001). Twenty thousand hours: Editor's introduction. *Learning Environments Research: An International Journal, 4*, 1-5. doi:http://dx.doi.org/10.1023/A:1011406709483

Fraser, B. J. (2002). Learning environments research: Yesterday, today and tomorrow. In S. C. Goh & M. S. Khine (Eds.), *Studies in educational learning environments: An international perspective* (pp. 1-25). Singapore: World Scientific Publishing.

Fraser, B. J. (2007). Classroom learning environments. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 103-124). Mahwah, NJ: Lawrence Erlbaum Associates.

Fraser, B. J. (2012). Classroom learning environments: Retrospect, context and prospect. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *The second international handbook of science education* (pp. 1191-1239). New York: Springer.

Fraser, B. J. (2015). Classroom learning environments. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 154-157). Dordrecht: Springer.

Fraser, B. J. (2018). Milestones in the evolution of the learning environments field over the past three decades In D. B. Zandvliet & B. J. Fraser (Eds.), *Thirty years of learning environments: Looking back and looking forward* (pp. 1-19): Brill Sense.

Fraser, B. J., Aldridge, J. M., & Adolphe, S. F. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education, 40*(4), 551-571. doi:http://dx.doi.org/10.1007/s11165-009-9133-1

Fraser, B. J., Aldridge, J. M., & Soerjaningsih, W. (2010). Instructor-student interpersonal interaction and student outcomes at the university level in Indonesia. *The Open Education Journal, 3*, 32-44. doi:http://dx.doi.org/10.2174/1874920801003010021

Fraser, B. J., Anderson, G. J., & Walberg, H. J. (1982). *Assessment of learning environments: Manual for Learning Environment Inventory (LEI) and My Class Inventory (MCI)*. Perth, Australia: Western Australian Institute of Technology.

Fraser, B. J., & Fisher, D. L. (1983). Use of actual and preferred classroom environment scales in person-environment fit research. *Journal of Educational Psychology, 75*(2), 303-313. doi:http://dx.doi.org/10.1037/0022-0663.75.2.303

Fraser, B. J., & Fisher, D. L. (1986). Using short forms of classroom climate instruments to assess and improve classroom psychosocial environment. *Journal of Research in Science Teaching, 23*, 387-413. doi:http://dx.doi.org/10.1002/tea.3660230503

Fraser, B. J., Fisher, D. L., & McRobbie, C. J. (1996). *Development, validation and use of personal and class forms of a new classroom environment instrument*. Paper presented at the American Educational Research Association, New York.

Fraser, B. J., & Kahle, J. B. (2007). Classroom, home, and peer environment influences on student outcomes in science and mathematics: an analysis of systemic reform data. *International Journal of Science Education, 15*, 1891-1909. doi:http://dx.doi.org/10.1080/09500690601167178

Fraser, B. J., & Lee, S. S. (2009). Science laboratory classroom environments in Korean high schools. *Learning Environments Research, 12*(1), 67-84. doi:http://dx.doi.org/10.1007/s10984-008-9048-1

Fraser, B. J., & McRobbie, C. J. (1995). Science laboratory classroom environments at schools and universities: A cross-national study. *Educational Research and Evaluation, 1*, 289-317. doi:http://dx.doi.org/10.1080/1380361950010401

Fraser, B. J., McRobbie, C. J., & Giddings, G. J. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science. *Science Education, 77*, 1-24. doi:http://dx.doi.org/10.1002/sce.3730770102

Fraser, B. J., & Treagust, D. F. (1986). Validity and use of an instrument for assessing classroom psychosocial environment in higher education. *Higher Education, 15*, 37-57. doi:http://dx.doi.org/10.1007/BF00138091

Fraser, B. J., Treagust, D. F., & Dennis, N. C. (1986). Development of an instrument for assessing classroom psychosocial environment at universities and colleges. *Studies in Higher Education, 11*, 43-54. doi:http://dx.doi.org/10.1080/03075078612331378451

Fraser, B. J., Williamson, J. C., & Tobin, K. (1987). Use of classroom and school climate scales in evaluating alternative high schools. *Teaching and Teacher Education, 3*, 219-231. doi:http://dx.doi.org/10.1016/0742-051X(87)90005-9

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*, 59-109. doi:http://dx,doi.org/10.3102/00346543074001059

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist, 56*(3), 218-226. doi:http://dx.doi.org/10.1037/0003-066X.56.3.218

Frenzel, A. C., Goetz, T., Ludtke, O., Pekrun, R., & Sutton, R. E. (2009). Emotional transmission in the classroom: Exploring the relationship between teacher and student enjoyment. *Journal of Educational Psychology, 101*(3), 705-716. doi:http://dx.doi.org/10.1037/a0014695

Furtak, E. M. (2006). The problem with answers: An exploration of guided science inquiry teaching. *Science Education, 90*, 453-467. doi:http://dx.doi.org/10.1002/sce.20130

Gaad, E., Arif, M., & Scott, F. (2006). Systems analysis of the UAE education system. *International Journal of Educational Management, 20*(4), 291-303. doi:http://dx.doi.org/10.1108/09513540610665405

Gadanidis, G., Sedig, K., & Liang, H.-N. (2004). Designing online mathematical investigation. *Journal of Computers in Mathematics and Science Teaching, 23*(3), 275-298.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922-939. doi:http://dx.doi.org/10.1002/tea.20248

Geyer, P. D. (2018). Adjustment-seeking behavior: The role of political skill and self-efficacy in training students to be more actively engaged in their studies. *Active Learning in Higher Education, 19*(3), 225-237. doi:http://dx.doi.org/10.1177%2F1469787417721993

Glynn, S. M., Bryan, R. R., Brickman, P., & Armstrong, N. (2015). Intrinsic motivation, self-efficacy, and interest in science. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in Mathematics and Science Learning* (pp. 189-202). Washington: AERA.

Goetz, T., Nett, U. E., Martiny, S. E., Hall, N. C., Pekrun, R., Dettmers, S., & Trautwein, U. (2012). Students' emotions during homework: Structures, self-concept antecedents, and achievement outcomes. *Learning and Individual Differences, 22*(2), 225-234. doi:http://dx.doi.org/10.1016/j.lindif.2011.04.006

Goh, S. C., & Fraser, B. J. (1996). Validation of an elementary school version of the Questionnaire on Teacher Interaction. *Psychological Reports, 79*, 512-522. doi:http://dx.doi.org/10.2466/pr0.1996.79.2.515

Goh, S. C., Young, D. J., & Fraser, B. J. (1995). Psychosocial climate and students outcomes in elementary mathematics classrooms: A multilevel analysis. *Journal of Experimental Education, 64*, 29-40. doi:http://dx.doi.org/10.1080/00220973.1995.9943793

Goos, M. (2004). Learning mathematics in a classroom community of inquiry. *Journal for Research in Mathematics Education, 35*(4), 258-291. doi:http://dx.doi.org/10.2307/30034810

Green, S. K., & Gredler, M. E. (2002). A review and analysis of constructivism for school-based practice. *School Psychology Review, 31*(1), 53-70.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Communication and Technology Journal, 29*, 75-91. doi:http://dx.doi.org/10.1007/BF02766777

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In *Handbook of qualitative research* (pp. 105-117). London: Sage.

Gupta, A., & Fisher, D. L. (2012). Technology-supported learning environments in science classrooms in India. *Learning Environments Research, 15*(2), 195-216. doi:http://dx.doi.org/10.1007/s10984-012-9103-9

Guthrie, J. T., Hoa, L. A., Wigfield, A., Tonks, S. M., Humenick, N. M., & Littles, E. (2007). Reading motivation and reading comprehension growth in the later elementary years. *Contemporary Educational Psychology, 32*(3), 282-313. doi:http://dx.doi.org/10.1016/j.cedpsych.2006.05.004

Hackett, G., & Betz, N., E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research Mathematics Education, 20*, 261-273. doi:http://dx.doi.org/10.2307/749515

Hall, E. T. (1959). *The silent language*. New York, NY: Doubleday.

Hall, E. T., & Hall, M. R. (1990). *Understanding cultural differences*. Yarmouth, UK: Intercultural Press.

Hamilton, J. A. (1983). Development of interest and enjoyment in adolescence. Part II. Boredom and psychopathology. *Journal of Youth and Adolescence, 12*, 363-372. doi:http://dx.doi.org/10.1007/BF02088720

Harwell, S. H., Gunter, S., Montgomery, S., Shelton, C., & West, D. (2001). Technology integration and the classroom learning environment: Research *for* action. *Learning Environments Research, 4*, 259-286. doi:http://dx.doi.org/10.1023/A:1014412120805

Hattie, J. A. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.

Hayes, M. T. (2002). Elementary preservice teachers' struggles to define inquiry-based science teaching. *Journal of Science Teacher Education, 13*, 147-165.

Heck, D. J., Banilower, E. R., Weiss, I. R., & Rosenberg, S. L. (2008). Studying the effects of professional development: The case of the NSF's local systemic change through teacher enhancement initiative. *Journal for Research in Mathematics Education, 39*(2), 113-152. doi:http://dx.doi.org/10.2307/30034894

Heindl, M., & Nader, M. (2018). Digital technologies in a design and technology lesson and their influence on a learner's situationally perceived value of a task when engaged in inquiry-based learning. *Journal of Computers in Mathematics and Science Teaching, 37*(3), 239-263.

Helding, K. A., & Fraser, B. J. (2013). Effectiveness of national board certified (NBC) teachers in terms of classroom environment, attitudes and achievement among secondary science students. *Learning Environments Research, 16*(1), 1-21. doi:http://dx.doi.org/10.1007/s10984-012-9104-8

Hesse-Bieber, S. N., & Leavy, P. (2006). *The practice of qualitative research*. Thousand Oaks, CA: Sage.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*, 111-127. doi:http://dx.doi.org/10.1207/s15326985ep4102_4

Hoekstra, A., Brekelmans, M., Beijaard, D., & Korthagen, F. (2009). Experienced teachers' informal learning: Learning activities and changes in behavior and cognition. *Teacher and Teacher Education, 25*, 663-673. doi:http://dx.doi.org/10.1016/j.tate.2008.12.007

Hoekstra, A., & Korthagen, F. (2011). Teacher learning in a context of educational change: Informal learning versus systematically supported learning. *Journal of Teacher Education, 62*(1), 76-92. doi:http://dx.doi.org/10.1177/0022487110382917

Hofstede, G. H., Hofstede, G. J., & Minkov, M. (1991). *Cultures and organizations: Software of the mind*. New York, NY: McGraw-Hill.

Hofstede, G. H., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind* (3rd ed.). New York, NY: McGraw-Hill.

Holdsworth, R. (2016). *Student voice and the education state resource*. Melbourne: Victorian Student Representative Council

Inda-Caro, M., Maulana, R., Fernández-García, C.-M., Peña-Calvo, J.-V., del Carmen Rodríguez-Menéndez, M., & Helms-Lorenz, M. (2019). Validating a model of effective teaching behaviour and student engagement: Perspectives from Spanish students. *Learning Environments Research, 22*(2), 229-251. doi:http://dx.doi.org/10.1007/s10984-018-9275-z

Ismail, N. A. (2009). Understanding the gap in mathematics achievement of Malaysian students. *The Journal of Educational Research, 102*, 389-394. doi:http://dx.doi.org/10.3200/JOER.102.5.389-394

Izard, C. E. (1977). *Human emotions*. New York, NY: Plenum Press.

James, W. (1995, 1907). *Pragmatism*. New York: Dover.

Jansen, B. A. (2011). Inquiry unpacked: An introduction to inquiry-based learning. *Library Media Connection, 29*(5), 10-12.

Jarrett, D. (1997). *Inquiry strategies for science and mathematics learning: It's just good teaching*. Portland, OR: Northwest Regional Educational Laboratory.

John-Steiner, V., & Mahn, H. (1996). Sociocultural approaches to learning and development: A Vygotskian framework. *Educational Psychologist, 31*, 191-206.

Johnson, B., & McClure, R. (2004). Validity and reliability of a shortened, revised version of the Constructivist Learning Environment Survey (CLES). *Learning Environments Research, 7*(1), 65-80. doi:http://dx.doi.org/10.1023/B:LERI.0000022279.89075.9f

Joiner, K. F., Malone, J. A., & Haimes, D. H. (2002). Assessment of classroom environments in reformed calculus education. *Learning Environments Research: An International Journal, 5*, 51-76. doi:http://dx.doi.org/10.1023/A:1015635122875

Kadijevich, D. (2008). TIMSS 2003: Relating dimensions of mathematics attitude to mathematics achievement. *Institute for Pedagogical Research, 40*(2), 327-346. doi:http://dx.doi.org/10.2298/ZIPI0802327K

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20*, 141-151. doi:http://dx.doi.org/10.1177/001316446002000116

Kang, J., & Keinonen, T. (2017). The effect of inquiry-based learning experiences on adolescents' science-related career aspiration in the Finnish context.

International Journal of Science Education, 39(12), 1669-1689. doi:http://dx.doi.org/10.1080/09500693.2017.1350790

Kapon, S., Laherto, A., & Levrini, O. (2018). Disciplinary authenticity and personal relevance in school science. *Science Education, 102*(5), 1077-1106. doi:http://dx.doi.org/10.1002%2Fsce.21458

Karavas-Doukas, E. (1996). Using attitude scales to investigate teachers' attitudes to the communicative approach. *English Language Teaching (ELT) Journal, 50*(3), 187-198. doi:http://dx.doi.org/10.1093/elt/50.3.187

Katz, D., & Sarnoff, I. (1954). The motivational basis of attitude change. *Journal of Abnormal and Social Psychology, 49*, 115-124.

Keys, C. W., & Kennedy, V. (1999). Understanding inquiry science teaching in context: A case study of an elementary teacher. *Journal of Science Teacher Education, 10*, 315-333.

Khalil, N. (2015). *Cooperative learning in science classes in the United Arab Emirates: Learning environment, attitudes, motivation, engagement and career aspirations.* (PhD). Curtin University, Perth, Australia. Retrieved from http://link.library.curtin.edu.au/p?cur_dspace_dc20.500.11937/2604

Khalil, N., & Aldridge, J. M. (2019). Assessing students' perceptions of their learning environment in science classes in the United Arab Emirates. *Learning Environments Research*, 1-22. doi:http://dx.doi.org/10.1007/s10984-019-09279-w

Kiany, G. R., & Shayestefar, P. (2011). High school students' perceptions of EFL teacher control orientations and their English academic achievement. *British Journal of Educational Psychology, 81*(3), 491-508. doi:http://dx.doi.org/10.1348/000709910X522177

Kidman, G., & Casinader, N. (2017). *Inquiry-based teaching and learning across disciplines: Comparative theory and practice in schools*. London: Palgrave Macmillan UK.

Kim, C., Park, S. W., & Cozart, J. (2014). Affective and motivational factors of learning in online mathematics courses. *British Journal of Educational Technology, 45*(1), 171-185. doi:http://dx.doi.org/10.1111/j.1467-8535.2012.01382.x

Kim, H.-B., Fisher, D. L., & Fraser, B. J. (1999). Assessment and investigation of constructivist science learning environments in Korea. *Research in Science and Technological Education, 17*(2), 239-249. doi:http://dx.doi.org/10.1080/0263514990170209

Kim, H.-B., Fisher, D. L., & Fraser, B. J. (2000). Classroom environment and teacher interpersonal behaviour in secondary science classes in Korea. *Evaluation and Research in Education, 14*(1), 3-22. doi:http://dx.doi.org/10.1080/09500790008666958

Kleve, B. (2004). *Teachers' implementation of a curriculum reform*. Paper presented at the CERME 4 European Research in Mathematics Education IV, Saint Feliu de Guizols, Spain.

Kline, R. B. (2011). *Principles and practice of structural equation modeling*. New York: Guilford Press.

Koh, N. K., & Fraser, B. J. (2014). Learning environment associated with use of mixed mode delivery model among secondary business studies students in Singapore. *Learning Environments Research, 17*(2), 157-171. doi:http://dx.doi.org/10.1007%2Fs10984-013-9139-5

Kosyvas, G. (2016). Levels of arithmetic reasoning in solving an open-ended problem. *International Journal of Mathematical Education in Science and Technology, 47*(3), 356-372. doi:http://dx.doi.org/10.1080/0020739x.2015.1072880

Koul, R., Roy, L., & Lerdpornkulrat, T. (2012). Motivational goal orientation, perceptions of biology and physics classroom learning environments, and gender. *Learning Environments Research, 15*(2), 217-229. doi:http://dx.doi.org/10.1007%2Fs10984-012-9111-9

Koul, R. B., & Fisher, D. L. (2005). Cultural background and students' perceptions of science classroom learning environment and teacher interpersonal behaviour in Jammu, India. *Learning Environments Research, 8*(2), 195-211. doi:http://dx.doi.org/10.1007/s10984-005-7252-9

Koul, R. B., Fisher, D. L., & Shaw, T. (2011). An application of the TROFLEI in secondary-school science classes in New Zealand. *Research in Science & Technological Education, 29*(2), 147-167. doi:http://dx.doi.org/10.1080/02635143.2011.573475

Krech, D. (1946). Attitudes and learning. *Psychological Review, 53*, 290-293.

Kreuzer, P., & Dreesmann, D. (2017). Museum behind the scenes - An inquiry-based learning unit with biological collections in the classroom. *Journal of Biological Education, 51*(3), 261-272. doi:http://dx.doi.org/10.1080/00219266.2016.1217906

Laine, E., Veermans, M., Lahti, A., & Veermans, K. (2017). Generation of student interest in an inquiry-based mobile learning environment. *Frontline Learning Research, 5*(4), 42-60. doi:http://dx.doi.org/10.14786/flr.v5i4.306

Layman, J. W., Ochoa, G., & Heikkinen, H. (1996). *Inquiry and learning*. New York: The College Board.

Leavy, A., & Hourigan, M. (2018). The beliefs of 'Tomorrow's Teachers' about mathematics: Precipitating change in beliefs as a result of participation in an initial teacher education programme. *International Journal of Mathematical Education in Science and Technology, 49*(5), 759-777. doi:http://dx.doi.org/10.1080%2F0020739X.2017.1418916

Lee, J. C., Yin, H., & Zhang, Z. (2009). Exploring the influence of the classroom environment on students' motivation and self-regulated learning in Hong Kong. *The Asia-Pacific Education Researcher, 18*(2), 219-232. doi:http://dx.doi.org/10.3860/taper.v18i2.1324

Lee, S. S. U., Fraser, B. J., & Fisher, D. L. (2003). Teacher-student interactions in Korean high school science classrooms. *International Journal of Science and*

Mathematics Education, 1, 67-85. doi:http://dx.doi.org/10.1023/A:1026191226676

Leikin, R., & Rota, S. (2006). Learning through teaching: A case study on the development of a mathematics teacher's proficiency in managing an inquiry-based classroom. *Mathematics Education Research Journal, 18*(3), 44-68. doi:http://dx.doi.org/10.1007/BF03217442

Lewin, K. (1936). *Principles of topological psychology*. New York: McGraw.

Liaw, M. L. (2007). Content-based reading and writing for critical thinking skills in an EFL context. *English Teaching and Learning, 31*, 45-87. doi:http://dx.doi.org/10.6330/ETL.2007.31.2.02

Liem, A. D., Lau, S., & Nie, Y. (2008). The role of self-efficacy, task value, and achievement goals in predicting learning strategies, task disengagement, peer relationship, and achievement outcome. *Contemporary Educational Psychology, 33*(4), 486-512. doi:http://dx.doi.org/10.1016/j.cedpsych.2007.08.001

Lightburn, M. E., & Fraser, B. J. (2007). Classroom environment and student outcomes among students using anthropometry activities in high-school science. *Research in Science & Technological Education, 25*(2), 153-166. doi:http://dx.doi.org/10.1080/02635140701250576

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140*, 5-55.

Linnenbrink-Garcia, L., Wormington, S. V., Snyder, K. E., Riggsbee, J., Perez, T., Ben-Eliyahu, A., & Hill, N. E. (2018). Multiple pathways to success: An examination of integrative motivational profiles among upper elementary and college students. *Journal of Educational Psychology, 110*(7), 1026-1048. doi:http://dx.doi.org/10.1037%2Fedu0000245

Liu, E. Z.-F., Lin, C.-H., Jian, P.-H., & Liou, P.-Y. (2012). The dynamics of motivation and learning strategy in a creativity-supporting learning environment in higher education. *Turkish Online Journal of Educational Technology - TOJET, 11*(1), 172-180.

Llewellyn, D. (2001). *Inquire within: Implementing inquiry-based science standards*. Thousand Oaks, CA: Corwin Press.

Logan, K. A., Crump, B. J., & Rennie, L. J. (2006). Measuring the computer classroom environment: Lessons learned from using a new instrument. *Learning Environments Research, 9*(1), 67-93. doi:http://dx.doi.org/10.1007/s10984-005-9004-2

Lotter, C. (2004). Preservice science teachers' concerns through classroom observations and student teaching: Special focus on inquiry teaching. *Science Educator, 13*(1), 29-38.

Maass, K., Swan, M., & Aldorf, A.-M. (2017). Mathematics teachers' beliefs about inquiry-based learning after a professional development course - An international study. *Journal of Education and Training Studies, 5*(9), 1-17. doi:http://dx.doi.org/10.11114/jets.v5i9.2556

MacBeath, J., Demetriou, H., Ruddock, J., & Myers, K. (2003). *Consulting pupils: A toolkit for teachers*. Cambridge: Pearson.

MacLeod, C., & Fraser, B. J. (2010). Development, validation and application of a modified Arabic translation of the What Is Happening in This Class? (WIHIC) questionnaire. *Learning Environments Research, 13*(2), 105-125. doi:http://dx.doi.org/10.1007/s10984-008-9052-5

Magen-Nagar, N., & Steinberger, P. (2017). Characteristics of an innovative learning environment according to students' perceptions: Actual versus preferred. *Learning Environments Research, 20*(3), 307-323. doi:http://dx.doi.org/10.1007%2Fs10984-017-9232-2

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical step-by-step guide for learning and teaching scholars. *All Ireland Journal of Teaching and Learning in Higher Education, 9*(3), 3351-33514.

Majeed, A., Fraser, B. J., & Aldridge, J. M. (2002). Learning environment and its association with student satisfaction among mathematics students in Brunei Darussalam. *Learning Environments Research, 5*(2), 203-226. doi:http://dx.doi.org/10.1023/A:1020382914724

Makar, K. (2007). Connection levers: Supports for building teachers' confidence and commitment to teach mathematics and statistics through inquiry. *Mathematics Teacher Education and Development, 8*, 48-73.

Mäkelä, T., Helfenstein, S., Lerkkanen, M.-K., & Poikkeus, A.-M. (2018). Student participation in learning environment improvement: Analysis of a co-design project in a Finnish upper secondary school. *Learning Environments Research, 21*(1), 19-41. doi:http://dx.doi.org/10.1007/s10984-017-9242-0

Manouchehri, A. (2007). Inquiry-discourse mathematics instruction. *Mathematics Teacher, 101*(4), 290-300.

Marrow, A. J. (1977). *The practical theorist: The life and work of Kurt Lewin*. New York: Basic Books, Inc.

Marshall, C., & Rossman, G. B. (1999). *Designing qualitative research* (3rd ed.). Newbury Park: Sage.

Marshall, J. C., & Horton, R. M. (2011). The relationship of teacher-facilitated, inquiry-based instruction to student higher-order thinking. *School Science and Mathematics, 111*(3), 93-101. doi:http://dx.doi.org/10.1111/j.1949-8594.2010.00066.x

Marshall, J. C., Smart, J., & Horton, R. M. (2010). The design and validation of EQUIP: An instrument to assess inquiry-based instruction. *International Journal of Science and Mathematics Education, 8*(2), 299-321. doi:http://dx.doi.org/10.1007/s10763-009-9174-y

Martin-Dunlop, C., & Fraser, B. J. (2008). Learning environment and attitudes associated with an innovative science course designed for prospective elementary teachers. *International Journal of Science and Mathematics Education, 6*(1), 163-190. doi:http://dx.doi.org/10.1007/s10763-007-9070-2

McCarty, T. L., Hadley Lynch, R., Wallace, S., & Benally, A. (1991). Classroom inquiry and Navajo learning styles: A call for reassessment. *Anthropology and Education Quarterly, 22*(1), 42–59. doi:http://dx.doi.org/10.1525/aeq.1991.22.1.05x1172b

McChesney, K. R. (2017). *Investigating teachers' experiences of professional development within a major education reform in the emirate of Abu Dhabi.* (PhD). Curtin University, Retrieved from https://espace.curtin.edu.au/handle/20.500.11937/57566

McChesney, K. R., & Aldridge, J. M. (2018). A new tool for practitioner-led evaluation of teacher professional development. *Teacher Development, 22*(3), 314-338. doi:http://dx.doi.org/10.1080/13664530.2017.1418418

McElvain, C. M., & Smith, H. A. (2016). Curiosité: Inquiry-based instruction and bilingual learning. *Journal of Curriculum and Teaching, 5*(2), 63-75. doi:http://dx.doi.org/10.5430/jct.v5n2p63

McRobbie, C. J., & Fraser, B. J. (1995). Science laboratory classroom environments at schools and universities: A cross-national study. *Educational Research and Evaluation, 1*, 289-317. doi:http://dx.doi.org/10.1080/1380361950010401

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology, 57*, 487-503. doi:http://dx.doi.org/10.1146/annurev.psych.56.091103.070258

Melo, M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction, 11*(1), 103-122. doi:http://dx.doi.org/10.12973/iji.2018.1118a

Merton, R. K. (1975). Thematic analysis in science: Notes on Holton’s concept. *Science as Culture, 188*(4186), 335-338. doi:http://dx.doi.org/10.1126/science.188.4186.335

Mettas, A., Karmiotis, I., & Chirstoforou, P. (2006). Relationship between students' self-beliefs and attitudes on science achievements in Cyprus: Findings from the Trends in International Mathematics and Science Study (TIMSS). *EURASIA Journal of Mathematics, Science & Technology Education, 2*, 41-52. doi:http://dx.doi.org/10.12973/ejmste/75437

Middleton, J. A., & Spanias, P. A. (1999). Motivation for achievement in mathematics: Findings, generalizations and criticisms of the research. *Journal of Research in Mathematics Education, 30*, 65-88. doi:http://dx.doi.org/10.2307/749630

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: an expanded sourcebook* (2nd ed.). California: Sage.

Miller, R. B., & Brickman, S. A. (2004). A model of future oriented motivation and self-regulation. *Educational Psychology Review, 16*, 9-33. doi:http://dx.doi.org/10.1023/B:EDPR.0000012343.96370.39

Mills, H., O'Keefe, T., & Jennings, L. (2004). *Looking closely, listening carefully: Learning literacy through inquiry*. Urbana, IL: National Council for Teachers of English.

Moos, R. H. (1974). *The social climate scales: An overview*. Palo Alto, CA: Consulting Psychologist Press.

Moos, R. H. (1976). *The human context: Environmental determinants of behavior*. New York: Wiley-Interscience.

Moos, R. H. (1979). *Evaluating educational environments: Procedures, measures, findings, and policy implications*. San Francisco: Jossey-Bass.

Morgan, D. L. (1988). *Focus groups as qualitative research*. Beverly Hills, CA: Sage.

Multon, K. D., Brown, S. D., & Lent, R. W. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology, 18*, 30-38. doi:http://dx.doi.org/10.1037/0022-0167.38.1.30

Murray, H. A. (1938). *Explorations in personality*. New York: Oxford University Press.

Murray, J., & Summerlee, A. J. S. (2007). The impact of problem-based learning in an interdisciplinary first-year program on student learning behaviour. *Canadian Journal of Higher Education, 37*(3), 87-107.

National Commission on Excellence in Education. (1983). *A nation at risk: An imperative for educational reform*. Washington, DC: US Department of Education.

National Commission on Mathematics and Science Teaching. (2000). *Before it's too late: A report to the nation from the National Commission on Mathematics and Science Teaching for the 21st Century*. Washington, DC: US Department of Education.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM, Inc.

National Research Council. (1996). *National science education standards*. Washington DC: National Academy Press.

National Research Council. (2004). *Engaging schools: Fostering high school students' motivation to learn*. Washington, DC: The National Academies Press.

Neale, D. (1969). The role of attitudes in learning mathematics. *The Arithmetic Teacher, 16*(8), 631-641.

Nebesniak, A. L., & Heaton, R. M. (2010). Student confidence and student involvement. *Mathematics Teaching in the Middle School, 16*(2), 96-103.

Neuliep, J. W. (2011). *Intercultural communication: A contextual approach* (5th ed.). Los Angeles, CA: Sage.

Nix, R. K., Fraser, B. J., & Ledbetter, C. E. (2005). Evaluating an integrated science learning environment using the Constructivist Learning Environment Survey. *Learning Environments Research, 8*(2), 109-133. doi:http://dx.doi.org/10.1007/s10984-005-7251-x

Noyes, A. (2012). It matters which class you are in: student-centred teaching and the enjoyment of learning mathematics. *Research in Mathematics Education, 14*(3), 273-290. doi:http://dx.doi.org/10.1080/14794802.2012.734974

Nunnaly, J. (1978). *Psychometric theory*. New York: McGraw-Hill.

Nystrand, M., & Gamoran, A. (1991). Instructional discourse, student engagement, and literature achievement. *Research in the Teaching of English, 25*, 261-290.

OECD. (2015). *Better skills, better jobs, better lives: A strategic approach to education and skills policies for the United Arab Emirates*. Paris: OECD Publishing.

OECD. (2017). *The OECD handbook for innovative learning environments*. Paris: OECD Publishing.

Ogbuehi, P. I., & Fraser, B. J. (2007). Learning environment, attitudes and conceptual development associated with innovative strategies in middle-school mathematics. *Learning Environments Research, 10*(2), 101-114. doi:http://dx.doi.org/10.1007/s10984-007-9026-z

Oh, P. S., & Yager, R. E. (2004). Development of constructivist science classrooms and changes in student attitudes toward science learning. *Science Education Journal, 15*, 105-113.

Oliveira, A. W. (2010). Improving teacher questioning in science inquiry discussions through professional development. *Journal of Research in Science Teaching, 47*(4), 422-453. doi:http://dx.doi.org/10.1002/tea.20345

Oliver, R. (2007). Exploring an inquiry-based learning approach with first-year students in a large undergraduate class. *Innovations in Education and Teaching International, 44*(1), 3-15. doi:http://dx.doi.org/10.1080/14703290601090317

Op't Eynde, P., De Corte, E., & Verschaffel, L. (2007). Students' emotions: A key component of self-regulated learning? In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 185-204). Burlington, MA: Elsevier.

Opolot-Okurut, C. (2010). Classroom learning environment and motivation towards mathematics among secondary school students in Uganda. *Learning Environments Research, 13*(3), 267-277. doi:http://dx.doi.org/10.1007/s10984-010-9074-7

Orgill, M. K., & Thomas, M. (2007). Analogies and the 5E model. *Science Teacher, 74*(1), 40-45.

Ozkal, K., Tekkaya, C., Cakiroglu, J., & Sungur, S. (2009). A conceptual model of relationships among constructivist learning environment perceptions, epistemological beliefs, and learning approaches. *Learning and Individual Differences, 19*(1), 71-79. doi:http://dx.doi.org/10.1016/j.lindif.2008.05.005

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*, 543-578. doi:http://dx,doi.org/10.3102/00346543066004543

Pajares, F. (2002). Gender and percieved self-efficiacy in self-regulated learning. *Theory into Practice, 41*, 116-125. doi:http://dx.doi.org/10.1207/s15430421tip4102_8

Pajares, F. (2006). Self-efficacy beliefs during adolescence: Implications for teachers and parents. In F. Pajares & T. Urdan (Eds.), *Adolescence and education. Vol.5: Self-Efficacy Beliefs of Adolescents* (Vol. 5, pp. 339-367). Greenwich, CT: Information Age.

Pajares, F., & Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. *Contemporary Educational Psychology, 24*, 124-139. doi:http://dx.doi.org/10.1006/ceps.1998.0991

Pajares, F., & Miller, M. D. (1995). Mathematics self-efficacy and mathematics performances: The need for specificity in assessment. *Journal of Counseling Psychology, 42*(2), 190-198. doi:http://dx.doi.org/10.1037/0022-0167.42.2.190

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332. doi:http://dx.doi.org/10.3102/00346543062003307

Parlett, M., & Hamilton, D. (1976). Evaluation as illumination. In D. Tawney (Ed.), *Curriculum Evaluation Today: Trends and Implications* (pp. 84-101). London: Macmillan.

Partin, M. L., & Haney, J. J. (2012). The CLEM model: Path analysis of the mediating effects of attitudes and motivational beliefs on the relationship between perceived learning environment and course performance in an undergraduate non-major biology course. *Learning Environments Research, 15*(1), 103-123. doi:http://dx.doi.org/10.1007%2Fs10984-012-9102-x

Patrick, H., Kaplan, A., & Ryan, A. M. (2011). Positive classroom motivational environments: Convergence between mastery goal structure and classroom social climate. *Journal of Educational Psychology, 103*(2), 367-382. doi:http://dx.doi.org/10.1037/A0023311

Patrick, H., Ryan, A. M., & Kaplan, A. (2007). Early adolescents' perceptions of the classroom social environment, motivational beliefs, and engagement. *Journal of Educational Psychology, 99*(1), 83-98. doi:http://dx.doi.org/10.1037/0022-0663.99.1.83

Peirce, C. S. (1878). How to make our ideas clear. *Popular Science Monthly, 12*, 286-302.

Peiro, M. M., & Fraser, B. J. (2009). Assessment and investigation of science learning environments in the early childhood grades. In M. R. Ortiz, C. (Ed.), *Educational evaluation: 21st century issues and challenges* (pp. 349-365). New York: Nova Science Publishers.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18*, 315-341. doi:http://dx.doi.org/10.1007/s10648-006-9029-9

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002a). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37*, 91-105. doi:http://dx.doi.org/10.1207/S15326985EP3702_4

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002b). Positive emotions in education. In E. Frydenberg (Ed.), *Beyond coping: Meeting goals, visions, and challenges* (pp. 149-173). Oxford, England: Oxford University Press.

Pekrun, R., & Stephens, E. J. (2012). Academic emotions. In K. R. Harris, S. Graham, & T. Urdan (Eds.), *APA Educational psychology handbook: Vol. 2. Individual differences and cultural and contextual factors* (pp. 3-31). Washington, D.C.: American Psychological Association.

Pendergast, D., Flanagan, R., Land, R., Bahr, M., Mitchell, J., Weir, K., . . . Smith, J. (2005). *Developing lifelong learners in the middle years of schooling*. Brisbane: Queensland Government

Perkins, D. (1999). The many facets of constructivism. *Educational Leadership, 57*(3), 6-16.

Perlman, D. (2013). Manipulation of the self-determined learning environment on student motivation and affect within secondary physical education. *Physical Educator, 70*(4), 413-428.

Petress, K. (2008). What is meant by "active learning?". *Education, 128*(4), 566-569.

Phelan, A. M. (2005). A fall from (someone else's) certainty: Recovering practical wisdom in teacher education. *Canadian Journal of Education/Revue Canadienne de l'e´ducation, 28*(3), 339-358. doi:http://dx.doi.org/10.2307/4126474

Piaget, J. (1963). *The origins of intelligence*. New York: Norton.

Piaget, J. (1971). *Biology and knowledge*. Chicago, IL: University of Chicago Press.

Piaget, J. (1973). *To understand is to invent: The future of education*. New York: Grossman.

Pickett, L. H., & Fraser, B. J. (2009). Evaluation of a mentoring program for beginning teachers in terms of the learning environment and student outcomes in participants' school classrooms. In A. T. Selkirk, M. (Ed.), *Teacher education: Policy, practice and research* (pp. 1-15). New York: Nova Science Publishers.

Pietsch, J., Walker, R., & Chapman, E. (2003). The relationship among self-concept, self-efficacy, and performance in mathematics during secondary school. *Journal of Educational Psycology, 95*(3), 589-603. doi:http://dx.doi.org/10.1037/0022-0663.95.3.589

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W., J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational and Psychological Measurement, 53*(3), 801-813. doi:http://dx.doi.org/10.1177/0013164493053003024

Polly, D., Wang, C., McGee, J., Lambert, R. G., Martin, C. S., & Pugalee, D. (2014). Examining the influence of a curriculum-based elementary mathematics professional development program. *Journal of Research in Childhood Education, 28*(3), 327-343. doi:http://dx.doi.org/10.1080/02568543.2014.913276

Polychroni, F., Hatzichristou, C., & Sideridis, G. (2012). The role of goal orientations and goal structures in explaining classroom social and affective characteristics. *Learning and Individual Differences, 22*(2), 207-217. doi:http://dx.doi.org/10.1016/j.lindif.2011.10.005

Ponte, J. I. E. (2001). Investigating mathematics and learning to teach mathematics. In F. L. Lin & T. Cooney (Eds.), *Making sense of mathematics teacher education* (pp. 53-72). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Ponterotto, J. G. (2005). Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science. *Journal of Counseling Psychology, 52*(2), 126-136. doi:http://dx.doi.org/10.1037/0022-0167.52.2.126

Prendergast, L. L., & Kaplan, A. (2015). Instructional context and student motivation, learning, and development: Commentary and implications for school psychologists. *School Psychology International, 36*, 638-647. doi:http://dx.doi.org/10.1177/0143034315613560

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: definitions, comparisons, and research bases. *Journal of Engineering Education, 95*(2), 123-138. doi:http://dx.doi.org/10.1002/j.2168-9830.2006.tb00884.x

Priniski, S. J., Hecht, C. A., & Harackiewicz, J. M. (2018). Making learning personally meaningful: A new framework for relevance research. *Journal of Experimental Education, 86*(1), 11-29. doi:http://dx.doi.org/10.1080%2F00220973.2017.1380589

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching, 42*(2), 185-217. doi:http://dx.doi.org/10.1002/tea.20048

Quek, C. L., Wong, A. F., & Fraser, B. J. (2005). Student perceptions of chemistry laboratory learning environments, student-teacher interactions and attitudes in secondary school gifted education classes in Singapore. *Research in Science Education, 35*(2), 299-321. doi:http://dx.doi.org/10.1007/s11165-005-0093-9

Qureshi, S., Vishnumolakala, V. R., Southam, D. C., & Treagust, D. F. (2017). Inquiry-based chemistry education in a high-context culture: A Qatari case study. *International Journal of Science and Mathematics Education, 15*(6), 1017-1038. doi:http://dx.doi.org/10.1007/s10763-016-9735-9

Radovan, M., & Makovec, D. (2015). Relations between students' motivation, and perceptions of the learning environment. *Center for Educational Policy Studies Journal, 5*(2), 115-138.

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist, 53*(3), 145-164. doi:https://doi.org/10.1080/00461520.2018.1447384

Reiss, K., & Reiss, M. (2006). Unterrichtsqualität und der mathematikunterricht [Quality of instruction and mathematics teaching]. In I. Hosenfeld & F. W. Schrader (Eds.), *Schulische Leistungen. Grundlagen Bedingungen, Perspektiven* (pp. 225-242). Münster: Waxmann.

Rentoul, J. A., & Fraser, B. J. (1979). Conceptualization of enquiry-based or open classroom learning environments. *Journal of Curriculum Studies, 11*(3), 233-245. http://dx.doi.org/10.1080/0022027790110306

Rhine, R. J. (1958). A concept formation approach to attitude acquisition. *Psychology Review, 65*, 362-370. doi:http://dx.doi.org/10.1037/h0043262

Robinson, E., & Fraser, B. J. (2013). Kindergarten students' and parents' perceptions of science classroom environments: Achievement and attitudes. *Learning Environments Research, 16*(2), 151-167. doi:http://dx.doi.org/10.1007/s10984-013-9138-6

Robson, C. (2002). *Real world research. A resource for social scientists and practitioner-researchers* (2nd ed.). Malden: Blackwell.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). *Science education now: A renewed pedagogy for the future of Europe*. Brussels: European Commission Directorate-General for Research Retrieved from http://ec.europa.eu/research/rtdinfo/index_en.html

Roehrig, G. H., & Luft, J. A. (2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education, 26*, 3-24. doi:http://dx.doi.org/10.1080/0950069022000070261

Ryan, R. M. (1995). Psychological needs and the facilitation of integrative processes. *Journal of Personality, 63*, 397-427. doi:http://dx.doi.org/10.1111/j.1467-6494.1995.tb00501.x

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78. doi:http://dx.doi.org/10.1037/0003-066X.55.1.68

Sakiz, G., Pape, S. J., & Hoy, A. W. (2012). Does perceived teacher affective support matter for middle school students in mathematics classrooms? *Journal of School Psychology, 50*(2), 235-255. doi:http://dx.doi.org/10.1016/j.jsp.2011.10.005

Saldana, J. (2013). *The coding manual for qualitative researchers*. Los Angeles: Sage.

Sawilowsky, S. (2009). New effect size rules of thumb. *Journal of Modern Applied Statistical Methods, 8*(2), 467-474. doi:http://dx.doi.org/10.22237/jmasm/1257035100

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*, 299-323. doi:http://dx.doi.org/10.1080/00461520.1991.9653136

Schoerning, E., & Hand, B. (2013). Using language positively: How to encourage negotiation in the classroom. *Science and Children, 50*(9), 42-45. doi:http://dx.doi.org/10.2505/4/sc13_050_09_42

Schuitema, J., Peetsma, T., & van der Veen, I. (2012). Self-regulated learning and students' perceptions of innovative and traditional learning environments: A longitudinal study in secondary education. *Educational Studies, 38*(4), 397-413. doi:http://dx.doi.org/10.1080/03055698.2011.643105

Schunk, D. H. (1995). Self-efficacy and education in instruction. In J. Maddux (Ed.), *Self-efficacy, adaptation and adjustment: Theory, research, and application* (pp. 281-303). New York: Plenum.

Schunk, D. H., & Pajares, F. (2002). The development of academic self-efficacy. In A. Wigfield & J. S. Eccle (Eds.), *Development of achievement motivation* (pp. 15-31). San Diego, CA: Academic Press.

Schunk, D. H., & Pajares, F. (2005). Competence beliefs in academic functioning. In A. J. E. C. Dweck (Ed.), *Handbook of competence and motivation* (pp. 85-104). New York: Guilford Press.

Scott, R. H., & Fisher, D. L. (2004). Development, validation and application of a Malay translation of an elementary version of the Questionnaire on Teacher Interaction. *Research in Science Education, 34*(2), 173-194. doi:http://dx.doi.org/10.1023/B:RISE.0000033759.09807.50

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22*, 63-75. doi:http://dx.doi.org/10.3233/EFI-2004-22201

Sheppard, I. (2008). Towards a constructivist pedagogy for year 12 mathematics. *Australian Senior Mathematics Journal, 22*(1), 50-58.

Shernoff, D. J. (2013). *Optimal learning environments to promote student engagement*. New York, NY: Springer.

Shernoff, D. J., & Bempechat, J. (Eds.). (2014). *Engaging youth in schools: Evidence-based models to guide future innovations* (Vol. 113). New York, NY: Teachers College, Columbia University.

Shernoff, D. J., Kelly, S., Tonks, S. M., Anderson, B., Cavanagh, R. F., Sinha, S., & Abdi, B. (2016). Student engagement as a function of environmental complexity in high school classrooms. *Learning and Instruction, 43*, 52-60. doi:http://dx.doi.org/10.1016/j.learninstruc.2015.12.003

Shernoff, D. J., Ruzek, E. A., & Sinha, S. (2017). The influence of the high school classroom environment on learning as mediated by student engagement. *School Psychology International, 38*(2), 201-218. doi:http://dx.doi.org/10.1177%2F0143034316666413

Siegel, M., & Borasi, R. (1994). Demystifying mathematics education through inquiry. In P. Ernest (Ed.), *Constructing mathematical knowledge: Epistemology and mathematical education* (pp. 201-215). Abingdon: Routledge.

Simonson, M., & Maushak, N. (2001). Instructional technology and attitude change. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology*. New York: Simon & Schuster Macmillan.

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology, 42*, 70-83. doi:http://dx.doi.org/10.1037/0012-1649.42.1.70

Singer, F. M., & Moscovici, H. (2008). Teaching and learning cycles in a constructivist approach to instruction. *Teaching and Teacher Education: An International Journal of Research and Studies, 24*(6), 1613-1634. doi:http://dx.doi.org/10.1016/j.tate.2007.12.002

Smith, S. Z., & Smith, M. E. (2006). Assessing elementary understanding of multiplication concepts. *School Science and Mathematics, 106*(3), 140-149. doi: http://dx.doi.org/10.1111/j.1949-8594.2006.tb18171.x

Soebari, T. S., & Aldridge, J. M. (2015). Using student perceptions of the learning environment to evaluate the effectiveness of a teacher professional development programme. *Learning Environments Research, 18*(2), 163-178. doi:http://dx.doi.org/10.1007/s10984-015-9175-4

Soebari, T. S., & Aldridge, J. M. (2016). Investigating the differential effectiveness of a teacher professional development programme for rural and urban classrooms in Indonesia. *Teacher Development, 20*(5), 701-722. doi:http://dx.doi.org/10.1080/13664530.2016.1185031

Solheim, O. J. (2011). The impact of reading self-efficacy and task value on reading comprehension scores in different item formats. *Reading Psychology, 32*(1), 1-27. doi:http://dx.doi.org/10.1080/02702710903256601

Spinner, H., & Fraser, B. J. (2005). Evaluation of an innovative mathematics program in terms of classroom environment, student attitudes, and conceptual development. *International Journal of Science and Mathematics Education, 3*(2), 267-293. doi:http://dx.doi.org/10.1007/s10763-004-6531-8

Spronken-Smith, R., Bullard, J., Ray, W., Roberts, C., & Keiffer, A. (2008). Where might sand dunes be on Mars? Engaging students through inquiry-based learning in geography. *Journal of Geography in Higher Education, 32*(1), 71-86. doi:http://dx.doi.org/10.1080/03098260701731520

Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related performance: A meta-analysis. *Psychological Bulletin, 2*, 240-261. doi:http://dx.doi.org/10.1037/0033-2909.124.2.240

Staples, M. (2007). Supporting whole-class collaborative inquiry in a secondary mathematics classroom. *Cognition and Instruction, 25*(2), 161-217. doi:http://dx.doi.org/10.1080/07370000701301125

Stern, G. G. (1970). *People in context: Measuring person-environment congruence in education and industry*. New York: Wiley.

Stevens, J. P. (1992). *Applied multivariate statistics for the social sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Stigler, J., & Hiebert, J. (2004). *The teaching gap*. New York: The Free Press.

Stokols, D. (1979). The human context: Environmental determinants of behavior. *Contemporary Sociology, 8*(1), 155-156.

Stonewater, J. K. (2005). Inquiry teaching and learning: The best math class study. *School Science and Mathematics, 105*(1), 36-36. doi:http://dx.doi.org/10.1111/j.1949-8594.2005.tb18034.x

Sullivan, P., Griffioen, M., Gray, H., & Powers, C. (2009). Exploring open-ended tasks as teacher learning. *Australian Primary Mathematics Classroom, 14*(2), 4-9.

Sultan, W. H., Woods, P. C., & Ah-Choo, K. (2011). A constructivist approach for digital learning: Malaysian schools case study. *Journal of Educational Technology & Society, 14*(4), 149-163.

Summerlee, A. J. S., & Murray, J. (2010). The impact of enquiry-based learning on academic performance and student engagement. *Canadian Journal of Higher Education, 40*(2), 78-94.

Supovitz, J. A., Mayer, D. P., & Kahle, J. B. (2000). Promoting inquiry-based instructional practice: The longitudinal impact of professional development in the context of systemic reform. *Educational Policy, 14*, 331-356. doi:http://dx.doi.org/10.1177/0895904800014003001

Swan, M. (2007). The impact of task-based professional development on teachers' practices and beliefs: A design research study. *Journal of Mathematics Teacher Education, 10*(4-6), 217-237. doi:https://doi.org/10.1007/s10857-007-9038-8

Tapola, A., & Niemivirta, M. (2008). The role of achievement goal orientations in students' perceptions of and preferences for classroom environment. *British Journal of Educational Psychology, 78*, 291-312. doi:http://dx.doi.org/10.1348/000709907X205272

Tapola, A., Veermans, M., & Niemivirta, M. (2013). Predictors and outcomes of situational interest during a science learning task. *Instructional Science: An International Journal of Learning and Cognition, 41*(6), 1047-1064. doi:http://dx.doi.org/10.1007/s11251-013-9273-6

Tarr, J. E., Reys, R. E., Reys, B. J., Chavez, O., & Shih, J. (2008). The impact of middle-grades mathematics curricula and the classroom learning environment on student achievement. *Journal for Research in Mathematics Education, 39*, 247-280. doi:http://dx.doi.org/10.2307/30034970

Taylor, P. C. (1997). *Tales of the field: Impressions of college education*. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*, 293-302. doi:http://dx.doi.org/10.1016/S0883-0355(97)90011-2

Tee, K. N., Leong, K. E., & Abdul Rahim, S. S. (2018). The mediating effects of critical thinking skills on motivation factors for mathematical reasoning ability. *Asia-Pacific Education Researcher, 27*(5), 373-382. doi:http://dx.doi.org/10.1007%2Fs40299-018-0396-z

Teh, G., & Fraser, B. J. (1994). An evaluation of computer-assisted learning in terms of achievement, attitudes and classroom environment. *Evaluation and Research in Education, 8*, 147-161. doi:http://dx.doi.org/10.1080/09500799409533363

Tempelaar, D. T., Niculescu, A., Rienties, B., Gijselaers, W. H., & Giesbers, B. (2012). How achievement emotions impact students' decisions for online learning, and what precedes those emotions. *Internet and Higher Education, 15*(3), 161-169. doi:http://dx.doi.org/10.1016/j.iheduc.2011.10.003

Tharp, R., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning and schooling in social context*. New York: Cambridge University Press.

Thompson, B. (1998). Review of 'what if there were no significant tests?'. *Educational and Psychological Measurement, 58*, 334-346.

Thompson, B. (2001). Significance, effect sizes, stepwise methods, and other issues: Strong arguments move the field. *Journal of Experimental Education, 70*, 80-93. doi:http://dx.doi.org/10.1080/00220970109599499

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications*. Washingtom, DC: American Psychological Association.

Thurstone, L. L., & Chave, E. J. (1929). *The measurement of attitude: A psychophysical method and some experiments with a scale for measuring attitude toward the church*. Chicago: University of Chicago.

Triandis, H. C. (1971). *Attitudes and attitude change*. New York: Wiley.

Trickett, E. J., & Moos, R. H. (1973). Social environment of junior high and high school classrooms. *Journal of Educational Psychology, 65*(1), 93-102. doi:http://dx.doi.org/10.1037/h0034823

Trinidad, S., Aldridge, J. M., & Fraser, B. J. (2005). Development, validation and use of the Online Learning Environment Survey. *Australasian Journal of*

Educational Technology, 21(1), 60-81. doi:http://dx.doi.org/10.14742/ajet.1343

Tshewang, R., Chandra, V., & Yeh, A. (2017). Students' and teachers' perceptions of classroom learning environment in Bhutanese eighth-grade mathematics classes. *Learning Environments Research, 20*(2), 269-288. doi:http://dx.doi.org/10.1007/s10984-016-9225-6

UAE National Media Council. (1995). UAEinteract. Retrieved from http://www.uaeinteract.com/culture/history.asp

UNESCO Institute for Statistics. (2015). Regional and country profiles. Retrieved from http://www.uis.unesco.org/DataCentre/Pages/country-profile.aspx?code=ARE

Unlu, M., Ertekin, E., & Dilmac, B. (2017). Predicting relationships between mathematics anxiety, mathematics teaching anxiety, self-efficacy beliefs towards mathematics and mathematics teaching. *International Journal of Research in Education and Science, 3*(2), 636-645. doi:http://dx.doi.org/10.21890/ijres.328096Age

Urdan, T. (2004). Predictors of academic self-handicapping and achievement: Examining achievement goals, classroom goal structures, and culture. *Journal of Educational Psychology, 96*, 251-264. doi:http://dx.doi.org/10.1037/0022-0663.96.2.251

Uztosun, M. S., Skinner, N., & Cadorath, J. (2018). An action research study into the role of student negotiation in enhancing perceived student engagement during English speaking classes at university level in Turkey. *Educational Action Research, 26*(1), 106-126. doi:http://dx.doi.org/10.1080/09650792.2016.1270223

Van Maanen, J. (1982). *Fieldwork on the beat*. Beverley Hills, CA: SAGE.

Van Maanen, J. (1988). *Tales of the Field: On Writing Ethnography*. Chicago, IL: University of Chicago.

Vandecandelaere, M., Speybroeck, S., Vanlaar, G., De Fraine, B., & Van Damme, J. (2012). Learning environment and students' mathematics attitude. *Studies in Educational Evaluation, 38*(3), 107-120. doi:http://dx.doi.org/10.1016/j.stueduc.2012.09.001

Vansteenkiste, M., Aelterman, N., De Muynck, G.-J., Haerens, L., Patall, E., & Reeve, J. (2018). Fostering personal meaning and self-relevance: A self-determination theory perspective on internalization. *Journal of Experimental Education, 86*(1), 30-49. doi:http://dx.doi.org/10.1080%2F00220973.2017.1381067

Velayutham, S., & Aldridge, J. M. (2013). Influence of psychosocial classroom environment on students' motivation and self-regulation in science learning: A structural equation modeling approach. *Research in Science Education, 43*(2), 507-527. doi:http://dx.doi.org/10.1007/s11165-011-9273-y

Velayutham, S., Aldridge, J. M., & Fraser, B. (2012). Gender differences in student motivation and self-regulation in science learning: A multi-group structural equation modeling analysis. *International Journal of Science and Mathematics Education, 10*(6), 1347-1368. doi:http://dx.doi.org/10.1007/s10763-012-9339-y

Velayutham, S., Aldridge, J. M., & Fraser, B. J. (2011). Development and validation of an instrument to measure students' motivation and self-regulation in science learning. *International Journal of Science Education, 33*(15), 2159-2179. doi:http://dx.doi.org/10.1080/09500693.2010.541529

Von Oppell, M. A., & Aldridge, J. M. (2015). Teacher beliefs and education reform in Abu Dhabi: 21st century skills. *MSKU Journal of Education, 2*(2), 36-60. doi:http://dx.doi.org/10.21666/mskuefd.31152

Vygotsky, L. (1934/1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. (1934/1987). Development of scientific (subject-matter) concepts (N. Minick, Trans.). In R. W. Rieher & A. S. Canton (Eds.), *The collected works* *of L. S. Vygotsky, Vol. 1, Thinking and speech* (pp. 167-242). New York: Plenum Press.

Vygotsky, L. (1962). *Thought and language*. Cambridge: Cambridge University Press.

Wahyudi, & Treagust, D. F. (2004a). Learning environment and students' outcomes in science classes in Indonesian lower secondary schools. *Journal of Science and Mathematics Education in Southeast Asia, 27*(1), 139-165.

Wahyudi, & Treagust, D. F. (2004b). The status of science classroom learning environments in Indonesian lower secondary schools. *Learning Environments Research, 7*(1), 43-63. doi:http://dx.doi.org/10.1023/B:LERI.0000022282.48004.18

Walberg, H. J., & Anderson, G. J. (1968). Classroom climate and individual learning. *Journal of Educational Psychology, 59*(6), 414-419. doi:http://dx.doi.org/10.1037/h0026490

Walberg, H. J., & Greenburg, R. C. (1997). Using the Learning Environment Inventory. *Educational Leadership, 54*(8), 45-47.

Walker, S. L., & Fraser, B. J. (2005). Development and validation of an instrument for assessing distance education learning environments in higher education: The Distance Education Learning Environments Survey (DELES). *Learning Environments Research, 8*(3), 289-308. doi:http://dx.doi.org/10.1007/s10984-005-1568-3

Wang, M. T., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal, 47*(3), 633-662. doi:http://dx.doi.org/10.3102%2F0002831209361209

Warwick, D. P., & Osherson, S. (1973). Comparative analysis in the social sciences. In D. P. Warwick, & Osherson, S (Ed.), *Comparative research methods: An overview* (pp. 3-41). Englewood Cliffs: NJ: Prentice-Hall.

Weaver, K. (2018). Pragmatic paradigm. In B. Frey, B. (Ed.), *The SAGE encyclopedia of educational research, measurement, and evaluation* (pp. 1287-1288). doi:https://dx.doi.org/10.4135/9781506326139.n534

Webb-Williams, J. (2018). Science self-efficacy in the primary classroom: Using mixed methods to investigate sources of self-efficacy. *Research in Science Education, 48*(5), 939-961. doi:http://dx.doi.org/10.1007%2Fs11165-016-9592-0

Wentzel, K. R., Battle, A., Russell, S., & Looney, L. (2010). Social supports from teachers and peers as predictors of academic and social motivation. *Contemporary Educational Psychology, 35*, 193-202. doi:http://dx.doi.org/10.1016/j.cedpsych.2010.03.002

Wheldall, K., Beaman, R., & Mok, M. (1999). Does the Individualized Classroom Environment Questionnaire (ICEQ) measure classroom climate? *Educational and Psychological Measurement, 59*(5), 847-854. doi:http://dx.doi.org/10.1177/00131649921970170

White-Clark, R., DiCarlo, M., & Gilchriest, N. (2008). "Guide on the side": An instructional approach to meet mathematics standards. *High School Journal, 91*(4), 40-44. doi:http://dx.doi.org/10.1353/hsj.0.0000

Wigfield, A., & Cambria, J. (2010). Students' achievement values, goal orientations, and interest: Definitions, development, and relations to achievement outcomes. *Developmental Review, 30*(1), 1-35. doi:http://dx.doi.org/10.1016/j.dr.2009.12.001

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*, 68-81. doi:http://dx.doi.org/10.1006/ceps.1999.1015

Wigfield, A., Tonks, S., & Eccles, J. S. (2004). Expectancy-value theory in cross-cultural perspective. In D. M. McInerney & S. V. Etten (Eds.), *Big theories revisited* (pp. 165-198). Greenwich, CT: Information Age Publishing.

Willms, J. D. (2003). Student engagement at school: A sense of belonging and participation: Results from PISA 2000. In J. D. Willms (Ed.). Paris: Organisation for Economic Co-operation and Development.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education, 38*(3), 321-341. doi:http://dx.doi.org/10.1007/s11165-007-9052-y

Wolters, C. A. (2003). Regulation of motivation: Evaluating an underemphasized aspect of self-regulated learning. *Educational Psychologist, 38*(4), 189-205. doi:http://dx.doi.org/10.1207/S15326985EP3804_1

Wong, A. F., & Fraser, B. J. (1994). *Science laboratory classroom environments and student attitudes in chemistry classes in Singapore*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Wu, H.-K., & Hsieh, C.-E. (2006). Developing sixth grader's inquiry skills to construct explanations in inquiry-based learning environments. *International Journal of Science Education, 28*(11), 1289-1313. doi:http://dx.doi.org/10.1080/09500690600621035

Wubbels, T., & Brekelmans, M. (2005). Two decades of research on teacher-student relationships in class. *International Journal of Educational Research, 43*(1-2), 6-24. doi:http://dx.doi.org/10.1016/j.ijer.2006.03.003

Wubbels, T., & Levy, J. (1993). *Do you know what you look like: Interpersonal relationships in education*. London, UK: Falmer Press.

Yang, X. (2015). Rural junior secondary school students' perceptions of classroom learning environments and their attitude and achievement in mathematics in West China. *Learning Environments Research, 18*(2), 249-266. doi:http://dx.doi.org/10.1007/s10984-015-9184-3

You, J. W. (2018). Testing the three-way interaction effect of academic stress, academic self-efficacy, and task value on persistence in learning among

Korean college students. *Higher Education: The International Journal of Higher Education Research, 76*(5), 921-935. doi:http://dx.doi.org/10.1007%2Fs10734-018-0255-0

Zandvliet, D. B., & Fraser, B. J. (2004). Learning environments in information and communications technology classrooms. *Technology, Pedagogy and Education, 13*, 97-123. doi:http://dx.doi.org/10.1080/14759390400200175

Zandvliet, D. B., & Fraser, B. J. (2005). Physical and psychosocial environments associated with networked classrooms. *Learning Environments Research, 8*, 1-17. doi:http://dx.doi.org/10.1007/s10984-005-7951-2

Zayed University. (n.d.). The story of the UAE. Retrieved from http://www.zu.ac.ae/main/en/careers/living/story.aspx

Zeidan, A. (2015). Constructivist learning environment among Palestinian science students. *International Journal of Science and Mathematics Education, 13*(5), 947-964. doi:http://dx.doi.org/10.1007/s10763-014-9527-z

Zentner, H. (1971). People in Context: Measuring Person-Environment Congruence in Education and Industry. (Book Review). In G. G. Stern (Ed.), *American Sociological Review* (Vol. 36, pp. 1156-1156): Sage Publications, Inc.

Zhang, X., & Head, K. (2010). Dealing with learner reticence in speaking class. *ELT Journal, 64*(1), 1-9. doi:http://dx.doi.org/10.1093/elt/ccp018

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*, 82-91. doi:http://dx.doi.org/10.1006/ceps.1999.1016

Zimmerman, B. J. (2002). Achieving academic excellence: A self-regulatory perspective. In M. Ferrari (Ed.), *The pursuit of excellence through education* (pp. 85-110). Mahwah NJ: Erlbaum.

Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self efficacy beliefs and personal goal setting. *American Educational Research Journal, 31*, 845-862. doi:http://dx.doi.org/10.3102/00028312029003663

Appendix A

Mathematics Explorations Rubric

Skill	Criteria	4	3	2	1	0
Inquiring Experimenting	Defining realistic problems	Writes a clear and complete problem Plans a complete process that will lead to a solution	Writes a clear and complete problem Plans a partly complete process that will lead to a solution	Writes an incomplete problem Plans a partly complete process that will lead to a solution	Writes an incomplete problem Plans an unsuitable process that does not lead to a solution	Writes no problem Writes no plan
Handling Researching	Gathering and recording information	Collects sufficient information, all is relevant Acknowledges sources	Collects sufficient information, most is relevant Acknowledges sources	Collects information, some is relevant	Collects information, little is relevant	Collects no relevant information
Creating	Generating solutions	Creates a complete solution to the problem Makes no errors	Creates a complete solution to the problem Makes one or two minor errors	Creates an incomplete solution to the problem Makes no obvious errors but does not solve the problem OR Creates a complete solution to the problem Makes many errors	Attempts to create a solution	Creates no solution
	Suggesting conclusions	Suggests accurate conclusions Gives reasons using results Reflects on the process	Suggests accurate conclusions Gives reasons using results	Suggests accurate conclusions Gives no reasons OR Suggests inaccurate conclusions Gives some reasons	Suggests inaccurate conclusions Gives no reasons	Suggests no conclusions
Participating	Collaborating with other students	Contributes fully to the group's work Understands the group's results comp letely	Contributes fully to the group's work Understands most of the group's results	Contributes partly to the group's work Understands some of the group's results	Contributes little to the group's work Understands little of the group's results	Makes no contribution

Appendix B

Permission to Adapt Table

BF Barry Fraser <B.Fraser@curtin.edu.au> Jennifer Robinson; Jill Aldridge

RE: Permission to adapt and use table

You replied to this message on 24/04/2019 07:31.

Jennifer

Hi. That sounds ok. The important thing is to have a footnote to the table that says it was adapted from Fraser (2012).

Barry

From: Jennifer Robinson [mailto:jennifer.m.robinson@postgrad.curtin.edu.au]
Sent: Tuesday, 23 April 2019 5:52 PM
To: Barry Fraser
Cc: Jill Aldridge
Subject: Permission to adapt and use table

Dear Barry,

I am writing to request permission to adapt and use a table from your chapter 'Classroom learning environments: Retrospect, context and prospect' from the book 'The second international handbook of science education' (2012). If possible, I would like to adapt and use the table as below in my literature review as part of my PhD thesis.

I look forward to hearing from you.

Appendix C

Criteria for Recommendation of Teachers Exemplary in the use of Explorations

1. The teacher follows/teaches/supports/models the process and skills of inquiry according to the ADEC Mathematics explorations rubric for grades 7-12:
   - Defining realistic problems (includes creating a plan)
   - Gathering and recording information
   - Generating solutions
   - Suggesting conclusions

   The teacher does not only use the inquiry process for explorations (continuous assessment tasks) but also uses it for day-to-day teaching and learning activities.

2. The teacher allows students to explore:
   - Acts as a facilitator rather than walking the students through every step of the process
   - Gives students opportunities to use various avenues to research and to produce products

3. The teacher uses skilful questioning:
   - Asks questions to stimulate thinking
   - Probes student responses for clarification and elaboration
   - Uses questions to prompt students rather than answering their questions directly

4. The teacher provides opportunities for students to reflect on the process and product and to discuss limitations.

5. The teacher nurtures collaboration among students and gives them significant responsibility for the learning of everyone in their group. He/she fosters communal sharing of knowledge.

6. The teacher extends the community of learners to include people, organisations and facilities away from the school.

Appendix D

Learning Environment in Inquiry Survey

English Version

Personal relevance		Almost always	Often	Some-times	Seldom	Almost never
1	I learn about the world outside of school	5	4	3	2	1
2	My new learning starts with problems about the world outside of school	5	4	3	2	1
3	I learn how Mathematics can be part of my out-of-school life	5	4	3	2	1
4	I get a better understanding of the world outside of school	5	4	3	2	1
5	I learn interesting things about the world outside of school	5	4	3	2	1
6	What I learn has nothing to do with my out-of-school life	5	4	3	2	1
Critical voice		**Almost always**	**Often**	**Some-times**	**Seldom**	**Almost never**
7	It's ok for me to ask the teacher "Why do I have to learn this?"	5	4	3	2	1
8	It's ok for me to question the way I'm being taught	5	4	3	2	1
9	It's ok for me to complain about teaching activities that are confusing	5	4	3	2	1
10	It's ok for me to complain about anything that prevents me from learning	5	4	3	2	1
11	It's ok for me to express my opinion	5	4	3	2	1
12	It's ok for me to speak up for my rights	5	4	3	2	1
Shared control		**Almost always**	**Often**	**Some-times**	**Seldom**	**Almost never**
13	I help the teacher to plan what I'm going to learn	5	4	3	2	1
14	I help the teacher to decide how well I am learning	5	4	3	2	1
15	I help the teacher to decide which activities are best for me	5	4	3	2	1
16	I help the teacher to decide how much time I spend on learning activities	5	4	3	2	1
17	I help the teacher to decide which activities I do	5	4	3	2	1
18	I help the teacher to assess my learning	5	4	3	2	1

Student negotiation		Almost always	Often	Some-times	Seldom	Almost never
19	I get the chance to talk to other students	5	4	3	2	1
20	I talk with other students about how to solve problems	5	4	3	2	1
21	I explain my understandings to other students	5	4	3	2	1
22	I ask other students to explain their thoughts	5	4	3	2	1
23	Other students ask me to explain my ideas	5	4	3	2	1
24	Other students explain their ideas to me	5	4	3	2	1
Involvement		**Almost always**	**Often**	**Some-times**	**Seldom**	**Almost never**
25	I discuss ideas in class	5	4	3	2	1
26	I give my opinions during class discussions	5	4	3	2	1
27	The teacher asks me questions	5	4	3	2	1
28	My ideas and suggestions are used during classroom discussions	5	4	3	2	1
29	I ask the teacher questions	5	4	3	2	1
30	I explain my ideas to other students	5	4	3	2	1
31	Students discuss with me how to go about solving problems	5	4	3	2	1
32	I am asked to explain how I solve problems	5	4	3	2	1
Investigation		**Almost always**	**Often**	**Some-times**	**Seldom**	**Almost never**
33	I carry out investigations to test my ideas	5	4	3	2	1
34	I am asked to think about the evidence for statements	5	4	3	2	1
35	I carry out investigations to answer questions coming from discussions	5	4	3	2	1
36	I explain the meaning of statements, diagrams and graphs	5	4	3	2	1
37	I carry out investigations to answer questions that puzzle me	5	4	3	2	1
38	I carry out investigations to answer the teacher's questions	5	4	3	2	1
39	I find out answers to questions by doing investigations	5	4	3	2	1
40	I solve problems by using information obtained from my own investigations	5	4	3	2	1

Appendix E

Learning Environment in Inquiry Survey

Arabic Version

العلاقة بالشخصية	تقريبا دائما	غالبا	أحيانا	نادرا	تقريبا أبدا
أتعلم عن العالم الموجود خارج المدرسة	5	4	3	2	1
تعلمي الجديد يبدأ بمسألة عن العالم الموجود خارج المدرسة	5	4	3	2	1
أتعلم كيف يمكن أن تكون الرياضيات جزء من حياتي خارج المدرسة	5	4	3	2	1
أحصل على فهم أكثر للعالم الموجود خارج المدرسة	5	4	3	2	1
أتعلم اشياء ممتعة عن العالم الموجود خارج المدرسة	5	4	3	2	1
ما أتعلمه ليس له أية علاقة بحياتي خارج المدرسة	5	4	3	2	1
صوت انتقادي	**تقريبا دائما**	**غالبا**	**أحيانا**	**نادرا**	**تقريبا أبدا**
‘يسمح لي أن أسأل المعلم "لماذا يجب علي تعلم هذا؟"	5	4	3	2	1
‘يسمح لي بأن أتساءل عن الطريقة التي يتم تعليمي بها	5	4	3	2	1
‘يسمح لي بأن أشكو عن الأنشطة التعليمية المربكة	5	4	3	2	1
يسمح لي بان أشكو عن أي شيئ يمنعني من التعلم	5	4	3	2	1
يسمح لي بالتعبير عن رأيي	5	4	3	2	1
يسمح لي بالتكلم للحصول على حقوقي	5	4	3	2	1
السيطرة المشتركة	**تقريبا دائما**	**غالبا**	**أحيانا**	**نادرا**	**تقريبا أبدا**
أنا أساعد المعلم للتخطيط لما سأتعلمه	5	4	3	2	1
أساعد المعلم على تحديد مدى تعلمي	5	4	3	2	1
أساعد المعلم حتى يحدد أي الأنشطة هي الأفضل لي	5	4	3	2	1
أساعد المعلم على تحديد كم من الوقت أستغرق لأتعلم الأنشطة	5	4	3	2	1
أساعد المعلم ليحدد أي الأنشطة أستطيع أن أنجز	5	4	3	2	1
أساعد المعلم على تقويم تعلمي	5	4	3	2	1

نقاش الطلاب	تقريبا دائما	غالبا	أحيانا	نادرا	تقريبا أبدا
تُعطى لي الفرصة لأتكلم مع الطلبة الآخرين	5	4	3	2	1
أتكلم مع الطلبة الآخرين عن كيفية حل المسائل	5	4	3	2	1
أوضح ما فهمته للطلبة الآخرين	5	4	3	2	1
أنا أطلب من الطلبة الآخرين أن يوضحوا أفكارهم	5	4	3	2	1
الطلبة الاخرون يطلبوا مني أن أوضح أفكاري	5	4	3	2	1
الطلبة الآخرون يوضحون أفكارهم لي	5	4	3	2	1
المشاركة	**تقريبا دائما**	**غالبا**	**أحيانا**	**نادرا**	**تقريبا أبدا**
أناقش الأفكار في الصف	5	4	3	2	1
أعطي رأيي خلال المناقشات الصفية	5	4	3	2	1
المعلم يوجه لي أسئلة	5	4	3	2	1
أفكاري واقتراحاتي خلال المناقشات الصفية تستخدم	5	4	3	2	1
أسال المعلم أسئلة	5	4	3	2	1
أوضح أفكاري للطلبة الاخرين	5	4	3	2	1
الطلبة يتناقشون معي ما الذي سيفعلونه لحل المسائل	5	4	3	2	1
يطلب مني توضيح كيفية حلي للمسألة	5	4	3	2	1
التحقق	**تقريبا دائما**	**غالبا**	**أحيانا**	**نادرا**	**تقريبا أبدا**
أنا أقوم بالتحقق لأختبر أفكاري	5	4	3	2	1
يطلب مني أن أفكر بأدلة لإثبات صحة عباراتي	5	4	3	2	1
أنا أقوم بالتحقق لكي أجيب على أسئلة نتجت عن النقاش	5	4	3	2	1
أنا أوضح معاني العبارات ،المخططات والرسوم البيانية	5	4	3	2	1
أنا أقوم بالتحقق لكي أجيب عن الأسئلة التي تحيرني	5	4	3	2	1
أنا أقوم بالتحقق لكي أجيب على أسئلة المعلم	5	4	3	2	1
أنا أجد اجابات الأسئلة عن طريق إجراء التحقق	5	4	3	2	1
أنا أحل المسائل باستخدام المعلومات التي حصلت عليها من تحققات قمت أنا بها	5	4	3	2	1

Appendix F

Student Attitudes Towards Mathematics Survey

English Version

Enjoyment of Mathematics classes		Almost always	Often	Some-times	Seldom	Almost never
41	I look forward to lessons in this subject	5	4	3	2	1
42	Lessons in this subject are fun	5	4	3	2	1
43	Lessons in this subject interest me	5	4	3	2	1
44	This subject is one of my favourite school subjects	5	4	3	2	1
45	There should be more lessons in this subject	5	4	3	2	1
46	I enjoy the activities that we do in this subject	5	4	3	2	1
47	These lessons increase my interest in this subject	5	4	3	2	1
Self-Efficacy		**Almost always**	**Often**	**Some-times**	**Seldom**	**Almost never**
48	I can master the skills that are taught	5	4	3	2	1
49	I can figure out how to do difficult work	5	4	3	2	1
50	Even if the Mathematics work is hard, I can learn it	5	4	3	2	1
51	I can complete difficult work if I try	5	4	3	2	1
52	I will receive good grades	5	4	3	2	1
53	I can learn the work we do	5	4	3	2	1
54	I can understand the contents taught	5	4	3	2	1
55	I am good at this subject	5	4	3	2	1
Task value		**Almost always**	**Often**	**Some-times**	**Seldom**	**Almost never**
56	What I learn can be used in my daily life	5	4	3	2	1
57	What I learn is interesting	5	4	3	2	1
58	What I learn is useful for me to know	5	4	3	2	1
59	What I learn is helpful to me	5	4	3	2	1
60	What I learn is relevant to me	5	4	3	2	1
61	What I learn is of practical value	5	4	3	2	1
62	What I learn satisfies my curiosity	5	4	3	2	1
63	What I learn encourages me to think	5	4	3	2	1

Appendix G

Student Attitudes Towards Mathematics Survey

Arabic Version

الاستمتاع بحصص الرياضيات	تقريبا دائما	غالبا	أحيانا	نادرا	تقريبا أبدا
أنا أتطلع بشوق لحصص الرياضيات	5	4	3	2	1
دروس الرياضيات ممتعة	5	4	3	2	1
الدروس في هذه المادة تهمني	5	4	3	2	1
الرياضيات هي إحدى موادي المدرسية المفضلة	5	4	3	2	1
يجب أن نأخذ حصص أكثر في الرياضيات	5	4	3	2	1
انا أستمتع بالأنشطة التي نقوم بها في الرياضيات	5	4	3	2	1
هذه الدروس تزيد من اهتمامي بالرياضيات	5	4	3	2	1

الكفاءة الذاتية	تقريبا دائما	غالبا	أحيانا	نادرا	تقريبا أبدا
أنا أستطيع أن أتقن المهارات التي تم تدريسها	5	4	3	2	1
أستطيع أن أجد طريقة لانجاز العمل الصعب	5	4	3	2	1
حتى لو كان التعامل مع الرياضيات صعبا فانني أستطيع أن أتعلمها	5	4	3	2	1
أستطيع أن أكمل العمل الصعب إذا حاولت	5	4	3	2	1
سوف أحصل على علامات عالية	5	4	3	2	1
أستطيع تعلم ما نقوم بعمله	5	4	3	2	1
أنا أستطيع فهم المحتوى الذي تم تدريسه	5	4	3	2	1
أنا جيد في هذه المادة	5	4	3	2	1
قيمة المهمة	**تقريبا دائما**	**غالبا**	**أحيانا**	**نادرا**	**تقريبا أبدا**
ما أتعلمه يمكن استخدامه في حياتي اليومية	5	4	3	2	1
إن ما أتعلمه ممتع	5	4	3	2	1
ما أتعلمه مفيد لي معرفته	5	4	3	2	1
إن ما أتعلمه يساعدني	5	4	3	2	1
إن ما أتعلمه له علاقة بي	5	4	3	2	1
إن ما أتعلمه له فائدة عملية	5	4	3	2	1
إن ما أتعلمه يرضي فضولي	5	4	3	2	1
إن ما أتعلمه يشجعني على التفكير	5	4	3	2	1

Appendix H

Guiding Questions for Lesson Observations

Guiding Questions for Lesson Observations

Personal Relevance
How relevant is the work to the students' lives? Are there opportunities to see the link between the topic in-class and real-life?
Critical Voice
Do students have opportunities to express opinions, ask questions about relevancy etc.?
Shared Control
Do students have an opportunity to direct the type or pace of teaching, learning or assessment in the classroom?
Student Negotiation
Do students have opportunities to collaborate, discuss and explain their work to other students in the classroom?
Involvement
Are there opportunities for students to participate in the lesson in discussions, problem-solving, asking and answering questions with other students and with the teacher?
Investigation
Do students construct knowledge through the use of investigations within the classroom? Are there opportunities to answer questions through a process of investigation? Do students investigate and provide evidence for new ideas/concepts?

Enjoyment of Mathematics Classes
Are students enjoying their time in the classroom? Are they engaged in the subject/activities?
Self-Efficacy
Are students coping with the work presented to them? Have they got a good attitude towards achieving the work? Do they appear to have a 'can do' attitude?
Task Value
Are the tasks the students are completing of value to them? Are they relevant, practical to them, interesting, thought-provoking?

Appendix I

Interview Schedule

Interview Schedule for Focus Groups

Research: Investigating the effectiveness of implementing an inquiry-based exploration approach in mathematics classrooms in Abu Dhabi.

Date:

Time of interview:

Place:

Focus group participants:

Focus Group Opening Statements: Hello! My name is Jennifer Robinson and I'm a student at Curtin University in Perth, Australia. I'm studying inquiry-based learning in mathematics classes in Abu Dhabi. Thank you for taking the time to talk with me today. The purpose of this focus group is to learn about what you think about the use of explorations in your mathematics lessons and how that affects how you feel about learning mathematics. There are no right, or wrong answers and I want you to be comfortable saying what you really think and how you really feel. If it's ok with you, I will be making notes as we talk. Everything you say today will remain confidential, meaning that only myself and those in the group will be aware of your answers.

Questions:

Personal Relevance

- Tell me about a time in your mathematics classes when you studied a topic that linked to your everyday life.

Critical Voice

- Can you describe a situation in class when you were able to express an opinion?
- Can you describe a situation in class when you were able to ask about the purpose or reason behind the topic you were studying?

Shared Control

- How is the pacing of the lesson determined? Is it possible to change this and if so, how?
- How is the content of the lesson determined? Is it possible to change this and if so, how?

Student Negotiation

- Are there opportunities for you to collaborate with other students and discuss your work? If so, when and how does this normally happen?

Involvement

- Do you feel involved in your mathematics classes? (in terms of discussion, problem-solving, asking and answering questions – with both other students and the teacher). If so, can you give an example of when this happened?

Investigation

- Can you describe a time when you completed a mathematical investigation in class?
- Can you describe a time when you investigated a new idea or topic and provided evidence to support the concept?

Enjoyment of Mathematics Classes

- Do you enjoy this mathematics class? Why or why not?

Self-Efficacy

- When studying mathematics in this class, do you feel like you can do the work and you can be successful? What makes you think that?

Task Value

- Can you describe a task in your mathematics class that was interesting or thought-provoking and you found it valuable?
- Are these types of tasks what you usually complete?

Is there anything else you'd like to tell me?

Potential Probes/Prompts:

Tell me more…

It sounds like you are saying…

How so?

Why is that important?

Could you give me an example of that?

Tell me about the last time you did that.

Wrap Up/Conclusion: Thank you again for taking the time to meet with me today and being so willing to participate in the focus group. I really appreciate your cooperation and considered responses to my questions. I want to remind you again that everything we have discussed today is confidential. If you are interested in the results of my study, once completed, it will be available on the ADEC website in the Research section.

Appendix J

Ethics Approval from Curtin University

Curtin University

Memorandum

To	Jennifer Robinson, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval **SMEC-15-13**
Date	17 May 2013
Copy	Jill Aldridge, SMEC

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 Low Risk (Ethical Requirements)" for the project titled *"Investigating the effectiveness of implementing an inquiry-based exploration approach in mathematics classrooms in Abu Dhabi"*. 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 4 years **13th May 2013** to **12th May 2014**.

Your approval has the following conditions:

(i) Annual progress reports on the project must be submitted to the Ethics Office.

(ii) It is your responsibility, as the researcher, to meet the conditions outlined above and to retain the necessary records demonstrating that these have been completed.

The approval number for your project is **SMEC-15-13**. Please quote this number in any future correspondence. If at any time during the approval term changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

[redacted]

PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies (Approval Number xxxx). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21).
For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

J:\SAE\SMEC\office\Pauline\ETHICS\Ethics Approval Letter 2013\Robinson.docx CRICOS Provider Code 00301J

Appendix K

Approval from ADEC Research Office

مجلس أبوظبي للتعليم
Abu Dhabi Education Council
Education First التعليم أولاً

Date: 25th October 2015	التاريخ: 25 أوكتوبر 2015
Ref: EDO/	الرقم: EDO/
To: Public Schools Principals,	**السادة/ مديري المدارس الحكومية**
Subject: Letter of Permission	**الموضوع: تسهيل مهمة باحثين**
Dear Principals,	**تحية طيبة وبعد،،،**
The Abu Dhabi Education Council would like to express its gratitude for your generous efforts & sincere cooperation in serving our dear students.	يطيبُ لمجلس أبوظبي للتعليم أن يتوجه لكم بخالص الشكر والتقدير لجهودكم الكريمة والتعاون الصادق لخدمة أبنائنا الطلبة.
You are kindly requested to allow the researcher/ **JENNIFER MAREE ROBINSON** , to complete her research on : **Investigating the effectiveness of implementing an inquiry-based exploration approach in mathematics classrooms in Abu Dhabi**	ونود إعلامكم بموافقة مجلس أبو ظبي للتعليم على موضوع الدراسة التي ستجريها الباحثة/**جينيفير ماري روبينسون** بعنوان: **Investigating the effectiveness of implementing an inquiry-based exploration approach in mathematics classrooms in Abu Dhabi**
Please indicate your approval of this permission by facilitating her meetings with the sample groups at your respected schools.	لذا، يرجى التكرم بتسهيل مهمة الباحثة ومساعدتها على إجراء الدراسة المشار إليها.
For further information: please contact **Mr Helmy Seada** on 02/6150140	للاستفسار: يرجى الاتصال بالسيد/ **حلمي سعدة** على الهاتف 02/6150140
Thank you for your cooperation. [redacted]	شاكرين لكم حسن تعاونكم
Sincerely yours,	وتفضلوا بقبول فائق الاحترام والتق[redacted]

مسعود عبد الله بدري
مدير وحدة البحوث والتخطيط وقياس الأداء

صندوق بريد: ٣٦٠٠٥، أبوظبي - إ.ع.م، هاتف: ٠٠٠٠ ٦١٥ ٢ ٩٧١+، فاكس: ٠٦٠٢ ٦١٥ ٢ ٩٧١+، البريد الإلكتروني: info@adec.ac.ae
P.O.Box. 36005, Abu Dhabi - U.A.E., Tel: +971 2 615 0000, Fax: +971 2 615 0602, Email: info@adec.ac.ae

Appendix L

Participant Information Sheet – Principals and Teachers

English Version

Curtin University
Science and Mathematics Education Centre
Participant Information Sheet – Principals & Teachers

My name is Jennifer Robinson. I am currently completing a piece of research for my Masters of Philosophy of Mathematics Education at Curtin University of Technology.

Purpose of Research

I am investigating how successful explorations are in Mathematics classrooms in Abu Dhabi from the point of view of the students in the class.

Your Role

I am interested in finding out about student attitudes towards explorations and whether they feel this affects the classroom atmosphere and environment. I will ask students in your class/school, questions in a survey about their Mathematics classes in relation to explorations.

Consent to Participate

The students' involvement in the research is entirely voluntary. They have the right to withdraw at any stage without it affecting their rights or my responsibilities. When they have signed the consent form, I will assume that they have agreed to participate and allow me to use their data in this research.

Confidentiality

The information the students provide will be kept separate from their personal details, and only myself and my supervisor will only have access to this. The completed questionnaire will not have their names or any other identifying information on it and in adherence to university policy, the questionnaire 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-15-13). If you would like further information about the study, please feel free to contact me on +971 2 6150 862 or by email jennifer.m.robinson@student.curtin.edu.au. Alternatively, you can contact my supervisor Jill Aldridge on J.Aldridge@curtin.edu.au.

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

Appendix M

Participant Information Sheet – Principals and Teachers

Arabic Version

Curtin University

جامعة كرتن

مركز تعليم الرياضيات والعلوم

ورقة معلومات المشارك- المدير والمعلمين

اسمي جيني روبنسون. أقوم حاليا ببحث عن فلسفة تعليم الرياضيات لاستكمال دراستي للماجستير في جامعة كرتن للتكنولوجيا

هدف البحث

أنا اتحقق من مدى نجاح الاستكشاف في حصص الرياضيات في أبو ظبي من وجهة نظر الطلاب الذين في الصفوف

دورك

انا مهتمة بمعرفة اتجاهات الطلاب نحو الاستكشاف وفيما إذا كانوا يشعرون أن هذا يؤثر على جو وبيئة الصف. سوف أقوم بسؤال الطلبة في صفك/ مدرستك أسئلة من خلال استفتاء يتعلق بالاستكشاف في حصص الرياضيات

الموافقة على المشاركة

مشاركة الطالب في البحث تطوعية بالكامل. الطلاب يملكوا الحق في الانسحاب في أية مرحلة دون أن يؤثر ذلك على حقوقهم أو واجباتهم. عندما يوقعوا على نموذج الموافقة فسوف أعتبر أنهم وافقوا على المشاركة ويسمحوا لي باستخدام بياناتهم في هذا البحث.

السرية

المعلومات التي سيزودني بها الطلاب سوف تحفظ منفصلة عن بياناتهم الشخصية فقط أنا والمسئولة عني في البحث يمكننا الاطلاع عليها. الاستفتاء المكتمل سوف لن يكون عليه اسمهم أو أية معلومات أخرى تعرف بشخصيتهم وهذا أيضا من سياسة الجامعة ، الاستفتاء سوف يحفظ في خزانة مغلقة على الاقل لمدة خمسة سنوات قبل ان يتخذ قرار بشأن اتلافه.

معلومات إضافية

هذا البحث تمت مراجعته والموافقة عليه من قبل لجنة أخلاق الأبحاث الإنسانية التابعة لجامعة كرتن للتكنولوجيا موافقة رقم SMEC-15-13

اذا كنت ترغب بمعرفة أية معلومات أخرى تتعلق بالدراسة يرجى التكرم بالاتصال بي على الرقم +97126150862 أو بالايميل

أو كبديل عن ذلك يمكنكم مخاطبة مسؤولتي جل الدردج على الايميل

jennifer.m.robinson@student.curtin.edu.au.

.J.Aldridge@curtin.edu.au

شكرا جزيلا لانضمامك لهذا البحث.

نحن نقدر بشكل كبير مشاركتك معنا.

Appendix N

Participant Information Sheet – Students

English Version

Curtin University
Science and Mathematics Education Centre
Participant Information Sheet - Students

My name is Jennifer Robinson. I am currently completing a piece of research for my Masters of Philosophy of Mathematics Education at Curtin University of Technology.

Purpose of Research

I am investigating how successful explorations are in Mathematics classrooms in Abu Dhabi from the point of view of the students in the class.

Your Role

I am interested in finding out about student attitudes towards explorations and whether they feel this affects the classroom atmosphere and environment. I will ask you questions in a survey about your Mathematics classes in relation to explorations.

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 only have access to this. The completed questionnaire will not have your name or any other identifying information on it and in adherence to university policy, the questionnaire 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-15-13). If you would like further information about the study, please feel free to contact me on +971 2 6150 862 or by email jennifer.m.robinson@student.curtin.edu.au. Alternatively, you can contact my supervisor Jill Aldridge on J.Aldridge@curtin.edu.au.

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

Appendix O

Participant Information Sheet – Students

Arabic Version

Curtin University

جامعة كرتن

مركز تعليم الرياضيات والعلوم

ورقة معلومات المشارك- الطلاب

اسمي جيني روبنسون. أقوم حاليا ببحث عن فلسفة تعليم الرياضيات لاستكمال دراستي للماجستير في جامعة كرتن للتكنولوجيا.

هدف البحث

أنا أتحقق من مدى نجاح الاستكشاف في حصص الرياضيات في أبو ظبي من وجهة نظر الطلاب الذين في الصفوف.

دورك

أنا مهتمة بمعرفة اتجاهات الطلاب نحو الاستكشاف وفيما إذا كانوا يشعرون أن هذا يؤثر على جو وبيئة الصف. سوف أقوم بسؤالك أنت أسئلة من خلال استفتاء يتعلق بالاستكشاف في حصص الرياضيات.

الموافقة على المشاركة

مشاركتك في البحث تطوعية بالكامل.أنت تملك الحق في الانسحاب في أية مرحلة دون أن يؤثر ذلك على حقوقك أو مسؤولياتك. عندما توقع على نموذج الموافقة فسوف أعتبر أنك وافقت على المشاركة وتسمح لي باستخدام بياناتك في هذا البحث.

السرية

المعلومات التي ستزودني بها سوف تحفظ منفصلة عن بياناتك الشخصية فقط أنا والمسئولة عني في البحث يمكننا الاطلاع عليها. الاستفتاء المكتمل سوف لن يكون عليه اسمك او اية معلومات اخرى تعرف بشخصيتك وهذا ايضا من سياسة الجامعة ، الاستفتاء سوف يحفظ في خزانة مغلقة على الاقل لمدة خمسة سنوات قبل ان يتخذ قرار بشأن اتلافه.

معلومات إضافية

هذا البحث تمت مراجعته والموافقة عليه من قبل لجنة أخلاق الأبحاث الإنسانية التابعة لجامعة كرتن للتكنولوجيا موافقة رقم SMEC-15-13

إذا كنت ترغب بمعرفة أية معلومات أخرى تتعلق بالدراسة يرجى التكرم بالاتصال بي على الرقم +97126150862 او بالايميل

او كبديل عن ذلك يمكنك مخاطبة المسئولة عني جل الدردج على الايميل

jennifer.m.robinson@student.curtin.edu.au.

.J.Aldridge@curtin.edu.au

شكرا جزيلا لانضمامك لهذا البحث.

نحن نقدر بشكل كبير مشاركتك معنا.

Appendix P

Participant Information Sheet – Parents

English Version

Curtin University

Curtin University
Science and Mathematics Education Centre
Participant Information Sheet – Parents

My name is Jennifer Robinson. I am currently completing a piece of research for my Masters of Philosophy of Mathematics Education at Curtin University of Technology.

Purpose of Research

I am investigating how successful explorations are in Mathematics classrooms in Abu Dhabi from the point of view of the students in the class.

Your Role

I am interested in finding out about student attitudes towards explorations and whether they feel this affects the classroom atmosphere and environment. I will ask your son/daughter, questions in a survey about their Mathematics classes in relation to explorations.

Consent to Participate

The students' involvement in the research is entirely voluntary. They have the right to withdraw at any stage without it affecting their rights or my responsibilities. When they have signed the consent form, I will assume that they have agreed to participate and allow me to use their data in this research.

Confidentiality

The information your son/daughter provides will be kept separate from their personal details, and only myself and my supervisor will only have access to this. The completed questionnaire will not have their name or any other identifying information on it and in adherence to university policy, the questionnaire 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-15-13). If you would like further information about the study, please feel free to contact me on +971 2 6150 862 or by email jennifer.m.robinson@student.curtin.edu.au. Alternatively, you can contact my supervisor Jill Aldridge on J.Aldridge@curtin.edu.au.

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

Appendix Q

Participant Information Sheet – Parents

Arabic Version

Curtin University

جامعة كرتن

مركز تعليم الرياضيات والعلوم

ورقة معلومات المشارك- ولي الامر

اسمي جيني روبنسون. أقوم حاليا ببحث عن فلسفة تعليم الرياضيات لاستكمال دراستي للماجستير في جامعة كرتن للتكنولوجيا

هدف البحث

أنا أتحقق من مدى نجاح الاستكشاف في حصص الرياضيات في أبو ظبي من وجهة نظر الطلاب الذين في الصفوف

دورك

أنا مهتمة بمعرفة اتجاهات الطلاب نحو الاستكشاف وفيما إذا كانوا يشعروا أن هذا يؤثر على جو وبيئة الصف. سوف أقوم بسؤال ابنك/ ابنتك أسئلة من خلال استفتاء يتعلق بالاستكشاف في حصص الرياضيات

الموافقة على المشاركة

مشاركة الطالب في البحث تطوعية بالكامل. الطلاب يملكوا الحق في الانسحاب في أية مرحلة دون أن يؤثر ذلك على حقوقهم أو مسؤولياتهم. عندما يوقعوا على نموذج الموافقة فسوف أعتبر أنهم وافقوا على المشاركة ويسمحوا لي باستخدام بياناتهم في هذا البحث.

السرية

المعلومات التي سيزودني بها ابنكم/ ابنتكم سوف تحفظ منفصلة عن بياناتهم الشخصية فقط أنا والمسئولة عني في البحث يمكننا الاطلاع عليها. الاستفتاء المكتمل سوف لن يكون عليه اسمهم أو أية معلومات أخرى تعرف بشخصيتهم وهذا ايضا من سياسة الجامعة ، الاستفتاء سوف يحفظ في خزانة مغلقة على الاقل لمدة خمسة سنوات قبل ان يتخذ قرار بشأن اتلافه.

معلومات إضافية

هذا البحث تمت مراجعته والموافقة عليه من قبل لجنة أخلاق الأبحاث الإنسانية التابعة لجامعة كرتن للتكنولوجيا موافقة رقم SMEC-15-

إذا كنت ترغب بمعرفة اية معلومات اخرى تتعلق بالدراسة يرجى التكرم بالاتصال بي على الرقم +97126150862 او بالايميل

أو كبديل عن ذلك يمكنكم مخاطبة مسؤولتي جل الدرجج على الايميل

jennifer.m.robinson@student.curtin.edu.au

.J.Aldridge@curtin.edu.au

شكرا جزيلا لانضمامك لهذا البحث.

نحن نقدر بشكل كبير مشاركتك معنا.

Appendix R

Instructions on Cover Page of Survey

English Version

What is happening in my Mathematics classroom with explorations?

DIRECTIONS

1. **Purpose of the Questionnaire**
This questionnaire asks you to describe important aspects of the Mathematics classroom which you are in right now. There are no right or wrong answers. This is not a test and your answers will not affect your assessment. Your opinion is what is wanted. Your answers will enable us to improve future Mathematics classes.

2. **How to Answer Each Question**
On the next few pages you will find 63 sentences. For each sentence, circle only one number corresponding to your answer. For example:

		Almost always	Often	Some-times	Seldom	Almost never
27	The teacher asks me questions	5	4	3	2	1

- If you think this teacher *almost always* asks you questions, circle the 5.
- If you think this teacher *almost never* asks you questions, circle the 1.
- Or you can choose the number 2, 3 or 4 if one of these seems like a more accurate answer.

3. **How to Change Your Answer**
If you want to change your answer, cross it out and circle a new number, For example:

27	The teacher asks me questions	5 (crossed out)	4 (circled)	3	2	1

4. **Completing the Questionnaire**
Now turn the page and please give an answer for every question.

Appendix S

Instructions on Cover Page of Survey

Arabic Version

ماذا يجري في صف الرياضيات بالنسبة للاستكشاف ؟

الإرشادات

1. **الهدف من الاستبيان**
يطلب منك هذا الاستبيان أن تصف المظاهر المهمة لصف الرياضيات الموجود أنت فيه الآن . لا يوجد إجابات صحيحة أو خاطئة . إنه ليس اختبارا و سوف لن تؤثر الإجابات في تقييمك . المطلوب هو رأيك . سوف تمكننا إجاباتك من تطوير حصص الرياضيات في المستقبل .

2. **كيفية الإجابة عن كل سؤال**
سوف تجد 63 جملة في الصفحات التالية . أجب بوضع دائرة حول رقم واحد فقط عند كل جملة . مثلا :

		تقريبا دائما	غالبا	أحيانا	نادرا	تقريبا أبدا
27	يطرح علي المعلم أسئلة	5	4	3	2	1

- إذا كنت تعتقد أن المعلم *تقريبا دائما* يطرح عليك أسئلة ، ضع دائرة حول الرقم 5 .
- إذا كنت تعتقد أن المعلم *تقريبا أبدا* لا يطرح عليك أسئلة ، ضع دائرة حول الرقم 1 .
- أو تستطيع أن تختار الأرقام 2، 3 أو 4 إذا كانت واحدة منها تبدو صحيحة أكثر .

3. **كيف تغير أجابتك**
إذا أردت تغيير إجابتك ، اشطبها و ضع دائرة على رقم جديد ، مثلا :

27	يطرح علي المعلم أسئلة	~~5~~	(4)	3	2	1

4. **إكمال الاستبيان**
لطفا اقلب الصفحة الآن و أجب عن جميع الأسئلة .