

Science and Mathematics Education Centre

**Learning Environment and Attitudes in
Middle School Mathematics**

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Doctor of Science Education

of

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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.

Human Ethics (For projects involving human participants/tissue, etc) The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated 2018. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC000262), Approval Number #SMEC-41-11.

Signature:



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Date: February 2019

ABSTRACT

The main purpose of this research was to investigate associations between perceptions of the learning environment and attitudes to mathematics among 221 year 9 students in Adelaide, South Australia. Because past studies of associations between the learning environment and student attitudes have been less common in mathematics classrooms than in science classrooms, this research filled a gap.

A modified version of the What Is Happening In this Class? (WIHIC) questionnaire was used to assess six aspects of the learning environment (namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity) and a modified version of the Test Of Mathematics-Related Attitudes (TOMRA) was used to assess three aspects of student attitudes to mathematics (namely, Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes).

For both the WIHIC and TOMRA, factorial validity was checked using exploratory factor analysis and internal consistency reliability was checked using Cronbach's alpha coefficient. But a distinctive feature of my study was that the factorial validity of the WIHIC also was investigated using confirmatory factor analysis. All of these analyses supported the satisfactory factorial validity and internal consistency reliability of both the WIHIC and TOMRA when used with middle-school students in South Australia. Other researchers and teachers are likely to find these modified and validated versions of the WIHIC and TOMRA useful for assessing the classroom learning environment and student attitudes to mathematics.

Another methodologically-unique feature of my study was that associations between classroom environment and student attitudes were investigated using two methods of analysis, namely, multiple regression and structural equation modelling, thus permitting comparison of the results from two different methods. Overall, there was relatively close agreement between the two methods in identifying moderate and consistently-positive associations between the classroom environment and students' attitudes to mathematics. This pattern among mathematics students in South Australia replicates considerable prior research internationally in a variety of subject areas.

Also sex differences in students' perceptions of the mathematics learning environment and their attitudes to mathematics were investigated using a one-way MANOVA for the set of six WIHIC and three TOMRA scales. The univariate ANOVA was interpreted separately for each scale when statistically-significant sex differences were found for the set of scales as a whole. Interestingly, female students perceived the mathematics learning environment more positively than their male classmates, but females' attitudes towards mathematics were less positive than their male peers. These sex differences were statistically significant for five out of the nine WIHIC and TOMRA scales, with moderate effect sizes ranging from 0.37 to 0.61 standard deviations for those five scales.

The specific environment–attitude associations identified in this study have practical implications mathematics teachers. By emphasising the classroom environment dimensions found to be linked empirically with positive student attitudes, mathematics teachers are likely to be able to improve their students' attitudes.

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Chapter 1

INTRODUCTION

1.1 Introduction

In a study of Australian school enrolments from 1992 to 2012, it was reported that, despite a 16% increase in the total number of students enrolled, the participation rate fell in most science and mathematics subjects among the Year 12 cohort during this 20-year period (Kennedy, Lyons & Quinn, 2014). The Australian Mathematical Sciences Institute (AMSI) suggested that a future high-technology research-driven economy in Australia would only be possible if these 20-year trends in enrolments in mathematical sciences could be reversed (Wienk, 2015). This AMSI report also identified that, while most students take at least some mathematics in Year 12, the proportion of students taking intermediate and advanced mathematics subjects in secondary school — particularly girls — has been in steady decline for two decades.

A study of year 5 and 6 primary-school students in New Zealand revealed that their views about mathematics were firmly grounded in their experiences at school (Grootenboer, 2002). By the time students begin middle schooling, they have developed perceptions of their mathematical ability and potential, as have most parents. It is often a challenge for mathematics teachers to work with students who have a strong negative self-perception, particularly if this perception is reinforced at home.

Fraser (2001) suggests that, because students spend approximately 20,000 hours in primary, secondary and tertiary classrooms, their perceptions of and reactions to what happens in these classrooms is significant. Providing a suitable learning environment is imperative because it has been shown to positively influence both attitudes and cognitive outcomes among students (Aldridge & Fraser, 2008; Fraser, 2007, 2012, 2018).

The central aim of this study was to investigate possible relationships between students' perceptions of the learning environment and their attitudes to mathematics. These associations were investigated using both multiple regression analysis and Structural Equation Modeling (SEM), and the results from these two types of analyses were compared. This study also investigated gender differences in students' perceptions of the mathematics learning environment and their attitudes towards mathematics.

This chapter briefly provides a background to the study (Section 1.2), a summary of some relevant past classroom environment research (Section 1.3) and a rationale for the study (Section 1.4). My research questions are delineated (Section 1.5) and a guiding framework and structural model for the study are explained (Section 1.6), before some of the limitations of this study (Section 1.7) and an overview of this thesis are briefly presented (Section 1.8).

1.2 Background to the Study

The decline in Australia's attainments and rankings in international educational assessments in mathematics and science have raised grave concerns (Australian Academy of Science, 2009; Office of the Chief Scientist, 2014). The Australian Curriculum, Assessment and Reporting Authority (ACARA, 2017) reported that mathematics performance in the National Assessment Program – Literacy and Numeracy (NAPLAN) had stalled or declined. The latest Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) reports for Australia revealed 'an absolute decline' in achievement levels in science and mathematics (ACER, 2016a, 2016b). Kennedy, Lyons and Quinn (2014) suggest that the educational sector, industry and government should be troubled by a decline in student participation in intermediate and advanced levels of mathematics because school Science, Technology, Engineering and Mathematics (STEM) is the basis for creating citizens with the levels of literacy and awareness required in the future. Australian rates of tertiary entrance into mathematical sciences degrees is half the OECD average (Timms, Moyle, Weldon & Mitchell, 2018). Despite a higher rate of university enrolment for Australian women, men are more likely to study (and later work in) the lucrative STEM fields (OECD, 2017). Also worrying is an ongoing gender gap in post-secondary degree achievement in mathematically-intensive STEM disciplines internationally (OECD, 2013), in the US (NSF, 2013) and in Australia (Office of the Chief Scientist, 2016).

The reasons why students choose to study lower-level mathematics or not to study mathematics at all in senior-high school have been the subject of much research.

Suggestions made by researchers include: ‘gaming’ or exploiting the system to maximise tertiary entrance rank while minimising effort (McNeilage, 2013a), disappearance of formal university prerequisites (McNeilage, 2013b), diverse state and territory education policies (Wilson & Mack, 2014), lack of appreciation of the importance of mathematics in science and lack of potential career information (Chinnappan, Dinham, Herrington & Scott, 2007) and student self-perceptions about their previous achievement, ability, interest in mathematics, as well as the difficulty and usefulness of mathematics (McPhan, Morony, Pegg, Cooksey & Lynch, 2008).

Past research has revealed that the students’ outcomes are influenced by the learning environment (Aldridge & Fraser, 2008; Fraser, 2007, 2012, 2018). When Lewin (1936) identified that the environment, personal characteristics and their interaction influence human behaviour, he established the theoretical foundation of the learning environments field. The historical background of the field of learning environments is discussed further in Section 2.2. Learning environment questionnaires have enabled the study of learning environments to expand, first beginning in the Western world and later throughout Asia (Fraser, 2002) and elsewhere. A number of historically-important and contemporary learning environment instruments are reviewed in Section 2.3.

Traditionally, the focus of mathematics education research has been the cognitive component rather than affective areas of learning such as attitudes. In a meta-analysis of past research, associations were identified between student attitudes to mathematics and teacher qualities, student personality or social factors, gender, parental influences, peer influences and intelligence (Dungan & Thurlow, 1989). Past learning

environment research has revealed positive associations between students' perceptions of the learning environment of their mathematics classroom and their attitudes to the subject (Afari, Aldridge, Fraser & Khine, 2013; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). Questionnaires for assessing attitudes to mathematics are reviewed in Section 2.6, particularly the Test of Mathematics-Related Attitudes (TOMRA) because it was selected for my study, together with a summary of studies that have included scales from the TOMRA.

Generally, in past learning environment research, more positive perceptions of the learning environment are held by female students than their male peers (Fraser, Giddings & McRobbie, 1995; Goh & Fraser, 1998; Quek, Wong & Fraser, 2005; Taylor & Fraser, 2013). My study included investigation of sex as a determinant of learning environment perceptions and student attitudes towards middle-school mathematics.

Sadler and Tai (2007) suggest that there are two pillars that support the study of college (tertiary) sciences, namely, the previous study of the same science subject and more-advanced mathematics in high school. If Australia's future lies in STEM industries, it is important to encourage students to maintain their study of mathematics and at more-advanced levels. Pathways from the classroom to a career in the STEM economy must be made clear (Office of the Chief Scientist, 2014). Because the Australian Curriculum allows students and families to start making decisions about mathematical pathways at year 10 (ACARA, nd), investigating middle-school students' perceptions of their classroom environments and their attitudes to mathematics might provide educators and other stakeholders with insights into how to reverse the downwards trends in enrollments and achievement in mathematics

discussed above.

1.3 Past Classroom Environment Research

Investigating social and psychological aspects of classrooms, and how to assess them quantitatively, have been the focus of past learning environment research (Fraser, 2012). A concise history of learning environments research is provided below and is explored in more detail in Chapter 2, especially in Section 2.5.

While the Learning Environment Inventory (LEI) was being developed in the United States by Walberg and Anderson (1968), Moos was independently developing the Classroom Environment Scale (CES) in the same country (Moos, 1979; Moos & Trickett, 1974, 1987; Trickett & Moos, 1973). Modified from the LEI, the My Class Inventory (MCI) was developed for use with children aged between 8 and 12 years (Fisher & Fraser, 1981). To assess relationships between teachers and students, Wubbels and a team of researchers in the Netherlands developed the Questionnaire on Teacher Interaction (QTI) (Wubbels, Créton & Hoomayers, 1992; Wubbels & Levy, 1993).

Fraser and colleagues developed the Individualised Classroom Environment Inventory (ICEQ) in Australia to assess those dimensions that distinguish individualised and conventional classrooms (Fraser, 1990). To investigate the unique environment of the science laboratory, the Science Laboratory Environment Inventory (SLEI) (Fraser, McRobbie & Giddings, 1993) was developed. Taylor, Fraser and Fisher (1997) created the Constructivist Learning Environment Scale (CLES) to

assess how well constructivist principles are reflected in the learning environment. This led to the development of the widely-used and frequently-validated What Is Happening In this Class? (WIHIC) questionnaire (Aldridge, Fraser & Huang, 1999; Fraser, Fisher & McRobbie, 1996), which was used in my study. The WIHIC formed the basis of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), which was designed and used to evaluate learning environments with a focus on outcomes (Aldridge & Fraser, 2008). Specially-selected or all WIHIC scales have been used in the creation of new learning environment questionnaires including the Outcomes-Based Learning Environment Questionnaire (QBLEQ) to monitor the implementation of outcomes-based education in South Africa (Aldridge, Laugksch, Seopa & Fraser, 2006) and the Constructivist-Orientated Learning Environment Scale (COLES) to provide feedback to both students and teachers to guide improvements in learning environments (Bell & Aldridge, 2014; Aldridge, Fraser, Bell & Dorman, 2012).

In my study, I used the WIHIC which was initially developed by Fraser, Fisher and McRobbie (1996) by combining modified and important scales from numerous existing questionnaires with additional scales to accommodate modern education interests. A decade and a half later, the WIHIC was the most frequently-used classroom instrument in the world (Fraser, 2012). The WIHIC has been used in many different forms, translated into numerous Asian, European and Middle Eastern languages, and used in many countries and in cross-national investigations (Fraser, 2002, 2018). The ability to use a research instrument in different countries and languages has allowed researchers to identify not only differences between the

countries' classroom environments, but also factors that influence the learning environment in different cultures (Aldridge et al., 1999).

Fraser (2012) identified as common lines of past learning environments research (1) the evaluation of educational innovations, (2) associations between classroom environment and student outcomes and (3) using learning environment scales as dependent variables. The WIHIC was used to evaluate a two-year mentoring program in science for beginning elementary teachers (Pickett & Fraser, 2009), both WIHIC and SLEI scales were used to evaluate an innovative university science course for female prospective elementary teachers and reveal improvements of greater than 1.5 standard deviations for all scales relative to earlier courses (Martin-Dunlop & Fraser, 2008), and the CLES was used to support the effectiveness of a Mixed Mode Delivery (MMD) by quantifying differences between the actual and preferred learning environment (Koh & Fraser, 2014). Relationships between students' cognitive and affective outcomes and their perceptions of the learning environment have been reported with the QTI in vocational education classrooms (Henderson & Fisher, 2008), with a modified version of the MCI with primary mathematics students (Goh, Young & Fraser, 1995), and with scales from the CLES and WIHIC with mathematics students (Dorman, 2001). In a variety of studies, learning environment scales have been used as dependent variables to investigate how classroom environment varies with other variables including school type, class size, grade-level, school environment, teacher personality, subject content and, the most-extensively researched determinant, gender (Fraser, 2012).

1.4 Rationale for and Significance of the Study

Studies of associations between the learning environment and attitudes have been less common in mathematics than in science classrooms. Traditionally mathematics educational researchers have concentrated on the cognitive component more than affective learning. There has been a relatively limited number of studies involving middle-school mathematics in the field of learning environments, and the WIHIC has not been previously validated specifically with middle-school students in Adelaide, South Australia. Thus, the first aim of my study was to address this gap in the research by validating the WIHIC with middle-school students in South Australia and using it to examine associations between the perceptions of middle-school mathematics students and their attitudes towards mathematics.

The Test of Science-Related Attitudes (TOSRA, Fraser, 1981) was originally designed to measure science-related attitudes among secondary students. Small modifications were made to TOSRA, involving replacing the word ‘science’ with ‘mathematics’, to form the Test of Mathematics-Related Attitudes (TOMRA) (Fraser & Raaflaub, 2013; Spinner & Fraser, 2005). In past studies, researchers have selected one or two scales from TOSRA or TOMRA that were specifically relevant to their research needs and used them in conjunction with learning environment questionnaires. My study attempted to cross validate three TOMRA scales (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes) among middle-school mathematics students in Adelaide, thereby adding to the growing body of knowledge involving mathematics and learning environments.

Gender differences have been widely researched in both learning environments and mathematics education research. Generally, research has revealed that females perceive a more favourable learning environment in their mathematics classrooms than their male peers (Fraser & Raaflaub, 2013; Goh and Fraser, 1998). Despite having more favourable perceptions of the learning environment, girls are still under-represented in senior-high school mathematics enrolments. For example, in Australia during 2013, 76% of girls completing Year 12 were enrolled in a mathematics course compared with 85% of boys and, furthermore, only 6.7% of girls were enrolled in an advanced mathematics subject compared to 12.7% of boys (Barrington & Evans, 2014). My study investigated sex differences in students' perceptions of the learning environment and their attitudes to mathematics.

Since 2000, new statistical methods for analysing data have evolved and been gradually taken up by learning environment researchers (den Brok, Mainhard & Wubbels, 2018). In particular, classroom environment questionnaires have been validated not only by exploratory factor analysis but also by confirmatory factor analysis. As well, associations between learning environment scales and student outcomes have been analysed using Structural Equation Modeling (SEM) in addition to multiple regression analysis. An important feature of my study is that I checked the validity of my learning environment questionnaire using both exploratory and confirmatory factor analyses, and I used and compared results from multiple regression and SEM analyses in investigating associations between students' perceptions of their mathematics learning environment and their attitudes towards mathematics.

For teachers and students, this research has the potential to highlight the influence of the learning environment on the attitudes of students, thereby providing evidence that investing time in creating positive learning environments is not wasted because it is likely to promote positive student attitudes. If teachers can create the types of learning environments that are linked with positive mathematical attitudes among middle-school students, perhaps more students will elect to continue to study mathematics after they are no longer mandated to do so.

1.5 Research Questions and Aims

The first aim of my study was to validate modified versions of the WIHIC and TOMRA with a sample of middle-school students from Adelaide. Two further aims were to identify any associations between the classroom learning environment and the attitudes of middle-school mathematics students and any sex difference in students' perceptions of their mathematics learning environment and their attitudes to the subject. The specific research questions for my study were:

1. Are modified versions of the WIHIC and the TOMRA questionnaires valid when used with middle-school students in Adelaide?
2. Are there associations between the classroom learning environment and student attitudes?
3. Is sex a determinant of students':
 - a. perceptions of the mathematics learning environment;
 - b. attitudes towards mathematics?

In this study, I used both exploratory and confirmatory factor analyses to cross-validate the WIHIC and I investigated associations between classroom learning environment and attitudes in middle-school mathematics using both multiple regression and structural equation modelling (SEM) analyses. This is significant because the relationships identified by each type of analysis could be compared and contrasted.

1.6 Guiding Framework and Structural Model for Study

In investigating associations between the classroom learning environment and students' learning outcomes (specifically attitudes in this study), I followed the precedent of many dozens of prior studies (see reviews of Fraser, 2012, 2014, 2018) of conceptualising student learning outcomes as dependent variables. Furthermore, numerous theoretical frameworks reviewed below provide guiding frameworks for research in which the learning environment is conceptualised as a predictor of student learning outcomes.

An influential antecedent to learning environment research specifically in educational settings was Lewin's (1936) field theory in business settings. Lewin's formula $B = f(P, E)$, emphasises the need to consider behaviour as a function of both the person and the environment. This model was modified and expanded for education by Walberg (1970) to become $L = f(I, A, E)$, with learning outcomes (L) (both cognitive and attitudinal) being a function of instruction (I), student aptitudes (A) and classroom learning environment characteristics (E). Although my study did not

comprehensively investigate aptitude variables, student gender was included as an independent variable.

The three determinants of student learning outcomes identified by Walberg (1970) – instruction, student aptitudes and the learning environment – are similar to the constructs included in other models. Cooley and Lohnes (1976) identified instructional dimensions, initial learner characteristics and contextual variables. Siegel and Siegel's (1964) instructional gestalt includes the same three areas of course variables, learner variables and learning environments, but adds instructor variables as a fourth area. Harnischfeger and Wiley (1978) proposed the teaching–learning process (similar to classroom environment) and background variables (which include instruction and teacher characteristics).

In later expansion of his work, Walberg (1981) incorporated the learning environment into a nine-factor model of educational productivity in which student learning outcomes depend on nine factors: student age, ability and motivation; the quality and quantity of instruction; and the psychosocial environments of the home, classroom, peer group and mass media. Using secondary analysis of huge data bases from the National Assessment of Educational Progress in the USA for three age levels (1955 17-year-olds, 2025 13-year-olds and 1950 9-year-olds), Walberg's educational productivity model was tested for both achievement and attitudinal outcomes (Fraser, Walberg, Welch & Hattie, 1987; Walberg, Fraser & Welch, 1986). Classroom and school environments were found to be strong predictors of both achievement and attitudes even when a comprehensive set of other factors in the productivity model were held constant.

For my use of Structural Equation Modeling (SEM) in exploring associations between classroom environment and students' attitudes to mathematics, a research model involving the three hypotheses shown in Figure 1.1 was developed. The first hypothesis (H1) was that students' perceptions of the six WIHIC classroom environment scales (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation, Equity) are related to the three TOMRA scales used to measure student attitudes to mathematics (Enjoyment of Mathematics Lessons, Attitude to Mathematics Inquiry and Adoption of Mathematical Attitudes). Additional hypotheses were that Attitude to Mathematical Inquiry is related to Enjoyment of Mathematics Lessons and Adoption of Mathematical Attitudes (H2) and that Enjoyment of Mathematics Lessons is associated with Adoption of Mathematical Attitudes (H3).

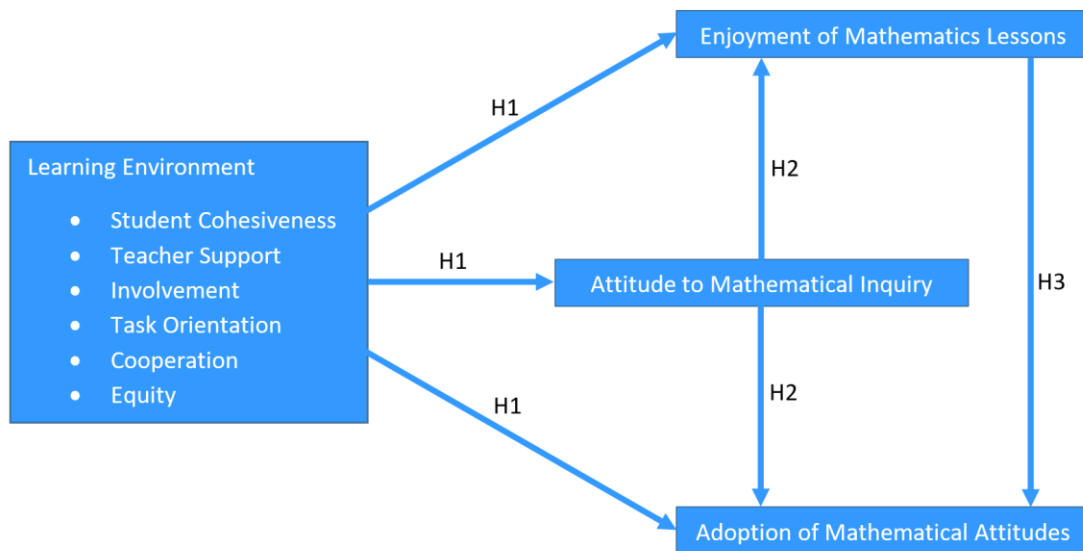


Figure 1.1 Hypothesised Structural Model for the Study

Using SEM, I investigated associations between the learning environment and attitude constructs identified above by testing both direct and indirect effects (den Brok et al.,

2018). In Chapter 4, total, direct and indirect effects derived from SEM are discussed in detail before comparing the magnitudes and statistical significance of direct effects based on SEM analyses and standardised regression weights obtained from multiple regression analysis.

1.7 Some Limitations of this Study

Limitations of this study are discussed comprehensively in Chapter 5, but selected limitations are identified here briefly. The sample selected for this study was limited to middle-school students from three independent schools in Adelaide, with neither Catholic nor South Australian Department of Education schools being included. While a conscious effort was made to include single-sex and coeducational schools in this study, no single-sex boys school agreed to participate. Therefore the findings of this study would have somewhat limited generalisability.

The sample size in this study was smaller and more limited than in some past learning environments studies (Fraser, 2018). Creswell (2008) suggests that the larger the size of a representative sample, then the greater is the statistical power of analyses and the validity of the inferences that can be drawn.

Using both quantitative and qualitative methods together can give a more complete understanding than either of the individual methods (Creswell, 2008, p. 552). Therefore another potential a limitation of my study is that it incorporated only quantitative data, even though this provided enough information to make generalisations and potentially identify new ideas for future research. As

recommended by Tobin and Fraser (1998) and Aldridge and Fraser (2000), future research ideally would involve both quantitative and qualitative research methods. A combination of these methods could help to deepen understanding the research questions posed in this study and provide information regarding social, cultural and educational aspects of the learning environment.

1.8 Overview of the Thesis

The purposes of the study were discussed in Chapter 1 together with relevant background and contextual information. Chapter 2 provides a detailed review of the learning environments research that is pertinent to the study. The history and foundations of the field are discussed, including the development of a wide variety of instruments for measuring different components of the learning environment. Because of the importance of the WIHIC in my study, greater emphasis is given to its development and its use in past research. The diverse use of learning environments questionnaires in educational research is also reviewed. Also a thorough review of the literature is provided about attitudes to mathematics and their assessment, with particular attention to the history and use of the TOMRA, which was used in this study.

Chapter 3 describes the process of recruiting schools to participate in the study and the selection of research participants. Detailed descriptions of the two questionnaires (the WIHIC and the TOMRA) used in my study are provided. The ethical considerations that ensured the confidentiality and safety of the participants are described in Chapter 3. This chapter also provides specifics details about how data

were collected and analysed in order to answer my research questions. This included validation of the WIHIC using both exploratory and confirmatory factor analysis, validation of the TOMRA, and investigation of associations between students' perceptions of their mathematics learning environment and their attitudes towards mathematics using simple correlation and multiple regression analyses. A research model for associations between the mathematics learning environment and students' attitudes towards mathematics was proposed and investigated using SEM. A MANOVA for the set of nine WIHIC and TOMRA scales was conducted to examine sex differences in students' perceptions of mathematics learning environments and attitudes towards mathematics.

In Chapter 4, findings from data analyses conducted to address the research questions outlined in Section 1.5 are reported. The validity of the modified WIHIC is reported based on both exploratory and confirmatory factor analyses. The reliability and validity of the modified TOMRA are also detailed. Section 4.3 reports associations between the learning environment and attitudes to mathematics using multiple regression and Structural Equation Modeling (SEM) analyses. A unique feature of my study is that it involved comparing results obtained for attitude–environment associations from two different methods of analysis (namely, multiple regression and SEM analyses). Sex differences in the students' perceived learning environment scales and attitudes to mathematics are reported in Section 4.4.

Chapter 5 concludes the thesis by summarising the findings and significance of the study. Limitations of the study are considered, recommendations for future research are given and concluding remarks are made.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

My study involved relationships between middle-school students' perceptions of the mathematics learning environment and their attitudes towards mathematics. Research on both classroom learning environment and attitudes towards mathematics have long and well-respected histories. However the combination of both areas in a study focused solely on mathematics is somewhat rare. This chapter reviews the historical background of the field of learning environments (Section 2.2), learning environment instruments (Section 2.3), the What Is Happening In this Class? (WIHIC) questionnaire (Section 2.4), research using learning environments questionnaires (Section 2.5) and assessment of attitudes to mathematics (Section 2.6) in order to form a context for my study.

2.2 Historical Background of the Field of Learning Environments

Fraser (2001) suggests students spend 20 000 hours in primary, secondary and tertiary classrooms and therefore their perceptions and reactions to what happens in their classrooms are significant for their educational experiences. Historically, student achievement has been used as a measure of the effectiveness of education, but Fraser (2012) suggests that this cannot give a comprehensive picture of the educational processes happening within classrooms. Over the past 40 years, learning environment

research has involved determinants and effects of social and psychological aspects on classrooms and how to assess them quantitatively (Fraser, 2012, 2018).

Lewin (1936) established that the environment and personal characteristics interact to determine human behaviour. Murray (1938) built on the pioneering work of Lewin, introducing the term *alpha press* to describe the assessment of the environment by an observer who is unconnected to the environment and the term *beta press* for a description of the environment by a person who is part of the environment.

In the United States of America, pioneering work had begun at the end of the 1960s on assessing environments specifically in education. Walberg and Anderson (1968) developed the Learning Environment Inventory (LEI) to assess the learning environment of Harvard Project Physics. At the same time, Moos was developing social climate scales to be used in hospitals and correctional facilities and the Classroom Environment Scale (CES) (Moos, 1979; Moos & Trickett, 1974, 1987; Trickett & Moos, 1973).

By the early 1990s in the Netherlands, Wubbels and a team of researchers had developed the Questionnaire on Teacher Interaction (QTI) to assess relationships between teachers and students (Wubbels, Créton & Hoomayers, 1992; Wubbels & Levy, 1993). In Australia, Fraser (1990) had developed the Individualised Classroom Environment Questionnaire (ICEQ) as the first questionnaire to assess those characteristics that differentiate conventional and individualised classrooms.

In the 1990s, Fraser and his colleagues were involved with the development of the Science Laboratory Environment Inventory (SLEI), used to specifically investigate the unique environment of the science laboratory (Fraser, McRobbie & Giddings, 1993) and the Constructivist Learning Environment Survey (CLES), used to assess how well a classroom learning environment reflects constructivist principles (Taylor, Fraser & Fisher, 1997). This led to the development of the widely-used and frequently-validated What Is Happening In this Class? (WIHIC) questionnaire (Fraser, Fisher & McRobbie, 1996).

2.3 Learning Environment Instruments

Learning environment questionnaires have been the instruments through which the study of learning environments has expanded, first beginning in the in the Western world and later throughout Asia (Fraser, 2002). This section reviews the following historically-important and contemporary instruments: Classroom Environment Scale (CES) (Section 2.3.1), Learning Environment Inventory (LEI) (Section 2.3.2), My Class Inventory (MCI) (Section 2.3.3), Individualised Classroom Environment Questionnaire (ICEQ) (Section 2.3.4), Questionnaire on Teacher Interaction (QTI) (Section 2.3.5), College and University Classroom Environment Inventory (CUCEI) (Section 2.3.6), Constructivist Learning Environment Questionnaire (CLES) (Section 2.3.7) and Science Laboratory Environment Inventory (SLEI) (Section 2.3.8).

2.3.1 *Classroom Environment Scale (CES)*

The Classroom Environment Scale (CES) was developed by Moos as part of his studies of human environments in psychiatric hospitals, correctional facilities, universities and other work sites (Moos, 1974, 1979; Moos & Trickett, 1974, 1987). The final published version of the CES contains nine scales and a total of 90 True–False items (or 10 items per scale). The CES was validated with a sample of 1083 Australian students by Fisher and Fraser (1983b). The CES was designed for conventional teacher-centred classrooms (Fraser, 2002).

2.3.2 *Learning Environment Inventory (LEI)*

During an evaluation of the Harvard Project Physics, the Learning Environment Inventory (LEI) was developed and validated (Walberg & Anderson, 1968). The final version of the LEI contained 15 scales and a total of 105 statements (or seven items per scale) describing school classes. Each statement has the four alternative responses of Strongly Disagree, Disagree, Agree and Strongly Agree. For some items, the scoring direction is reversed. The LEI was designed for conventional teacher-centred classrooms (Fraser, 2002).

2.3.3 *My Class Inventory (MCI)*

Modified from the LEI, the My Class Inventory (MCI) was developed for use with children aged between 8 and 12 years (Fisher & Fraser, 1981). The 15 scales in the original LEI were reduced to five (Cohesiveness, Friction, Satisfaction, Difficulty and

Competitiveness) in the MCI to minimise fatigue among the younger respondents. The original version of the MCI required a Yes–No response. Later, a three-point response format (Seldom, Sometimes and Most of the Time) was used in a study of 1512 primary mathematics students in Singapore (Goh, Young & Fraser, 1995). Other modifications made to the LEI to form the MCI include simplification of the wording of items to make them easier to read and provisions for responding on the questionnaire to avoid transfer errors between the questionnaire and a response sheet. Reverse scoring is required for some of the items on the MCI. Two forms of the MCI are available to measure perceptions of the actual environment and the preferred environment (Fraser, 1989). Like its predecessor, the MCI was designed for conventional teacher-centred classrooms (Fraser, 2002).

The MCI was used in English with 1565 lower-secondary mathematics students in Brunei Darussalam (Majeed, Fraser & Aldridge, 2002). When the Satisfaction scale was used as an outcome variable, satisfactory factorial validity and reliability were found for a version of the MCI with the three scales of Cohesiveness, Difficulty and Competition. Sex differences and associations with satisfaction were reported for the MCI.

An integrated mathematics and children’s literature project called SMILE (Science and Mathematics Integrated with Literature Experiences) was evaluated using the MCI with 120 grade 5 students in Florida (Mink & Fraser, 2005). The researchers found similarity between students’ actual and preferred classroom environments after the SMILE project was implemented, suggesting that the project had positive impact.

The MCI was used to evaluate science kits with a sample of 588 grade 3–5 students in Texas (Scott Houston, Fraser & Ledbetter, 2008). This study confirmed the validity of the MCI and suggested that higher student satisfaction and cohesiveness were associated with the use of the kits.

Sink and Spencer (2005) provided support for a short form of the MCI as a tool for measuring the accountability of elementary-school counselors. A large sample of 2835 grade 4–6 students in Washington State responded to an 18-item short form of the MCI (assessing cohesiveness, competitiveness, friction and satisfaction). The researchers found that this version was valid and they discussed practical implications for counselors.

2.3.4 Individualised Classroom Environment Questionnaire (ICEQ)

The Individualised Classroom Environment Questionnaire (ICEQ) was developed by Rentoul and Fraser (1979) in a long and a short form. The long form contains 50 items measuring five dimensions, while the short form contains 25 items measuring the same dimensions – Personalisation, Participation, Interdependence, Investigation and Differentiation (Fraser, 1990). Each statement has the five frequency alternative responses of Almost Never, Seldom, Sometimes, Often and Very Often. The scoring direction is reversed for many items.

2.3.5 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) was developed in the Netherlands

specifically to investigate teacher–student relationships (Wubbels, Créton & Hoomayers, 1992; Wubbels & Levy, 1993). The QTI assesses students’ perceptions of eight behaviour aspects of their teacher based on proximity (cooperation–opposition) and influence (dominance–submission). A five-point response scale ranging from Never to Always is used for each item. Items include statements such as “She/he gets angry” (Admonishing behaviour). The original Dutch version contains 77 items, an American version has 64 items and a short version developed for research in Singapore has 48 items (Goh & Fraser, 1996). The instrument now has now been translated into more than 14 languages (Wubbels & Brekelmans, 2012).

The QTI was originally used at the senior-high school level in the Netherlands. Since then, cross-validation studies have been undertaken at a range of grade levels in the USA (den Brok, Levy, Rodriguez, & Wubbels, 2002; Levy, den Brok, Wubbels & Brekelmans, 2003; Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995; Henderson, Fisher & Fraser, 2000), Singapore (Goh & Fraser, 1996), Brunei Darussalam (Scott & Fisher, 2004), Indonesia (Fraser, Aldridge & Soerjaningsih, 2010) and the Netherlands (e.g. Wubbels, Brekelmans, den Brok, & van Tartwijk, 2006; Wubbels & Levy, 1993).

The QTI has been widely used in science classrooms. An English version of the QTI was used in Singapore with 497 gifted and non-gifted secondary-school chemistry students (Quek, Wong & Fraser, 2005). These researchers reported some sex and stream (i.e. gifted and non-gifted) differences in QTI scores. A version of the QTI translated into Korean was validated and used in separate studies involving 439

science students (Lee, Fraser & Fisher, 2003) and 543 students (Kim, Fisher & Fraser, 2000).

2.3.6 College and University Classroom Environment Inventory (CUCEI)

In higher education classrooms, curiously, little classroom environment research had been undertaken by the mid-1980s. Therefore, in 1986, the College and University Classroom Environment Inventory (CUCEI) was developed to be used with small classes (or seminars) of less than 30 participants in tertiary institutions (Fraser & Treagust, 1986; Fraser, Treagust & Dennis, 1986). In its final form, the CUCEI contains seven scales and a total of 49 items (seven per scale). Each statement has four alternative responses, namely, Strongly Disagree, Disagree, Agree and Strongly Agree. The scoring direction (or polarity) is reversed for approximately half of the items.

The CUCEI was used with 536 students and 106 teachers across 45 classes in an evaluation of two alternative high schools (Fraser, Williamson & Tobin, 1987). This study aimed to evaluate alternative high schools for mature-age learners in terms of student perceptions of classroom environment and teacher perceptions of school environment. Compared with a control group, those students at alternative schools perceived that their classrooms had greater involvement, innovation, satisfaction and individualisation. At the same time, teachers perceived greater achievement orientation, professional interest and innovativeness at the alternative schools.

Logan, Crump and Rennie (2006) used a modified form of the CUCEI in two separate studies involving secondary and tertiary computing classrooms in Wellington, New Zealand. Statistical analysis of data from both of these studies identified a number of common problems associated with using the CUCEI. Recommendations were made by the authors to improve the validity and reliability of the instrument, including that data collection be supplemented by other means including interviews and classroom observation.

Hasan and Fraser (2015) used a modified Arabic version of the CUCEI in a study in the United Arab Emirates. The researchers investigated the effectiveness of activity-based teaching strategies in college-level mathematics. Four CUCEI scales were used to assess classroom environment and another scale from the same instrument was used to assess student satisfaction. The sample included 84 male students from 8 classes. The qualitative data collected through observations and interviews allowed the researchers to establish connections with the scales assessed using the CUCEI. The significance of this research was that it was one of the first studies of learning environments in the United Arab Emirates (UAE), it validated the modified Arabic translation of the CUCEI, and it revealed very large pretest–posttest changes on learning environment and satisfaction scales.

2.3.7 Constructivist Learning Environment Questionnaire (CLES)

The CLES was developed by Taylor et al. (1997) to help researchers and teachers to assess the extent to which constructivist philosophies are present in the environment of a particular classroom. The CLES has five scales (Personal Relevance,

Uncertainty of Science, Critical Voice, Shared Control and Student Negotiation). Data analyses supported the factorial validity and reliability when used with secondary science students in Australia ($N=494$) and Texas, USA ($N=1600$) (Taylor et al., 1997).

Nix, Fraser and Ledbetter (2005) also supported the validity of the CLES in a study involving 1079 students from 59 classes in Texas. The CLES was used in this study to evaluate an innovative professional development programme for science teachers. When the students of teachers involved with the professional development programme were compared with students of teachers who were not involved, it was found that the former perceived classrooms more favourably than did students of other teachers.

Aldridge, Fraser, Taylor and Chen (2000) used the CLES in a cross-national study of junior high-school science classroom learning environments in Taiwan and Australia. A Mandarin translation of the CLES was administered in this study involving 1879 students in 50 classes in Taiwan. In Australia, the English version of the CLES was used with 1081 students in 50 classes. The research supported the factor structure, reliability and ability to differentiate between classrooms not only for the English version, but also for the Mandarin version of the CLES. Another significant insight highlighted by this study was that Australian students perceived their classrooms as more constructivist than Taiwanese students.

The CLES has been successfully translated into other languages. Peiro and Fraser (2009) administered English and Spanish versions of a modified form of the CLES to

739 grade K–3 science students in Florida. Kim, Fisher and Fraser (1999) translated the CLES into Korean and administered it to 1083 grade 10 students in 25 classes. The reliability and factor structure of the Spanish and Korean versions of the CLES were established, and significant relationships emerged between classroom environment and student attitudes.

The CLES has been used in studies involving subjects other than science. In a South African study, the English version of the CLES was used with a sample of 1864 mathematics students in 43 classes in grades 4–6 (Aldridge, Fraser & Sebela, 2004). Data analyses allowed the researchers to cross-validate this version of the CLES (factor structure, reliability and ability to differentiate between classrooms). The aim of this study was to encourage mathematics teachers to reflect on and improve their constructivist practices in their classrooms during a 12-week intervention.

Spinner and Fraser (2005) used the CLES in a study involving two separate samples of 53 and 66 grade 5 students in Florida. The students were studying the innovative mathematics programme called the Class Banking System (CBS). As well as cross-validating the CLES, these researchers reported that CBS students experienced more favourable pre–post changes than comparison students on most CLES scales.

Koh and Fraser (2014) used a five-scale modified version of the CLES to evaluate the Mixed Mode Delivery (MMD) pedagogical model. When the magnitudes of the difference between actual and preferred learning environment were compared between secondary students taught using the MMD model ($N=2216$) and a control group ($N=991$), the MMD model was perceived to have more-positive learning

environments for all CLES scales. Data analyses also supported the validity of the CLES.

Fraser and Lee (2015) used a 25-item, 5-scale Korean-language version of the CLES in conjunction with a 35-item Korean-language version of the Test of Science Related Attitudes to investigate associations between students' attitudes and the constructivist orientation of their classroom learning environments. The study involved 440 students in 13 classes across 3 Korean schools. The students were organised in three different streams including humanities ($N=146$, grade 11), science-orientated ($N=195$, grade 11) and science-independent ($N=99$, grade 10). As well as providing support for the validity of the CLES, associations between student attitudes to science and the nature of the classroom environment replicated those in many previous studies (Fraser, 2012).

2.3.8 Science Laboratory Environment Inventory (SLEI)

Fraser, Giddings and McRobbie designed an instrument specifically to assess the unique environment of the science laboratory class (Fraser, Giddings & McRobbie, 1995; Fraser & McRobbie, 1995; Fraser et al., 1993). The SLEI has five scales, each with seven items. A five-point frequency response format is used: Almost Never, Seldom, Sometimes, Often and Very Often. Typical items include "I use the theory from my regular science class sessions during laboratory activities" (Integration). It is noteworthy that the SLEI was validated with 5447 students in 269 classes in six different countries (the USA, Canada, England, Israel, Australia and Nigeria). The SLEI has since been cross-validated in Australia with 1594 students in 92 classes

(Fraser & McRobbie, 1995) and 489 senior high-school biology students (Fisher, Henderson & Fraser, 1997).

The SLEI has been translated into Korean for a study of differences between the classroom environments of science-independent, science-oriented and humanities streams (Fraser & Lee, 2009). The Korean version of the SLEI proved to be valid (factor structure, reliability and ability to differentiate between classrooms) with a group of 439 high-school students. Also students in the science-independent stream generally perceived the learning environment more favourably than students of the other streams.

A Singaporean study with 1592 high school students in 56 chemistry classes involved using a modified version of the SLEI to investigate relationships between students' perceptions of the laboratory classroom and their attitudes to chemistry (Wong & Fraser, 1996). This study was a first of its kind in Asia and replicated the statistically-significant associations between psychosocial aspects of the laboratory classroom environment and students' attitudinal outcomes reported by McRobbie and Fraser (1993).

Lightburn and Fraser (2007) used the SLEI with a sample of 761 high-school biology students from 25 classes in south-eastern USA. The effectiveness of using anthropometry activities was evaluated using the SLEI. The SLEI's factor structure, internal consistency reliability and ability to differentiate between classrooms were supported. Using anthropometric activities was effective in terms of classroom environment and student attitudes.

In Australia, Rogers and Fraser (2013) used the SLEI with 431 year 9 and 10 science students to reveal that perceptions of learning environment, attitudes and aspirations varied with sex and the frequency of practical work. The SLEI was factorially valid and reliable. Positive laboratory learning environments were associated with positive students' attitudes and aspirations in science.

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

Because the WIHIC was used in my study, a more comprehensive review of literature about this questionnaire is provided in this section. The WIHIC combines modified and important scales from numerous existing questionnaires with additional scales to accommodate modern educational interests (Fraser, 2012; Fraser, Fisher & McRobbie, 1996). Since its development, the WIHIC has been used in many different forms and has been translated into numerous Asian, European and Middle Eastern languages (Fraser, 2002). The use of the WIHIC has contributed to knowledge in the field of learning environments through cross-national, interdisciplinary and gender investigations (Fraser, 2007). The WIHIC is the most-frequently used classroom instrument in the world today (Fraser, 2012) and this is why I selected it as an appropriate tool for my study.

The literature describing the validity and application of the WIHIC is reviewed in Section 2.4.1. Because WIHIC scales have been successfully included in other questionnaires, three examples are discussed below. Section 2.4.2 describes how four scales from the WIHIC were combined with scales from other questionnaires to

develop the Outcomes-Based Learning Environment Questionnaire (OBLEQ), seven WIHIC scales were combined with two new scales to form the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), and six scales from the WIHIC were included in developing the Constructivist-Oriented Learning Environment Scale (COLES).

2.4.1 Validity and Application of WIHIC

The original version of the WIHIC containing nine scales and 90 items (Fraser et al., 1996) was compiled by modifying important scales identified from a wide range of pre-existing questionnaires. To ensure that the WIHIC could assess more contemporary issues in education, such as constructivism and equity, new scales were added. This version was then refined (Fraser et al., 1996) using a sample of 355 junior high school students. The data collected with the questionnaire were supplemented by an extensive interview process which allowed the researchers to identify student perspectives of their own classroom environments, to investigate further the responses made to the questionnaire, and to investigate the wording and importance placed on the scales used in the original version of the WIHIC. At this stage of development, the WIHIC contained 54 items and seven scales. A later version containing 80 items in eight scales was then field-tested in using 1081 Australian students in 50 classes and 1879 Taiwanese students in 50 classes (Aldridge & Fraser, 2000). This study led to the final the form of the WIHIC (Aldridge, Fraser & Huang, 1999), with seven eight-item scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, Equity) and with frequency responses ranging from Almost Never to Very Often. Aldridge and Fraser

(2000) supported the WIHIC's factorial validity, internal consistency reliability and ability to differentiate between the perceptions of students in different classrooms.

It is mainly over the last decade that the current form of the WIHIC has been used in educational research. During this time, the WIHIC has been widely used and frequently validated by educational researchers (Fraser, 2007, 2012, 2018). The WIHIC has provided a foundation questionnaire that learning environment researchers have been able to modify and tailor to suit their particular studies (Fraser, 2007). This includes translating it into other languages including: Mandarin (Aldridge et al., 1999; Aldridge & Fraser, 2000); Indonesian (Fraser, Aldridge & Adolphe, 2010; Wahyudi & Treagust, 2004), Korean (Kim et al., 2000); Arabic (Afari, Aldridge, Fraser & Khine, 2013; Alzubaidi, Aldridge & Khine, 2016; MacLeod & Fraser, 2010), Greek (Charalampous & Kokkinos, 2017), Spanish (Helding & Fraser, 2013), Myanmar (Khine, Fraser, Afari, Oo & Kyaw, 2018) and IsiZulu (Aldridge, Fraser & Ntuli, 2009). The WIHIC has been used widely across academic disciplines including science (den Brok, Fisher, Rickards & Bull, 2006; Fraser et al., 2010; Koul & Fisher, 2005; Wolf & Fraser, 2008), mathematics (Dorman, 2003; Taylor & Fraser, 2012), geography (Chionh & Fraser, 2009) and English (Bi, 2015; Lim & Fraser, 2018). It has also been utilised with students of different ages ranging from kindergarten (Robinson & Fraser, 2013), grades 3–5 (Pickett & Fraser, 2009; Zaragoza & Fraser, 2017), grades 4-6 (Peer & Fraser, 2015), middle school (Cohn & Fraser, 2016; Kim et al., 2000; Wahyudi & Treagust, 2004; Wolf & Fraser, 2008), secondary school (Chionh & Fraser, 2009; Dorman, 2003; Fraser et al., 2010), university (Alzubaidi et al., 2016; Khine et al., 2018; Martin-

Dunlop & Fraser, 2008), college (Afari et al., 2013) and computer education courses for working adults (Khoo & Fraser, 2008).

The WIHIC's validity has been replicated across nations. These types of studies are particularly interesting because they show that the WIHIC (originally written in English) retains its validity when translated into different languages. To ensure that the meanings of the items are unaltered by the process of translation, an independent third party often back-translates the questionnaire back into English (Brislin, 1970). This English version is then compared with the original version so that any adjustments that are required can be made, as described by Aldridge and Fraser (2000) and Aldridge et al. (1999).

Aldridge and Fraser (2000) used an English version and a Mandarin translation of the WIHIC in a cross-cultural study of Australian and Taiwanese science classrooms. When the WIHIC was administered to 50 classes in each of Australia and Taiwan, it exhibited sound validity and reliability as an instrument for measuring the learning environment in two different countries and in two languages (Aldridge & Fraser, 2000). This research also was distinctive in that multiple research methods were used. Qualitative data (classroom observations, interviews and narrative stories) added to the broad range of questions that could be explored and made the data more meaningful when examined together with the quantitative data collected using the WIHIC (Aldridge et al., 1999).

The WIHIC was reported to be a valid measure of classroom environment with a sample of 3980 high school students studying mathematics from Australia, the UK

and Canada (Dorman, 2003). Across genders, three countries and three different school grade levels, factorial invariance suggested that the WIHIC is a highly-robust instrument (Dorman, 2003). This allows stakeholders in education to use this instrument to assess the classroom environment in useful and varied ways. Dorman (2003) suggests that the confidence with which the WIHIC can be used in Western countries needs to be tested in a greater variety of cultures, particularly the Middle East and South and Central America.

Fraser et al. (2010) used a modified WIHIC in a cross-national study of science students in Indonesia and Australia. An important contribution of this study was the translation of the WIHIC into Bahasa Indonesian for future learning environments investigations in the region. This study demonstrated the validity and reliability of the WIHIC for both the Indonesian and Australian samples. Fraser et al. (2010) suggest that further research should include qualitative methods in order to put the data generated by this study into a social, cultural and educational context. Wahyudi and Treagust (2004) cross-validated an Indonesian-language version of a modified form of the WIHIC in lower-secondary schools in Indonesia.

Arabic translations of the WIHIC have been used in studies in the United Arab Emirates (Afari et al., 2013; MacLeod & Fraser, 2010) and Jordan (Alzubaidi et al., 2016). MacLeod and Fraser (2010) developed and validated parallel Arabic and English versions of the WIHIC in a study involving 763 college students in 82 classes. Afari et al. (2013) developed and validated a version of the WIHIC, in which the Arabic translation of each item was placed beneath the corresponding English item, with a sample of 352 first- and second-year mathematics students at three

colleges. Alzubaidi et al. (2016) developed and validated another Arabic translation of the WIHIC using 994 students across three faculties of a university.

Giallousi, Gialamas, Spyrellis and Plavlatou (2010) selected scales from the WIHIC and translated them into the Greek language to develop the How Chemistry Class is Working (HCCW) questionnaire. This study was used to contrast the classroom environment perceptions of Greek and Cypriot students. Charalampous and Kokkinos (2017) developed and validated a new version of the WIHIC for use with elementary-school students, written in the Greek language, known as the G-EWIHIC.

Helding and Fraser (2013) used English and Spanish versions of the WIHIC in a study involving 924 grades 8 and 10 science students in Florida. This study supported the validity and reliability of the WIHIC for assessing perceptions of the classroom environment and replicated past findings in that learning environment dimensions were consistently and positively related to student outcomes (Fraser, 2007; Helding & Fraser, 2013).

Students' perceptions of the science learning environment at the university level were investigated using a Myanmar-language version of the WIHIC (Khine et al., 2018). This study established the factorial validity and internal consistency reliability of this version of the WIHIC with 251 students in Myanmar. Khine et al. (2018) reported that the WIHIC's factorial validity was supported by both exploratory and confirmatory factor analyses, thus replicating the findings of studies in other countries, languages and cultures (Fraser 2012, 2014).

In South Africa, a primary-school version of the WIHIC written in IsiZulu was administered to 1077 primary students to investigate if using feedback from a learning environment instrument could guide improvements in the teaching practices of in-service teachers undertaking a distance-education programme (Aldridge et al., 2009). 31 teachers were involved in the study that involved using discrepancies between students' actual and preferred learning environments to formulate teaching strategies to narrow these discrepancies over 12 weeks. The WIHIC displayed satisfactory factorial validity and internal consistency reliability for both the actual and preferred versions and supported the success of teachers' attempts to improve their teaching (Aldridge et al., 2009).

Studies involving translations of the WIHIC have established it as a valid and valuable learning environment questionnaire. The WIHIC has successfully been used when translated into Mandarin (Aldridge & Fraser, 2000) and Korean (Kim et al., 2000).

The ability for a research instrument to be used in different countries, despite language differences, has allowed researchers not only to identify differences between the countries in regards to the classroom environment, but also to identify factors that influence the learning environment in different cultures (Aldridge et al., 1999).

Unlike some other questionnaires used in educational research, the WIHIC can be used in any classroom and is not specific to a particular discipline. Since its development, the WIHIC has been used extensively in the field of science and, to a lesser extent, in mathematics. Zandvliet and Fraser (2005) and Khoo and Fraser

(2008) both completed studies of the learning environments associated with computing subjects. Although there is a large investment in the technologies, Zandvliet and Fraser (2005) suggest that there is little evidence that the quality of the education that the technology is supporting has changed. Student satisfaction with their computing classes was a focus of both studies, and modified versions of the WIHIC were validated in each study. Khoo and Fraser (2008) were able to show consistent positive associations between satisfaction and the classroom environment. Zandvliet and Fraser (2005) showed that student satisfaction had direct associations with psychosocial environment variables (Student Cohesiveness, Involvement, Autonomy/Independence, Task Orientation and Cooperation).

Differences between students' perceptions of their geography and mathematics classroom environments were investigated using the WIHIC (Chionh & Fraser, 2009). Actual and preferred versions of the WIHIC were used to examine differences between student perceptions of the classroom they were in and the classroom they would like to be part of. A seven-scale version of the WIHIC was validated in the study involving 2310 students. This version of the WIHIC was able to successfully differentiate between different classrooms. Chionh and Fraser (2009) suggest cautiously that: teachers who wish to improve student achievement need to create a learning environment where students work cohesively; and teachers interested in promoting positive attitudes and self-esteem should create learning environments that focus on teacher support, task orientation and equity.

Actual and preferred forms of the WIHIC were also used in a study of 978 Australian secondary school students (Dorman, 2008). Separate confirmatory factor analyses for

the actual and preferred forms of the WIHIC supported the original seven-scale structure. This study suggested “strong evidence of the sound psychometric properties of the WIHIC” (p. 179). Wahyudi and Treagust (2004) used the WIHIC to identify a gap between actual and preferred perceptions of learning environment among lower-secondary Indonesian students. For every scale except Teacher Support, female students reported more positive perceptions of the preferred and actual classroom learning environment (Wahyudi & Treagust, 2004). Wahyudi and Treagust (2004) suggested that, as a learning environments instrument, the WIHIC was internally robust, had high reliability and was also able to differentiate between the perceptions of students in different groups; thus it could be used with confidence in research. Numerous subsequent studies have also used actual and preferred forms of the WIHIC successfully (Chionh & Fraser, 2009; MacLeod & Fraser, 2010; Robinson & Fraser, 2013).

Historically, classroom environments research has involved many subject areas, but research in English classrooms has only recently begun (Lim & Fraser, 2018). A Chinese study investigated whether psychosocial aspects of the learning environment were related to the motivation of university students studying English (Bi, 2015). This study validated a modified version of the WIHIC and involved approximately 1000 first- and second-year university students, all of whom were majoring in English. A Singaporean study involving 441 grade 6 students cross-validated a modified version of the WIHIC and replicated past research findings in other subject areas concerning some of the predictors and consequences of the learning environment (Lim & Fraser, 2018).

The WIHIC has also been used to investigate differences between males and females in perceptions of the science classrooms (Fraser et al., 2010; Wahyudi & Treagust, 2004; Wolf & Fraser, 2008) and computing classrooms (Khoo & Fraser, 2008). Traditionally science and, more recently, computing classrooms have been considered to be the domain of males. Gender differences in classroom environment perceptions are important when trying to identify the classroom environments that best suit males and females.

When Wolf and Fraser (2008) used the WIHIC to investigate whether inquiry-based laboratory teaching was beneficial for middle-school science students in terms of the learning environment, student attitude and achievement, some differences in the effectiveness of inquiry-based activities were found according to student gender. Male students benefitted more than female students when inquiry-based methods were used. As found in other studies, the WIHIC was able to differentiate between the perceptions of students in different classes (Wolf & Fraser, 2008).

Taylor and Fraser (2012) investigated associations between, and sex differences in, mathematics anxiety and learning environment in Southern California. 746 high-school students in 34 mathematics classes in four different schools were surveyed using the WIHIC and Plake and Parker's (1982) Revised Mathematics Anxiety Rating Scale (RMARS). Student interviews were also conducted as part of the study. Statistically-significant sex differences were particularly evident for the learning environment scales of Task Orientation and Cooperation, but not for mathematics anxiety.

In a cross-national study, differences in the perceptions of the classroom environment held by Australian and Indonesian science students were investigated by Fraser et al. (2010). The WIHIC was found to be valid and reliable in both countries. As predicted, cultural differences between the two nations meant that there were significant gender differences in perceptions. Girls in Australia perceived greater Student Cohesiveness than Australian boys, but interestingly there were negligible gender differences in perceptions of Student Cohesiveness among Indonesian students. Fraser et al. (2010) suggest that quantitative data-gathering instruments, such as the WIHIC, are useful for generating data that can be compared, but qualitative data are needed to investigate the influence of society and culture on student perceptions of the learning environment.

Khoo and Fraser (2008) also investigated the effects of gender on the classroom psychosocial environment as part of their evaluation of adult computer courses in Singapore using the WIHIC. Male students perceived greater Involvement, Trainer Support and Satisfaction, while females perceived greater Equity. When Khoo and Fraser (2008) investigated the effect of age on the perceptions of participants, older females perceived greater Trainer Support than younger females.

Peer and Fraser (2015) investigated sex, grade-level and stream differences in learning environment and attitudes to science in a study involving 4 primary schools in Singapore. 5 scales from the WIHIC, 2 scales of the Test of Science Related Attitudes (TOSRA) and 3 scales from the CLES were administered to 1081 students in 55 classes. Although small in magnitude, statistically-significant findings were

found for sex differences, grade-level differences, stream differences, the stream-by-sex interaction and the grade-by-stream interaction.

Zaragoza and Fraser (2017) used the WIHIC and TOSRA to investigate differences between field-study classrooms and traditional science classrooms in terms of the learning environment and students' attitudes to science. The study involved 765 grade 5 students from 17 schools in Florida and also investigated the effectiveness of field-study classrooms for students of differing sex and English proficiency. The modified version of the WIHIC and TOSRA demonstrated satisfactory internal consistency reliability and factorial validity. The effectiveness of the field-studies classrooms was supported for learning environment and student attitude criteria (Zaragoza & Fraser, 2017).

Working with a sample of 367 grade 8 science students across two U.S. states, Long and Fraser (2015) used the WIHIC to investigate the relative effectiveness of two alternative middle-school science curriculum sequences (general and topic-specific). Also, the differential effectiveness of the two sequences was investigated for two ethnic groups. The researchers reported sound validity for the WIHIC and that the topic-specific sequence was enjoyed by more students (effect size of 0.74 standard deviations). The models were equally effective for Caucasian students, but the general model was more effective for Hispanic students.

Attitudes and actual and preferred learning environments in mathematics and science classrooms utilising laptop computers were investigated by Fraser and Raaflaub (2013). A modified version of the WIHIC was validated for a sample of 1173 grade

7–12 students from Ontario, Canada. The researchers reported large and statistically-significant differences between actual and preferred classroom environments. While female students held more favourable perceptions about the learning environment, their male peers had more positive attitudes. When compared with mathematics students, science students perceived a more-positive learning environment and held more positive attitudes.

Cohn and Fraser (2015) investigated the effectiveness of using Student Response Systems (SRS) with a sample of 1097 grade 7 and 8 students (532 students using SRS and 565 students who did not used SRS) in New York. The researchers used a new instrument called the How Do You Feel About This Class? (HDYFATC) questionnaire that contains several WIHIC scales, one TOSRA scale and a new scale developed by the researchers called Comfort. Very large differences of between 1.17 to 2.45 standard deviations were reported between users and non-users of SRS for various leaning environment scales, attitudes and achievement.

2.4.2 Incorporating WIHIC Scales in Other Questionnaires

The Outcomes-Based Learning Environment Questionnaire (OBLEQ) is an example of a learning environment questionnaire that includes WIHIC scales. Aldridge, Laugksch, Seopa and Fraser (2006) combined four WIHIC scales (Involvement, Investigation, Cooperation and Equity), one scale from the ICEQ (Differentiation), one scale from the CLES (Personal Relevance) and a new scale (Responsibility for Own Learning) to develop the OBLEQ. This instrument, which was developed to monitor and guide change towards outcomes-based education by assessing students'

perceptions (actual and preferred) of their learning environment, was the first of its kind in South Africa. The OBLEQ was validated with 2638 Grade 8 science students from 50 classes in 50 South African schools in the Limpopo Province.

The WIHIC was the basis for the development of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI). The TROFLEI was designed and used by Aldridge and Fraser (2008) during a study to evaluate a new post-secondary school that utilised information communication technology (ICT) in the delivery of programmes that had a focus on outcomes. The TROFLEI combines the seven scales of the WIHIC (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Investigation, Cooperation and Equity) with the Differentiation scale from the ICEQ and two new scales: Computer Usage and Young Adult Ethos. The Differentiation scale was included to assess how successfully the teacher was able to accommodate a range of student interests and abilities. Computer Usage assesses the extent to which students utilise computers to obtain information and communicate with peers. Young Adult Ethos assesses the extent to which the teacher treated students as young adult learners.

The TROFLEI has 80 items (ten in each eight-item scales) with a five-point frequency response scale (Almost Never, Seldom, Sometimes, Often and Very Often). Just as the WIHIC does, the TROFLEI presents actual and preferred classroom environment items in an efficient side-by-side format. Aldridge, Dorman and Fraser (2004) reported strong factorial validity and reliability for the preferred and actual forms of the TROFLEI with 2317 grade 11 and 12 students from West Australia and Tasmania. The actual form in the same study was able to differentiate between the perceptions of

students in different classrooms. Multitrait–multimethod modelling with a subsample of 1249 students (772 from West Australia and 477 from Tasmania) supported the construct validity and sound psychometric properties of the TROFLEI (Aldridge et al., 2004). The results of this study also indicated that the actual and preferred forms of the TROFLEI shared a common structure.

The TROFLEI has been used to evaluate a new school emphasising outcomes-focused education (Aldridge & Fraser, 2008) and investigate associations between students' affective outcomes and their perceptions of the classroom environment (Dorman & Fraser, 2009). A study involving 980 students from grades 9–12 supported the cross-cultural reliability and validity of the TROFLEI in Turkey and the USA (Welch, Cakir, Peterson & Ray, 2012). Koul, Fisher and Shaw (2011) validated the TROFLEI with 1027 high-school students from New Zealand and reported differences between students' perceptions of their actual and preferred learning environments, year levels and genders. Associations between learning environment, attitudes and self-efficacy also were investigated.

The Constructivist-Orientated Learning Environment Survey (COLES) was developed to provide feedback to both teachers and students in order to improve the learning environment (Bell & Aldridge, 2014; Aldridge, Fraser, Bell & Dorman, 2012). All scales of the WIHIC except Investigation are included in the COLES together with Differentiation from the ICEQ, Personal Relevance from the CLES, Young Adult Ethos from the TROFLEI and, significantly, two new scales associated with assessment called Formative Assessment and Assessment Criteria. The new instrument was validated with 2043 grade 11 and 12 students from 147 classes in 9

Australian schools (Aldridge et al., 2012). The COLES was used by Rijken, Fraser and Aldridge (2016) to investigate the effectiveness of teacher action research using students' perceptions of the learning environment. This study involved 2673 grade 8–12 students and 171 teachers from a single coeducational secondary school in Australia and reported statistically-significant improvements for the learning environment and students' self-efficacy (Rijken et al., 2016).

2.5 Research Using Learning Environment Questionnaires

Fraser (2002, 2007, 2012, 2018) summarized numerous and diverse applications of classroom learning environment instruments in past research. These applications include: associations between student outcomes and environment; determinants of classroom environment; evaluation of educational innovations; differences between student and teacher perceptions of actual and preferred environment; use of qualitative research methods; cross-national studies; school psychology; transition between different levels of schooling; and typologies of classroom environments.

My study involved associations between middle-school students' perceptions of their learning environment in the mathematics classroom and their attitudes towards mathematics, as well as differences between students of different sexes in their classroom environment perceptions. Because associations between student outcomes and the environment and determinants of classroom environment were central to my study, detailed literature reviews of past research in these two areas are included below along with other areas. The discussion below is organised into four sections, namely, evaluation of educational initiatives (Section 2.5.1), associations between

student outcomes and classroom environment (Section 2.5.2), using learning environment scales as dependent variables (Section 2.5.3) and a brief overview of other applications (Section 2.5.4).

2.5.1 Evaluation of Educational Initiatives

It has been common for researchers to use learning environment criteria for evaluating different educational initiatives. Fraser (1979), in a study evaluating the Australian Science Education Project (ASEP), reported that students involved with the program perceived their classrooms to be more satisfying and individualized and to have a better material environment relative to a control group. When the CLES was used in a Korean study of the effectiveness of constructivist instruction (Oh & Yager, 2004), students' perceptions became more positive over time. The CLES was also used in the evaluation of an innovative science teacher development program among 1079 students from north Texas (Nix et al., 2005). Students of science teachers who had attended the program perceived greater Personal Relevance and Uncertainty of Science than did students of other science and non-science teachers in the same school.

When the WIHIC was used to investigate the effectiveness of inquiry-based science laboratory activities in middle schooling (Wolf & Fraser, 2008), the researchers reported greater Student Cohesiveness in the inquiry-based group relative to a non-inquiry based group, as well as the differential effectiveness of inquiry instruction for female and male students. Khoo and Fraser (2008) used a revised version of the WIHIC with a group of working adults in evaluating a computer application course

and investigating age and sex differences in perceptions of the learning environment. A modified version of the WIHIC was used to evaluate a two-year mentoring program in science for beginning elementary-school teachers (Pickett & Fraser, 2009). When seven teachers took part in the study involving students from grades 3–5, some improvements were found in the classroom learning environment and students' attitudes and achievement over time. A study involving the WIHIC with 924 grade 8 students in Florida revealed that students of teachers who were National Board Certified had more favourable perceptions of their classroom environment (Helding & Fraser, 2013).

The How Do You Feel About This Class? questionnaire was used to investigate the effectiveness of using Student Response Systems (SRS) with 1097 middle-school science students (Cohn & Fraser, 2015). Students using SRS electronically respond to a question, which allows their responses to be tracked during class activities by an instructor, without being identified by their peers. A computer can collate the class responses and project them onto a screen for the class to see. When Cohn and Fraser (2015) investigated the effectiveness of SRS, large differences of between 1.17 and 2.45 standard deviations were found between SRS and non-SRS groups for all learning environment, attitude and achievement scales.

A questionnaire based on the COLES and Students' Adaptive Learning Engagement in Science (SALES) was used as part of a whole-school initiative aimed at improving classroom environments (Rijken et al., 2016). A mixed-method approach involved utilising quantitative data from questionnaires and qualitative data from classroom observations and teacher feedback. Rijken et al. (2016) reported that, over the three

years of the study, statistically-significant differences were evident for seven scales of the COLES. Effect sizes for differences between years ranged from small to medium, according to Cohen's (1988) criteria.

The SLEI was used with 761 high-school biology students in an evaluation of the effectiveness of anthropometric activities (Lightburn & Fraser, 2007). Significantly higher scores on some attitude and SLEI scales were found for the groups using anthropometric activities relative to control groups. A combination of WIHIC and SLEI scales was used to evaluate an innovative university science course among 525 female prospective elementary teachers in California (Martin-Dunlop & Fraser, 2008). Differences greater than 1.5 standard deviations were found for all scales between students' perceptions of the new innovative course compared with earlier courses.

The TROFLEI was used to monitor and evaluate the promotion of outcomes-focused education in a new senior-high school in Western Australia over a four-year period (Aldridge & Fraser, 2008). This study, involving 2317 students from 166 classes, also demonstrated that the learning environment influences students' cognitive and affective outcomes, replicating the findings of past studies (Fraser, 2007).

The CLES was used in investigating the effectiveness of using a Mixed Mode Delivery (MMD) pedagogical model among 2216 secondary business studies students in Singapore (Koh & Fraser, 2014). This study attempted to address the lack of research on the effectiveness of the MMD by using a learning environment framework. The evaluation of the MMD was based on the magnitude of the gaps

between the actual and preferred learning environment. Compared with teachers in the control group, MMD teachers' actual classroom environments were more consistent with the preferences of their students.

A learning environment framework was also used to evaluate the relative effectiveness of a general science curriculum model and a topic-specific model (Long & Fraser, 2015). Using a sample of 367 middle-school students, this study in the United States also involved the differential effectiveness of the two curriculum sequences for different racial groups. The researchers found that the general curriculum model better suited Hispanic students, but that the two models were equally effective for Caucasian students. Also enjoyment of science was higher among students who followed the topic-specific curriculum.

2.5.2 Associations Between Student Outcomes and Classroom Environment

Relationships between the cognitive and affective outcomes of students and how they perceive psychosocial features of their learning environment have been the basis for much learning environment research. Relationships between outcome measures and student perceptions of classroom environment have been replicated in studies using diverse samples (from numerous different countries and grade levels), outcome measures and learning environment instruments (Fraser, 2007, 2012, 2014). In particular, past studies have revealed associations between learning environments and attitudes. Some examples of these studies are reviewed below.

Associations of learning environment with students' cognitive and affective outcomes have been established using the SLEI in studies in senior high school science classes in Australia, including 1594 chemistry students (Fraser & McRobbie, 1995; McRobbie & Fraser, 1993) and 489 biology students (Fisher et al., 1997) and in Singapore with 1592 grade 10 chemistry students (Wong & Fraser, 1996). The SLEI was developed in class and personal forms and cross-nationally field tested and validated with 5447 students in 269 classes in 6 different countries (United States, Canada, England, Israel, Australia and Nigeria) and then cross-validated with 1594 students in 92 Australian classes (Fraser & McRobbie, 1995).

Relationships between the patterns of perceived teacher–student interaction and student outcomes were investigated using the QTI with a sample of 489 senior-high school biology students in Australia (Fisher et al., 1995). In this study, QTI scales generally were significantly associated with student attitude scores. Attitudes were more positive in classrooms where the students perceived that the teacher exhibited greater leadership, helpful/friendly and understanding behaviours.

Associations between interpersonal behaviour and student outcomes in vocational educational classes were investigated using the QTI and two attitude scales (Henderson & Fisher, 2008). 157 year 11–12 students in 9 Work Studies classes took part in the Western Australian study. Students held favourable views of the Work Studies course and there were strong relationships between some aspects of teacher interpersonal behaviour and students' attitudes.

The link between interpersonal teacher behaviour and the cognitive and affective outcomes of Physics and English as a Foreign Language (EFL) students was investigated using the QTI in the Netherlands (den Brok, Brekelmans & Wubbels, 2004). Third-year classes of 45 Physics (826 students) and 32 EFL teachers (941 students) were involved. This study suggested that interpersonal behaviour as perceived by students could be important when researching educational effectiveness. Henderson, Fisher and Fraser (2000) used the QTI and SLEI to investigate associations between biology teachers' interpersonal behaviour and laboratory learning environments and students' attitudinal, achievement and performance outcomes. Teacher interpersonal behaviour was measured using the QTI, while the SLEI was used to measure the laboratory learning environment. Student outcomes were measured using laboratory practical tests and an external written examination. This study suggested that, rather than being overlapping features of the learning environment, the constructs assessed by the QTI and SLEI are complementary when investigating their associations with student outcomes.

The MCI was used in a study of 1512 primary-school mathematics students in Singapore to research associations between classroom environment and the student outcomes of achievement and attitude (Goh et al., 1995). 4 scales of the MCI were used to measure the classroom environment and outcomes were measured with the Liking Maths Scale and Mathematics Exercise. Goh's study was distinctive in comparing the results obtained using multiple regression analysis with those obtained using hierarchical linear model analysis.

Associations between the learning environment in mathematics classrooms and students' achievement and attitudes to mathematics have been widely investigated. Goh and Fraser (1998, 2000) used the MCI and QTI in a study with 1512 primary mathematics students in Singapore. Dorman (2001) used the CLES and WIHIC with a sample of 1055 Australian secondary mathematics students and suggested that classroom environment has a positive relationship with academic efficacy. When the CLES was used in a South African study involving 1864 mathematics students, it was found that greater emphasis on aspects of constructivism assessed by the instrument were linked with improved student attitudes (Sebela, Fraser & Aldridge, 2004). A study involving 1565 lower-secondary mathematics students in Brunei Darussalam revealed statistically-significant associations between the learning environment and student satisfaction for most MCI scales (Majeed et al., 2002). In a large study in Singapore involving 2310 mathematics and geography students, associations were established between scales of the WIHIC and student examination results, attitudes and self-esteem (Chionh & Fraser, 2009). When 365 Australian high-school students responded to the WIHIC, it was found that using multimedia was associated with a more-positive learning environment and improved student engagement (Chipangura & Aldridge, 2016). A Chinese study using a modified version of the WIHIC identified significant positive correlations between the mathematics classroom learning environment and student attitudes and achievements in mathematics (Bi, 2015).

In Western countries, there is a long history of using a variety of strong, repeatedly-validated questionnaires to assess student perceptions classroom learning environment (Fraser, 1998). As discussed in Section 2.3, learning environment questionnaires have

been translated into many languages, including Spanish (CLES), Arabic (WIHIC), Mandarin (CLES, WIHIC), Indonesian (WIHIC) and Korean (QTI, SLEI, CLES, WIHIC), as learning environments research has expanded globally. The use of learning environment questionnaires to specifically investigate outcome–environment associations has involved the WIHIC being translated into: Mandarin for use with 1879 junior high school science students (Aldridge et al., 1999); Korean for use with 543 Grade 8 science students (Kim et al., 2000); Bahasa in a cross-national study involving 567 Australian and 594 Indonesian students (Fraser et al., 2010); and Arabic for use in tertiary mathematics classrooms in the UAE (Afari, Aldridge & Fraser 2012; Afari et al., 2013).

Classrooms are generally hierarchical in nature and therefore classroom environment data taken from intact classes reflect the hierarchical structure of those classes. Overlooking this structure can lead to bias and imprecision. The use of multilevel analysis in learning environment research acknowledges the hierarchical structure of classrooms, but historically few studies have used it in addition to multiple regression analysis or similar techniques (Dorman, 2012). Two studies of outcome–environment associations that compared results from multiple regression analysis and the hierarchical linear model are reviewed below.

Goh, Young and Fraser (1995) investigated associations between scores on a modified version of the MCI and attitudes with a sample of 1512 grade 5 mathematics students. The study revealed that using the two different methods of analysis generally showed agreement. The use of the hierarchical linear model analysis in this

study provided understanding of associations between student outcomes and classroom environment that had not previously been possible.

In Wong, Young and Fraser's (1997) study, associations between a modified version of the SLEI and three student attitude measures were examined using a group of 1592 Grade 10 chemistry students in Singapore. This study also used conventional multiple regression analysis together with hierarchical linear model analysis to examine the relationships between learning environment and attitudes. Relationships between the chemistry laboratory classroom environment and students' attitudes were positive and similar for the two different methods of analysis.

Secondary analyses of National Assessment of Educational Achievement data and National Assessment of Educational Progress data revealed that classroom and school environment was a strong predictor of cognitive and affective outcomes when various other factors were held constant (Fraser, Welch & Walberg, 1986; Walberg, Fraser & Welch, 1986). Fraser (2012) lists 21 studies that have used and validated the WIHIC and states that 13 of these studies investigated associations between the learning environment and a variety of student outcomes. These 13 studies replicated associations between student outcomes and classroom environment for a range of subject areas, countries, student outcomes, grade levels and languages.

Fraser and Kahle (2007) undertook secondary analysis of large databases collected during a Statewide Systemic Initiative. The researchers examined the effects of different environments (class, home and peer) on student outcomes using data collected over 3 years. Almost 7000 middle-school science and mathematics students

from 392 classes in 200 schools were part of the study. In addition to the questionnaire, a panel of experts developed an achievement measure that was independent of any particular curriculum. The researchers confirmed the importance of extending the study of classroom learning environments to those of the home and the peer group. Importantly, classroom learning environment accounted for variance in achievement and attitudes in addition to that attributable to peer or home environments.

2.5.3 Using Learning Environment Scales as Dependent Variables

Dimensions of the classroom environment have been used as dependent variables in numerous studies of how the classroom environment varies with other factors such as the type of school, grade level, class size, the nature of the school-level environment, subject content and teacher personality (Fraser, 2012). In a Japanese study, Hirata and Sako (1998) investigated differences in the perceived learning environments of at-risk (delinquent and non-attendees) and normal students. A Singaporean study involved differences in the perceived learning environment of gifted and non-gifted students (Quek et al., 2005). Khine and Fisher (2004) found that students' perceptions of the learning environment depended on whether the teacher was Asian or Western in a study conducted in Brunei. Differences in the perceived learning environment between students in science-orientated, science-independent and humanities-orientated streams were the subject of studies in Korea (Fraser & Lee, 2009; Lee et al., 2003). Also in Korea, the perceived level of classroom constructivism in Grade 10 was compared with that in Grade 11 (Kim et al., 1999). Differences between classroom environments have been found for different school

subjects, including year 10 geography and mathematics classes in Singapore (Chionh & Fraser, 2009) and mathematics and science classes in Canada (Fraser & Raaflaub, 2013).

Fraser (2002) identified student gender as the most-extensively researched determinant of classroom environment in Asia. Gender studies have been completed in numerous Asian countries including Singapore (Chionh & Fraser, 2009; Goh & Fraser, 1998; Khoo & Fraser, 2008; Lim & Fraser, 2018; Peer & Fraser, 2015; Quek et al., 2005; Wong & Fraser, 1996), Brunei (Khine & Fisher, 2004) and Korea (Kim et al., 2000). Gender differences have also been investigated in the Western world including Canada (Fraser & Raaflaub, 2013) and the United States (den Brok et al., 2006; Hoang, 2008; Taylor & Fraser, 2012, 2013). Studies involving within-class comparisons of students' perceptions have generally shown that males have somewhat less-positive views of their classroom environment than female peers.

2.5.4 Brief Overview of Other Applications

Fisher and Fraser (1983a) used the ICEQ to investigate differences between students' and teachers' perceptions of the same actual classroom environment, as well as differences between the actual environment and the preferred environment of students or teachers. Using a sample of 116 classes and 56 teachers, the researchers identified that students perceived a more positive classroom environment than actually existed on all ICEQ dimensions and that teachers perceived a more positive classroom environment than students in the same classrooms on four ICEQ scales. These findings are consistent with patterns identified in the USA (Moos, 1979), Australia

(Fraser & McRobbie, 1995) and Singapore (Wong and Fraser, 1996), as well as in other settings including work environments and hospital wards (Moos, 1974).

Combining both quantitative and qualitative methods in educational studies has greater merit than choosing one or the other, as illustrated by numerous learning environment studies (Fraser & Tobin, 1991; Tobin & Fraser, 1998). Aldridge et al. (1999) used a mixed-methods approach in a learning environment study in Taiwan and Australia by combining use of the WIHIC questionnaire with classroom observations and interviews with students and teachers. The qualitative information collected was used to further explain patterns observed in the quantitative data. Fraser and Tobin (1989) used interpretive research methods including interviews, observations and case studies with quantitative data from questionnaires to investigate differences in the learning environments created by exemplary teachers and non-exemplary teachers. Tobin, Kahle and Fraser (1990) used interviews, student written work and observations together with quantitative data collected from questionnaires in a study of higher-level cognitive learning. Fraser (1999) completed a multi-level study of a science class in Australia that integrated the perspectives of a teacher-researcher with that of six university-based researchers. Qualitative methods in this study included regular classroom observations, student diaries, interviews (teacher-researcher, students, school administrators and parents), video recordings, field notes and team meetings, while quantitative data were collected through questionnaires. Qualitative methods can be useful when the researchers want to obtain deeper insights into students' learning environment perceptions (Khoo & Fraser, 2008).

Fraser (2012) suggests that there are at least two reasons why cross-national studies present potential for forming new understandings in educational research. Aldridge et al. (1999) used the WIHIC in a cross-national study with 50 junior high-school classes in each of Taiwan and Australia. The largest differences between the countries were for Involvement and Equity. Australian students perceived these scales more positively than Taiwanese students did. Similar cross-national studies in high-school science classes include Fraser et al. (2010) in Indonesia and Australia and Aldridge and Fraser (2000) in Taiwan and Australia.

2.6 Assessment of Attitudes to Mathematics

Studies of associations between the learning environment and student attitudes have been far more common in science classrooms than in mathematics classrooms, possibly because mathematics educational researchers generally focus on cognitive rather than affective areas of learning. Because the field of learning environments has involved a relatively limited number of studies of middle-school mathematics, my research into relationships between student attitudes and classroom environment addresses a gap. Therefore, for the purposes of this thesis, it is important to provide this literature review devoted to the topic of assessment of attitudes to mathematics.

Historically, the affective areas of learning such as attitudes have not been as common in research as cognitive areas in mathematics education. When researchers have studied 'attitude' to mathematics, the definitions of this term vary widely. This section reviews attempts to define and assess student attitudes to mathematics. It encompasses the historical development of the Test of Mathematics-Related Attitudes

(TOMRA), the instrument used to quantify student attitudes towards mathematics in my study, and reviews past research that has used this instrument. The reliability and validity of TOMRA scales have been demonstrated in numerous studies (Afari et al., 2012; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005) and this is why I selected it as an appropriate tool for my study.

McLeod (1992) adopted the term 'affect' rather than 'attitude' to define all of the emotions, beliefs and feelings regarding mathematics. He defines 'emotions' as short-lived, changing and not necessarily cogitative, whereas 'beliefs' are formed during the study of mathematics over a longer period of time and are cogitative. These 'beliefs' include opinions about the role of the teacher, the learner and the social context in which mathematics is taught. Finally, 'attitudes' are defined by McLeod to be the enjoyment that students feel during lessons, their likes and dislikes and how they prefer to be taught mathematics.

In a meta-analysis of research on attitudes towards mathematics, Dungan and Thurlow (1989) found that research had identified associations between student attitudes to mathematics and teacher qualities, student personality or social factors, gender, parental influences, peer influences and intelligence. These attitudes were originally attributed only to classroom or internal factors but, over time, the influence of external and social norms has been investigated.

Gender differences in achievement and attitudes to mathematics have been studied since the 1970s (Aksu, 1991; Fennema & Sherman, 1976; Ma, 1997; Ma & Kishor, 1997). The study of gender differences actually highlights the role that the

environment plays in learning (Leder, 1992). Gender differences in regards to learning and attitudes seem to be attributable to personal and situational environments. This suggestion fits well with research on classroom environments for which it is commonly accepted that the perceived environment of the whole class and that of the individual learner are important influences on student outcomes (Aldridge & Fraser, 2008; Fraser, 2007, 2012).

In the *Handbook of International Research in Mathematics Education*, English (2008) identified that there are insufficient connections between mathematics education research and learning environments research. English suggests that helping students reach their full potential in mathematics requires greater integration of these two areas of research, while at the same time allowing understandings from learning environments research in other disciplines to be included in the mathematics classroom.

The Fennema-Sherman Attitude Scale (1976) was one of the first and probably is the most well-known survey for assessing attitudes towards mathematics. It was originally developed to study gender differences in attitudes using nine scales: attitude towards success in mathematics; mathematics as male domain; mother, father and teacher scales; confidence in learning mathematics; mathematics anxiety; effective motivation in mathematics; and perceived usefulness of mathematics. These scales encompass a wide range of the possible factors involved in student attitudes to mathematics. This survey was shown to be reliable and valid, even in a shortened form, in subsequent research (Melcancon, Thompson, & Becnel, 1994; Mulhern & Rae, 1998). Internal consistency reliability and construct validity were reported for

an Arabic translation of the shortened form of the Fennema-Sherman Attitude Scale (Alkhateeb, 2004).

Sandman's Mathematics Attitude Inventory (1980) also was designed to assess student attitudes to mathematics using six scales: the value of mathematics, self-concept in mathematics, anxiety in mathematics, enjoyment of mathematics, motivation in mathematics, and perceptions of mathematics teachers. The main difference that distinguishes this instrument from the Fennema-Sherman Attitude Scale is that the concept of 'enjoyment' is included as part of student attitude.

The attitudes of students towards the study of science have also been investigated over the years. Many instruments have been developed in an attempt to quantify scientific attitudes utilising Likert (1932), Thurstone (1928) and Guttman (1944) scales. Kind, Jones and Barmby (2007) summarised the significant, well-recognised and enduring problems with past attitude scales, based on syntheses by Munby (1983, 1997) and Osborne, Simons and Collins (2003), as being ambiguity in construct descriptions to be quantified, the merging of theoretically-diverse constructs into one unidimensional scale, low reliability and problems with construct validity.

The Test of Science Related Attitudes (TOSRA) was designed by Fraser (1978, 1981) to be used with secondary students to measure science-related attitudes using seven scales: Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. The TOSRA is scored using a five-point Likert (1932) scale. Fraser et al. (2010) suggest that the TOSRA addresses

most of the issues identified by Kind et al. (2007) and Munby (1997), because it defines each construct by providing different scales based on Klopfer's (1971) classification of students' attitudinal aim, and it does not merge theoretically-diverse constructs to form one scale. Furthermore, past studies have provided evidence that TOSRA scales have satisfactory scale reliability, structure, unidimensionality and interdependence.

The TOSRA has been widely used in studies to quantify attitudes towards science (Allen & Fraser, 2007; Fraser et al., 2010; Wolf & Fraser, 2008; Wong & Fraser, 1996). Modified versions of the TOSRA have also been used to assess students' satisfaction with an adult computer application course in Singapore (Khoo & Fraser, 2008) and computer networked classrooms in Australia and Canada (Zandvliet & Fraser, 2005).

Many studies involving large numbers of students from many countries have used the TOSRA and WIHIC in combination to investigate relationships between the learning environment and student outcomes (e.g., Aldridge et al., 1999; Koul & Fisher, 2005; Zandvliet & Fraser, 2004, 2005).

In an attempt to measure student attitudes to mathematics, small modifications have been made to the TOSRA by replacing the word 'science' with 'mathematics' to develop the Test of Mathematics-Related Attitudes (TOMRA). For example, "Science lessons are fun" becomes "Mathematics lessons are fun" (Fraser & Raaflaub, 2013; Spinner & Fraser, 2005).

Since 2002, the TOMRA has been used in mathematics education research to investigate the effect of innovative mathematics programs on attitudes to mathematics (Spinner & Fraser, 2005), how innovative strategies for teaching influence student attitudes (Ogbuehi & Fraser, 2007), the effects of grade-level and gender and ethnicity on attitudes (Hoang, 2008). Afari et al. (2012) and Afari et al. (2013) successfully used one scale of the TOMRA (Enjoyment of Mathematics Lessons) to assess the attitudes of students using games in the mathematics classroom.

A recent Australian study of 541 students in 15 schools focused on the transition from primary- to high-school mathematics in terms of changes in classroom environment, student attitudes and student anxiety towards mathematics (Deieso & Fraser, 2019). This study included three established instruments, namely, the WIHIC, TOMRA and Revised Mathematics Anxiety Ratings Scale. Relative to year 7 students, year 8 students (following transition) reported a decrease in their involvement in mathematics learning environments and a decline in their attitudes to mathematics (attitude to inquiry, enjoyment and anxiety), largely replicating patterns observed in previous research involving the transition from primary to high school (Ferguson & Fraser, 1999).

The TOMRA is not the only successful modification made to the TOSRA. In 2006, Walker modified three TOSRA scales to evolve the Test of Geography-Related Attitudes (ToGRA). The three scales were selected because they transferred well from the study of science (Leisure Interest in Science, Enjoyment of Science Lessons and Career Interest in Science) to geography and were renamed Leisure Interest in Geography, Enjoyment of Geography and Career Interest in Geography. In a study

involving 388 ninth-grade geography students, the ToGRA was shown to have acceptable validity and reliability for use by other researchers at the secondary-school level (Walker, 2006).

The TOSRA has also been modified for use in language classes. The Test of Spanish-Related Attitudes-L₁ (TOSRA-L₁) was developed by Adamski, Fraser and Peiro (2013). Two of the original TOSRA scales were reworded to focus on Spanish (Cultural Attitudes and Enjoyment of Spanish Lessons). The TOSRA-L₁ was used to assess 223 Hispanic Grade 4–6 students' attitudes towards Spanish in South Florida. Liu and Fraser (2013) also successfully adapted the TOSRA for investigating student attitudes towards English among a sample of 308 Grade 11 students in three mainland provinces of China (Liaoning, Heilongjiang and Jilin). Also, associations between students' attitudes and perceptions of classroom environment were investigated.

Three scales of the TOMRA were used in my study to assess students' attitudes towards mathematics: Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes.

2.7 Conclusion

The purpose of this chapter was to review the literature relevant to my study in two main sections: Learning Environments Research and Assessment of Attitudes to Mathematics.

The chapter began with a historical background of the field of learning environments in Section 2.2. Since the pioneering research of Walberg and Moos, the past 40 years of learning environments research has seen significant developments in the variety of instruments and depth of research. Section 2.3 reviewed the literature relating to some of these instruments, including the CES, LEI, MCI, ICEQ, QTI, CUCEI, CLES and SLEI.

The What Is Happening In this Class? (WIHIC) is currently the most-frequently used instrument for assessing classroom environment in the world. Because I chose the WIHIC for my study, a more comprehensive review of this instrument was included in Section 2.4 of this chapter. The WIHIC was developed from a wide range of pre-existing questionnaires with scales added to accommodate modern educational ideas (Fraser et al., 1996). The initial version of the WIHIC contained nine scales and 90 items, which was refined after statistical analysis of the responses of 355 junior high-school students to the questionnaire and an extensive interview process to include 54 items in seven scales. Aldridge et al. (1999) further refined the WIHIC to include seven eight-item scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, Equity). Since then, the WIHIC has repeatedly been shown to be a reliable and valid instrument in studies reviewed by Fraser (2012, 2014, 2018).

Unlike some of the subject-specific questionnaires used in educational research, the WIHIC focuses on the classroom environment. This is a reason for selecting this particular questionnaire for my study. The WIHIC has been used specifically to assess mathematics classroom environments in numerous studies (e.g. Chionh &

Fraser, 2009; Fraser & Raaflaub, 2013; Ogbuehi & Fraser, 2007; Taylor & Fraser, 2013).

In Section 2.5, pertinent past learning environments research was reviewed to provide further context for my study. Because associations between student outcomes and environment and determinants of classroom environment (specifically, student gender) are the focus of my research questions, particular importance was given to past studies also involving these areas. Studies involving the evaluation of educational initiatives were reviewed before a brief overview of other types of learning environment studies was given.

To provide further background for my study, Section 2.6 reviewed the foundations of assessing attitudes to mathematics. Historically the study of attitudes towards mathematics has focused on the decline of attitudes as students mature and on gender differences. A review of the literature relating to the development of methods to assess student attitudes to mathematics began with the Fennema-Sherman Attitude Scale and Sandman's Mathematics Inventory. Because the Test of Mathematics-Related Attitudes (TOMRA) was used in my study, a more-comprehensive review of its development and subsequent use in research was included in this chapter. The TOMRA was adapted from the Test of Science Related Attitudes (TOSRA) (Fraser, 1978). The TOMRA has enabled researchers to quantify attitudes specifically to mathematics, including the work of Afari et al. (2012), Afari et al. (2013), Deieso and Fraser (2019), Hoang (2008), Ogbuehi and Fraser (2007) and Spinner and Fraser (2005). The TOSRA also has been adapted for assessing the attitudes of students in

other subjects including geography (Walker, 2006), Spanish (Adamski et al., 2013) and English (Liu & Fraser, 2013).

My study brought together the two fields of learning environment and attitudes to mathematics. It adds to the growing body of knowledge involving mathematics and learning environments. It attempted to highlight the importance of the learning environment in promoting the attitudes of students to studying mathematics.

Chapter 3

METHODOLOGY

3.1 Introduction

The main focus of my research was associations between students' attitudes to middle-school mathematics and their perceptions of the classroom environment in Adelaide, South Australia. Additional aims were to validate modified versions of the What Is Happening In this Class? (WIHIC) questionnaire and the Test of Mathematics Related Attitudes (TOMRA) for use with middle-school students in Adelaide and to investigate sex differences in students' a) perceptions of the mathematics learning environment and b) attitudes towards mathematics? This chapter outlines the research methods used to investigate these specific research questions.

A review of the literature relevant to this research, including the theoretical foundations of previous learning environment studies, was presented in Chapter 2. Emphasis was given to the WIHIC and TOMRA because they were used in this study.

This chapter includes a detailed description of the sample (Section 3.2), the instruments used to collect data (Section 3.3), the process of data collection (Section 3.4), ethical considerations (Section 3.5) and methods of data analysis (Section 3.6). A summary of the chapter (Section 3.7) is provided.

3.2 Sample

This study involved student from suburban Adelaide, South Australia. The three schools involved were members of the Association of Independent Schools of South Australia (AISSA) whose schools encompass a diverse range of religious beliefs including Christian, Anglican, Seventh-day Adventist, Christadelphian, Baptist, Lutheran, Greek Orthodox, Islamic and Uniting (AISSA, nd). The independent schools included in my study were two co-educational and one single-sex (all girls) schools that were selected based on willingness to be involved. Because I work in a school which is a member of AISSA, I was able to use my connections within the system to encourage schools to be involved. These schools provided a sample of students from a range of abilities and geographical locations across Adelaide.

Using convenience sampling (Creswell, 2008), a total of 221 students across 13 year 9 classes were recruited to be part of my study and to complete the survey containing selected scales from the WIHIC and TOMRA. Year 9 students were selected for this study because they were in their final year of middle schooling and their experiences of middle-school mathematics would be best reflected in their responses towards the end of this period. The sample comprised students who had parental permission and who also gave their own permission to be part of the study. Ethical considerations regarding the selection of the sample and other issues are discussed in detail in Section 3.5.

Approximately 67% of the students were female and 26% were male, with 7% of students not indicating their gender on the questionnaire booklet. Table 3.1 displays

the gender composition of the schools involved. Because of the inclusion of a single-sex (all girls) school, there was a gender imbalance in the sample.

Table 3.1 Size and Gender Distribution of the Sample by School Type

School Type	Number of Students			
	Total	Male	Female	Unidentified
Coeducational	102	36	53	13
Coeducational	52	20	29	3
Single-sex Girls' School	67	0	67	0
Total	221	56	149	16
Approximate % of Sample	100	26	67	7

The sample for this study is fairly typical of the population of the Adelaide area, except that it could have been more representative of the male student population and other educational systems (for example, public and Catholic schools). Suggestions for improving the generalisability of future research are discussed in Chapter 5.

3.3 Instruments Used to Collect Data

This study used two widely-used and extensively-validated questionnaires, namely, the WIHIC and the TOMRA. Modifications were made to both questionnaires so that they contained only scales and items that were salient to the research questions posed in Chapter 1. Details of the modifications made to the WIHIC questionnaire can be found in Section 3.3.1, followed by consideration of the modifications made to the TOMRA in Section 3.3.2.

3.3.1 *WIHIC*

The WIHIC is now the most frequently-used classroom environment instrument around the world (Fraser, 2012) and this led me to select it as an appropriate tool to be used in my study. The WIHIC questionnaire was initially developed by Fraser, Fisher and McRobbie (1996) to assess student perceptions of the learning environment and this was modified to form the WIHIC's final version by Aldridge, Fraser and Huang (1999). The WIHIC contains seven eight-item scales that assess Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. The historical background of learning environment instruments was outlined in Section 2.3, followed by Section 2.4 which specifically focussed on the WIHIC and an overview of research using learning environments questionnaires in Section 2.5.

To ensure a meaningful evaluation of associations between the classroom learning environment and student attitudes, careful consideration was given to the retention or omission of each of the WIHIC's original scales. The modified version of the WIHIC used in my study incorporated six of the seven WIHIC scales (namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity). Table 3.2 demonstrates how the six WIHIC scales used in this study align with the Six Principles for Effective Teaching of Mathematics suggested by the Australian Council for Educational Research (Sullivan, 2011) and also in the USA align with the National Council of Teachers of Mathematics' Six Principles for School Mathematics (NCTM, 2000). The WIHIC's Investigation scale was

considered to align less well with the principles of both Sullivan (2011) and the NCTM (2000) and therefore was omitted for the purposes of my research.

A scale description and sample item for each scale in the WIHIC are provided in Table 3.3. Moos' (1979) conceptual framework for human environments has been an integral part of learning environments theory. Table 3.3 also shows the classification of WIHIC scales according to Moos, whose framework characterises human environments as having relationship (the nature and intensity of personal relationships), personal growth (opportunities for personal development and self-enhancement) and system maintenance and change dimensions (involving whether the environment emphasises order, clear expectations and responsiveness to change).

A copy of the final version of the WIHIC used in my study is provided in Appendix A. The questionnaire includes an information page with directions to students about how to complete the questionnaire, a sample question and place for students to indicate their gender. After the information page, the 48 items from the seven WIHIC scales are presented, followed by the 15 items from the three TOMRA scales (Section 3.3.2). Teachers were asked to read the instructions aloud to the class before the students started answering items in the questionnaire booklet.

In the past, many questionnaires have used negatively-worded reversed-scored items which can be confusing for students. No negatively-worded items were included in my study, as suggested by Barnette (2000), to minimise or eliminate unnecessary confusion.

Table 3.2 Alignment of Six WIHIC Scales with ACER’s Six Principles for Effective Teaching of Mathematics and NCTM’s Six Principles for School Mathematics

	Principle	Elaboration of the Principle	WIHIC Scale(s)
Australian Six Principles for Effective Teaching of Mathematics*	Articulating Goals	Identify key ideas that underpin the concepts you are seeking to teach, communicate to students that these are the goals of the teaching, and explain to them how you hope they will learn.	Task Orientation
	Making Connections	Build on what students know, mathematically and experientially, including creating and connecting students with stories that both contextualise and establish a rationale for the learning.	Task Orientation
	Fostering Engagement	Engage students by utilising a variety of rich and challenging tasks that allow students time and opportunities to make decisions, and which use a variety of forms of representation.	Involvement
	Differentiating Challenges	Interact with students while they engage in the experiences, encourage students to interact with each other, including asking and answering questions, and specifically plan to support students who need it and challenge those who are ready.	Student Cohesiveness Teacher Support Equity
	Structuring Lessons	Adopt pedagogies that foster communication and both individual and group responsibilities, use students’ reports to the class as learning opportunities, with teacher summaries of key mathematical ideas.	Student Cohesiveness Cooperation
	Promoting Fluency and Transfer	Fluency is important, and it can be developed in two ways: by short everyday practice of mental processes; and by practice, reinforcement and prompting transfer of learnt skills.	Task Orientation
US NCTM Six Principles for School Mathematics#	Equity	Excellence in mathematics education requires equity—high expectations and strong support for all student.	Equity
	Curriculum	A curriculum is more than a collection of activities; it must be coherent, focused on important mathematics, and well-articulated across the grades.	Task Orientation
	Teaching	Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.	Teacher Support
	Learning	Students must learn mathematics with understanding, actively building new knowledge from experience and previous knowledge.	Involvement
	Assessment	Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.	Teacher Support
	Technology	Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning.	Involvement

* Adapted from Australian Council for Educational Research (Sullivan, 2011)

Adapted from US National Council of Teachers of Mathematics (NCTM, 2000)

Table 3.3 Scale Description and Sample Item for Each Scale in the What Is Happening In this Class? (WIHIC) Questionnaire

Scale Name	Scale Description	Sample Item	Moos' Schema
Student Cohesiveness	The extent to which students know, help and are supportive of one another.	I know others students in this class.	R
Teacher Support	The extent to which the teacher helps, befriends, trusts and is interested in the students.	The teacher takes a personal interest in me.	R
Involvement	The extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class.	I explain my ideas to other students.	R
Investigation	The extent to which skills and processes of inquiry and their use in problem solving and investigations are emphasised.	I carry out investigations to test my ideas.	P
Task Orientation	The extent to which it is important to complete activities planned and to stay on the subject matter.	I pay attention in this class.	P
Cooperation	The extent to which students cooperate rather than compete with one another on learning tasks.	I work with other students in this class.	P
Equity	The extent to which students are treated equally by the teacher.	I am treated the same as other students in this class.	S

Note: R = Relationship, P = Personal Development, S = System Maintenance and System Change.

All items are scored 1, 2, 3, 4 and 5, respectively, for the responses of Almost Never, Seldom, Sometimes, Often and Almost Always.

The Investigation scale was not used in this study.

This table is based on Dorman (2003).

Historically, questionnaire items have not always been presented in ‘blocks’ belonging to the same scale, but rather in a ‘random’ or ‘cyclical’ manner. Because presenting items in blocks of statements pertaining to the one scale reduces confusion among students (Aldridge & Fraser, 2008), both WIHIC and TOMRA items were arranged in blocks in the survey used in this study. To ensure that responses accurately reflect the opinions of the students completing the survey, it is also important that the wording of statements is simple, concise, written in plain English and suitable for completion in a timely manner.

The modified version of the WIHIC employed in my study used all of the original eight items for each scale, but the Investigation scale was omitted because it was less relevant to my study. The 48 items were organised in blocks under the name of the WIHIC scale. Items were specifically selected to address the research questions posed to ensure that the questionnaire used in my study was kept as brief as possible. This reduced the chance of student fatigue and, at the same time, minimised the chance that completing the questionnaire would negatively impact on the delivery of the curriculum for either the student participants or the class teacher.

Students were asked to respond by circling Almost Never, Seldom, Sometimes, Often and Almost Always to the items which were scored 1, 2, 3, 4 and 5, respectively. An extensive literature review regarding the development of the WIHIC was provided in Sections 2.3 and 2.4 and its validity and applications in Section 2.4.1. The WIHIC is based on a wide range of pre-existing questionnaires with new scales added to assess some current educational interests (Fraser, 2012). Many different forms of the WIHIC have been used since its development and it has provided a significant contribution to the body of knowledge in the field of learning environments through a wide variety of investigations across the world (Fraser, 2007, 2014, 2018). The WIHIC has been used in past research applications, including investigating differences between males and females in their classroom perceptions and possible relationships between student outcomes and the learning environment scales, as in my study.

The WIHIC was used in a cross-national study in Indonesia and Australia involving 1161 students to reveal differences between countries and sexes in students'

perceptions of the learning environment (Fraser, Aldridge & Adolphe, 2010). Female students perceived significantly more Cohesiveness and Equity in their classrooms compared with male students. Australian female students also reported higher Student Cohesiveness scores than Australian males but, for Indonesian students, there was no difference in how the different sexes perceived Student Cohesiveness in their classrooms.

A Singaporean study with 2310 grade 10 students involved associations between the learning environment and three types of student outcomes (external examination results, self-esteem and attitudes) in mathematics and geography classes using the WIHIC (Chionh & Fraser, 2009). Examinations scores were found to be better in classrooms with greater Student Cohesiveness, while self-esteem and attitudes were more favourable in learning environments with greater perceived levels of Teacher Support, Task Orientation and Equity.

Khoo and Fraser (2008) used the WIHIC in a Singaporean study of 250 adults to evaluate a computer application course in terms of student satisfaction and the classroom learning environment. When student age and sex were also investigated, females perceived greater Equity than males, whereas male students reported greater Trainer Support, Involvement and Satisfaction. Older students reported higher levels of satisfaction compared with their younger counterparts and older female students reported higher levels of Trainer Support than younger females.

Despite the long tradition of the WIHIC being used to investigate learning environments, its use in mathematics classrooms has been somewhat limited,

although it has been successfully used in a number of studies in mathematics since 2000. The relationship between the learning environment and mathematics anxiety has been investigated by Taylor and Fraser (2012, 2013) with 745 high school students in California and Deieso and Fraser (2019) with 541 primary and high school students in South Australia.

Associations between the learning environment and student attitudes in mathematics classes have been investigated using the WIHIC by Afari, Aldridge and Fraser (2012) and Afari, Aldridge, Fraser and Khine (2013) using 352 college students, Chionh and Fraser (2009) using 2310 grade 10 students, Ogbuehi and Fraser (2007) with 661 middle-school students, and Rijken and Fraser (2015) with 284 first-year high-school students. Fraser and Raaflaub (2013) investigated sex differences in perceptions of the learning environment and attitudes 1173 among Canadian students in science and mathematics classes. Another study involving 600 students and the WIHIC focused on sex, grade-level and ethnicity differences in attitudes and learning environment perceptions (Hoang, 2008).

3.3.2 TOMRA

Over the years, researchers have attempted to study ‘attitude’ but the definitions of this construct are wide and varied. Traditional research concentrated on the cognitive component rather than affective learning. ‘Attitudes’ are defined by McLeod (1992) to be the enjoyment that students feel during lessons, their likes and dislikes and how they prefer instruction. Dungan and Thurlow (1989) report that attitudes were originally attributed only to the classroom or internal factors, but over time the

influence of external and social norms have been investigated. The Fennema-Sherman Attitude Scale (1976) was one of the first and probably is the most well-known survey for assessing attitudes towards mathematics. Section 2.6 discussed assessing attitudes to mathematics in detail.

The Test of Science Related Attitudes (TOSRA) (Fraser, 1978, 1981), was designed to be used with secondary-school students to measure science-related attitudes. It has been widely validated and used in studies to quantify attitudes towards science (Allen & Fraser, 2007; Fraser et al., 2010; Wolf & Fraser, 2008). Modified versions of the TOSRA have also been used to assess students' satisfaction with an adult computer application course in Singapore (Khoo & Fraser, 2008) and with computer networked classrooms in Australia and Canada (Zandvliet & Fraser, 2005). The TOSRA has been successfully modified and used in non-science subjects including geography (Walker, 2016), Spanish (Adamski, Fraser & Peiro, 2013) and English (Lim & Fraser, 2018; Liu and Fraser, 2013).

In an attempt to measure student attitudes to mathematics, minor changes were made to the TOSRA to form the Test of Mathematics-Related Attitudes (TOMRA) (Fraser & Raaflaub, 2013; Spinner & Fraser, 2005). Table 3.4 provides a sample item for each TOSRA scale selected for my study and the corresponding wording for each TOMRA scale (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes). The theoretical background of the TOMRA and studies that have validated it were detailed in Section 2.6 and are outlined briefly here to identify research applications and justify the selection of three scales of the TOMRA for use in my study.

Table 3.4 A Comparison of Wording of Items for Test of Science Related Attitudes (TOSRA) and Test of Mathematics Related Attitudes (TOMRA) for Three Scales Used

TOSRA Scale Name	Sample Item	TOMRA Scale Name	Sample Item
Enjoyment of Science Lessons	School should have more science lessons each week.	Enjoyment of Mathematics Lessons	School should have more mathematics lessons each week.
Attitude to Scientific Inquiry	I would prefer to find out why something happens by doing an experiment rather than being told.	Attitude to Mathematical Inquiry	I would prefer to find out why something happens by doing a problem rather than being told.
Adoption of Scientific Attitudes	In science experiments, I like to use new methods which I have not tried before.	Adoption of Mathematical Attitudes	When solving problems in mathematics, I like to use new methods which I have not tried before.

All items were scored 1, 2, 3, 4 and 5, respectively, for the responses of Almost Never, Seldom, Sometimes, Often and Almost Always in my study.

This table is adapted from Fraser (1981).

Since the development of the TOMRA, researchers have used specially-selected scales to assess mathematical attitudes relevant to their studies. Afari et al. (2012) and Afari et al. (2013) used Enjoyment of Mathematics Lessons to evaluate games when used in higher-education mathematics classes in the United Arab Emirates. Spinner and Fraser (2005) used two scales from the TOMRA, namely, Enjoyment of Mathematics Lessons and Normality of Mathematicians, to investigate the effect of innovative mathematics programs on attitudes to mathematics among 119 students in Miami-Dade County Public Schools. Ogbuehi and Fraser (2007) used Normality of Mathematicians and Enjoyment of Mathematics Lessons to investigate how innovative strategies for teaching influence student attitudes using a sample of 661 Californian middle-school students. Hoang (2008) investigated the effects of grade-level, gender and ethnicity on attitudes using the scales Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons with 600 students in California. Rijken (2015) used Enjoyment of Mathematics Lessons with a sample of 284 high-

school students in South Australia to investigate the effectiveness of Project-Based Mathematics in terms of learning environment, attitudes, academic efficacy and achievement. More recently, Earle and Fraser (2017) involved 914 middle-school mathematics students in Miami in evaluating the impact of online resources on the learning environment and student attitudes using three TOMRA scales (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Normality of Mathematicians). Deieso and Fraser (2019) used two TOMRA scales (Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons) to investigate changes in learning environment, attitudes and anxiety when 541 students changed from primary to secondary mathematics in schools in South Australia.

Furthermore, the TOMRA has been used successfully in conjunction with the WIHIC in mathematics classrooms to investigate associations between the learning environment and student outcomes including attitudes (Deieso & Fraser, 2019; Hoang, 2008; Ogbuehi & Fraser, 2007).

For all the reasons outlined above, the TOMRA was selected for my study to assess students' attitudes towards mathematics. As explained in Section 3.3.1, students completed a questionnaire booklet and, on the front cover, clear instructions were provided about how to respond to the statements. The WIHIC items were immediately followed by the 15 items from three TOMRA scales, namely, Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes. To avoid having to remove all negatively-worded items, as suggested by Barnette (2000), all TOMRA items used were specifically chosen

because they were positively worded. This reduced unnecessary confusion for students completing the questionnaire.

The TOMRA's original five-point Likert response scale (Strongly Disagree, Disagree, Not Sure, Agree, Strongly Agree) was changed to the same five-point frequency scale as the WIHIC (Almost Never, Seldom, Sometimes, Often, Almost Always) to ensure that a consistent response scale was used in order to reduce confusion among students. This also made sure that the lesson time taken to complete the questionnaire was kept to a minimum. The responses to the items were scored 1, 2, 3, 4 and 5, corresponding to the 5 alternative responses of Almost Never, Seldom, Sometimes, Often and Almost Always, respectively.

3.4 Data Collection

Contact was initiated with schools through the Head of Mathematics who remained the primary contact person with the schools during the data-collection phase of this study. Copies of my ethics approval from Curtin University (Appendix B), participant information sheet for parents (Appendix C), participant information sheet for students (Appendix D) and the complete survey (Appendix A) were made available. Section 3.5 outlines all of the ethical considerations during my study. The Head of Mathematics then took this information to the school principal to seek approval. It was made clear in all documentation that the confidentiality of the schools and individuals would be respected and maintained throughout the study. Once the principal gave permission, logistical considerations for the rest of the study were negotiated with the Head of Mathematics at each school. Before the

questionnaire could be administered, both parent and student permission forms needed to be signed and returned to the school. Information regarding ethics approval and contact details of the researcher were provided to both the parents and students. The teacher of each class was asked to explain to the students the purpose of my research and invite them to participate. Students were informed that their participation was entirely voluntary and that they could withdraw at any stage of the process.

The classroom teacher administered the questionnaire during a normal mathematics lesson, at a time convenient for the teacher and the school, to reduce the impact on the delivery of curriculum and the level of anxiety that the presence of an external party might have caused the students. It was possible for the class teacher to administer the questionnaire because it was straightforward and brief and its administration required no specialised training to supervise. The questionnaire was completed in 10 to 15 minutes. I believe that the absence of the researcher in the classroom during data collection was a strength of this study.

3.5 Ethical Considerations

To ensure the confidentiality and safety of the participants in my study, protocols and procedures were put in place to ensure that potential ethical concerns were addressed. This study was conducted within the requirements of the National Statement of Ethical Conduct in Human Research (NHMRC, 2007) and Curtin University. Initially, approval was obtained from the Human Research Ethics Committee of Curtin University (see a copy of the ethics approval letter in Appendix B). This

section outlines the ethical considerations during different stages of my study for protecting participating individuals and schools, including the ethical protocols of Information (Section 3.5.1), Permission (Section 3.5.2), Privacy and Confidentiality (Section 3.5.3) and Consideration and Acknowledgement (Section 3.5.4) (Howitt, 2008).

3.5.1 Information

Initial contact was made with schools usually through the Head of Mathematics. Written information about the study was provided for the principal for consideration, including a brief explanation of the nature of the research, data-collection methods, my research proposal, ethics approval from Curtin University, the survey to be administered and a letter for parents and students. If the principal expressed a willingness to be involved in the study, the dates of questionnaire administration were negotiated with the Head of Mathematics.

3.5.2 Permission

As explained above, permission was granted from the Human Research Ethics Committee of Curtin University before the commencement of my study. Because the participants were minors, signed permission was obtained from both students and their caregivers. A parent consent form, briefly outlining the purposes and nature of the research was distributed to the Year 9 students. It was communicated to the caregivers that they had the right to withdraw their child at any time without consequence and that the research was anonymous and was not used for assessment

purposes. The contact telephone numbers of my doctoral supervisor and myself were provided in the letter in case of further questions. (Copies of the information sheet, parent and student consent forms are provided in Appendices C and D.)

On the day the questionnaire was administered, students were reminded that their answers were anonymous and time was given to have their questions addressed. Students were reminded that their participation in the research was voluntary and that they were able to withdraw at any time.

3.5.3 Privacy and Confidentiality

Student responses remained anonymous, ensuring that confidentiality was guaranteed. No information was requested that could identify individuals or schools. Students were not required to provide their names or personal details. During data preparation and entry, schools and students were coded numerically to remove any identifying dimensions. Access to the data was only available to my doctoral supervisor and me.

3.5.4 Consideration and Acknowledgement

To ensure that consideration was achieved, there was an extensive period of consultation between the participating schools and me. The schools determined the best time for the survey to be administered and to what classes. The survey was designed to be completed within a single 45-minute lesson to minimise disruption to the class, student learning or school programme. At the conclusion of the study, participants were acknowledged and the school was sent a letter of appreciation.

3.6 Data Analyses

The statistical analyses performed on the data collected using the WIHIC and TOMRA questionnaires are identified in this section. Section 3.6.1 discusses the validation of the WIHIC. A significant feature of this study was that the validity of the WIHIC questionnaire was investigated using both exploratory factor analysis (Section 3.6.1.1) and confirmatory factor analysis (Section 3.6.1.3). Section 3.6.1.2 discusses analyses for the internal consistency reliability of the WIHIC and its ability to differentiate between classrooms. Section 3.6.2 discusses the validation of the TOMRA.

Den Brok, Mainhard and Wubbels (2018) describe two main phases in the development of quantitative research methods in learning environments research. They suggest that the first phase (1965–2000) emphasised descriptive and correlational statistics, while the second phase (2000–present) involved advanced statistical methods including multilevel analysis or Structural Equation Modeling (SEM). A noteworthy feature of my study is that both multiple regression and SEM analyses were used to investigate associations between students' perceptions of their mathematics learning environment and their attitudes towards mathematics (Section 3.6.3). Simple correlation and multiple regression analyses are discussed in Section 3.6.3.1, whereas Structural Equation Modelling analysis is detailed in Section 3.6.3.2, including the development of a research model, how the overall fit of the research model was assessed and the hypotheses tested. Using SEM, researchers can investigate associations between the variables being investigated, testing both direct and indirect statistical effects (den Brok et al., 2018).

Section 3.6.4 describes the method of analysis for ascertaining the statistical significance of sex differences for the seven WIHIC and three TOMRA scales.

3.6.1 Validation of WIHIC

Before my other research questions were investigated, ideally, the data collected from the modified questionnaires first would have been validated. The data from the WIHIC were analysed in various ways to investigate the validity and reliability of the modified version.

3.6.1.1 Exploratory Factor Analysis

The internal structure of the 48 items of the WIHIC for the sample of 221 Year 9 students was statistically analysed via exploratory factor analysis to check the factorial validity of the WIHIC when used with middle-school students in metropolitan Adelaide. Only items with a factor loading of at least 0.3 for its *a priori* scale and a factor loading of less than 0.3 with the other scales were retained. Items that did not meet these criteria were omitted from subsequent consideration. A cut-off criterion of 0.3 for factor loadings is consistent with guidelines suggested by Hair, Black, Babin and Anderson (2010). Principal axis factor analysis with oblimin rotation and Kaiser normalisation was used to confirm the *a priori* structure and hence validate the modified versions of the questionnaires.

3.6.1.2 *Internal Consistency Reliability and Ability to Differentiate Between Classrooms*

For each WIHIC scale, internal consistency was estimated using Cronbach's alpha coefficient. Internal consistency is the extent to which the same construct is being measured by the different items in the same scale.

Another desirable characteristic of a classroom environment scale is the ability to show that students in the same classroom hold similar perceptions of the classroom environment, but different perceptions from those held by students in other classrooms. An analysis of variance (ANOVA) was used to investigate this characteristic for each WIHIC scale with class membership as the main effect. The η^2 statistic provided an estimate of the strength of the association between class membership and WIHIC scores.

3.6.1.3 *Confirmatory Factor Analysis*

To establish whether a hypothesised measurement model for the WIHIC provided a good fit to the data, confirmatory factor analysis methods also were used (Hu & Bentler, 1999) with the sample in South Australia using Analysis of Moment Structure (AMOS) version 22 software (Arbuckle, 2013). The measurement model consisted of the 48 WIHIC items in six scales. Confirmatory factor analysis was used to examine fit to the model (Bagozzi, Yi & Phillips, 1991). As recommended by Harrington (2009) and Kline (2010), I checked the fit of the data to the model with five indices: Chi-square (χ^2); Tucker-Lewis Index (TLI); Comparative Fit Index (CFI); Incremental Index of Fit (IFI); Root mean square error of approximation

(RMSEA); and standardised root mean square residual (RMSR). Hu and Bentler (1999) suggest χ^2 values of less than 3 indicate a well-fitting model. According to Hu and Bentler (1999) and Schumacker and Lomax (2004), a TLI value of at least 0.90 indicates satisfactory fit. Byrne (2010) and McDonald and Ho (2002) suggest that a CFI value of at least 0.90 indicates satisfactory fit. According to Hair et al. (2010), RMSEA and SRMR values of 0.08 or lower indicate a well-fitting model.

3.6.2 Validation of TOMRA

A similar principal axis factor analysis with oblimin rotation and Kaiser normalisation was performed to determine the factorial validity of the 15 TOMRA items used with the same sample of 221 students. Again, items that did not have a factor loading of at least 0.3 on their *a priori* scale and a loading smaller than 0.3 on the other scales were omitted from subsequent consideration.

The internal consistency was determined for the revised TOMRA. The alpha coefficient for each of the three scales of the TOMRA was again used as a measure of internal consistency reliability. The analysis that students in the same classroom hold similar perceptions of the classroom environment, but different perceptions from those held by students in other classrooms, was not performed for the TOMRA scales because the ability to differentiate between classrooms is not relevant for attitude scales.

3.6.3 Associations Between Students' Perceptions of their Mathematics Learning Environment and their Attitudes Towards Mathematics

To investigate my second research question, introduced in Chapter 1, associations between WIHIC and TOMRA scales were investigated using, first, multiple regression analysis and, second, Structural Equation Modeling (SEM).

In Chapter 2, considerable research was reviewed that has consistently replicated positive associations between students' perceptions of the learning environment and their attitudes. In science classrooms, positive associations have been found between classroom environment and attitudes in Indonesia and Australia (Fraser et al., 2010), Korea (Kim, Fisher & Fraser, 2000) and the USA (Helding & Fraser, 2013; Martin-Dunlop & Fraser, 2008; Wolf & Fraser, 2008), including samples from grade 4 and 5 (Allen & Fraser, 2007) and kindergarten (Robinson & Fraser, 2013). In mathematics classrooms, associations between the learning environment and enjoyment of mathematics were reported by Afari, Aldridge, Fraser and Khine (2013) and Ogbuehi and Fraser (2007), whereas Hoang (2008) found statistically-significant and positive correlations between attitudes (Attitude to Inquiry, Enjoyment of Mathematics Lessons) and learning environment scales among 600 high-school mathematics students in California. Associations between learning environment and attitudes were identified in mathematics and geography classes in a Singaporean study involving 2310 grade 10 students (Chionh & Fraser, 2009).

3.6.3.1 *Simple Correlation and Multiple Regression Analyses*

Using simple correlation and multiple regression analyses, associations between the six learning environment scales and the three attitude scales were investigated. The WIHIC learning environment scales were used as the independent variables and the TOMRA attitude scales as the dependent variables.

The simple correlation analysis provides bivariate associations between an attitude scale and a learning environment dimension. Multiple regression analysis provides a multivariate and more-economical representation of the joint influence of correlated environment scales on attitudes. The multiple correlation describes the multivariate association between each attitude scale and the set of six learning environment scales. The independent relationship between a particular environment scale and an attitude scale, when all of the other environment scales are jointly controlled, is reflected in the regression coefficients.

3.6.3.2 *Structural Equation Modeling (SEM)*

Associations between the classroom learning environment and students' attitudes to mathematics also were investigated using SEM based on the model in Figure 3.1. Section 2.4.1 included a review of a study by Wolf and Fraser (2008) who investigated possible associations between the science learning environment and attitudes using the WIHIC, while Section 2.6 reviewed research assessing student attitudes to mathematics was presented. Of particular importance to this study were reported relationships between the learning environment and attitudes in mathematics

of Deieso and Fraser (2019) and Ferguson and Fraser (1999). The review of the literature presented in Chapter 2 helped to inform three hypotheses introduced in Chapter 1 and depicted in Figure 3.1:

1. Students' perceptions of the classroom environment are related to:
 - Enjoyment of Mathematics Lessons
 - Attitude to Mathematical Inquiry
 - Adoption of Mathematical Attitudes.
2. Attitude to Mathematical Inquiry is related to Enjoyment of Mathematics Lessons and Adoption of Mathematical Attitudes.
3. Enjoyment of Mathematics Lessons is associated with Adoption of Mathematical Attitudes.

Based on these three hypothesis above, the research model in Figure 3.1 was formulated. The 48 items from the WIHIC are displayed on the left of Figure 3.1 as rectangles because they are measured variables. The items have arrows pointing to them (representing the direction of the relationship) from the WIHIC scales which, as latent constructs, are represented as ovals. Similarly, the 15 items from the TOMRA are displayed as rectangles on the right of Figure 3.1 and are connected to the TOMRA scales by arrows. The arrows between the scales of the WIHIC and the TOMRA indicate the direct relationships hypothesised between WIHIC and TOMRA scales and among TOMRA scales. Associations between what the three endogenous variables from TOMRA scales (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry, Adoption of Mathematical Attitudes) were tested in the research model. The explanatory power of the research model (Santosa, Wei, & Chan, 2005) was assessed using the coefficient of determination (R^2) of the

endogenous variables. “The higher the squared multiple correlation, the greater the joint explanatory power of the hypothesised antecedents” (Diamantopoulos & Sigauw, 2000, p. 92).

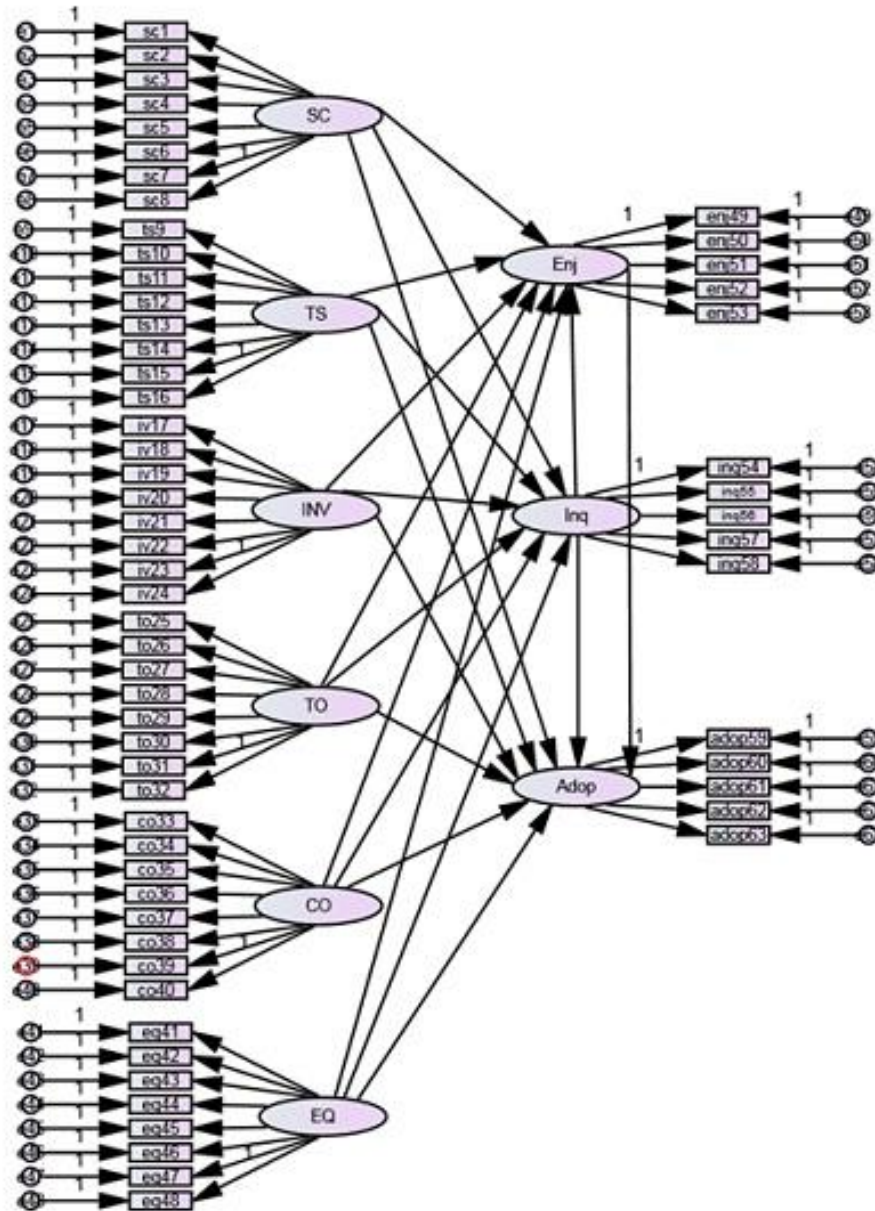


Figure 3.1 Hypothesised Conceptual Model of Relationships between Students' Perceptions of the Learning Environment and Attitudes to Mathematics

The standardised path coefficient and the t -value for the path for each hypothesised relationship were calculated to test the hypotheses. The standardised total effect, direct effect and indirect effect associated with each of the three scales were used to assess the extent to which the exogenous variables were related to the endogenous variables. The relationships between the variables in the model were identified using path coefficients (the standardised version of linear regression weights), which are used to identify possible links between variables in the structural equation modelling approach (Shipley, 2000).

To test whether a single parameter was equal to zero, the t -value was used (Diamantopoulos & Siguaw, 2000). Multiple comparison procedures need to be used because the use of t -values on parameters minimizes the overall rate of Type I error (Fornell & Larcker, 1981). The t -value of a parameter therefore needs to be larger than 1.96 and smaller than -1.96 to be considered statistically significant.

3.6.4 Sex as a Determinant of Students' Perceptions of their Mathematics Learning Environment and Attitudes towards Mathematics

My third and final research question, introduced in Chapter 1, involved sex as a determinant of students' perceptions of the mathematics learning environment and attitudes towards mathematics.

To examine this question and determine sex differences, a one-way MANOVA for the set of nine WIHIC and TOMRA scales was conducted. If Wilks' lambda criterion revealed statistically significant sex differences for the set of scales as a whole, the univariate ANOVA would be interpreted separately for each of the nine scales. Also

the effect size was calculated to determine the magnitude of the difference between males and females, as distinct from its statistical significance. The effect size (Cohen's *d*) gives an indication of the importance of a potential difference, expresses a difference in standard deviation units, and is calculated by dividing the difference between the means by the pooled standard deviation (Cohen, 1988).

3.7 Summary of the Chapter

This chapter has described the sample and the scales from the WIHIC and TOMRA used in my study and the steps taken to ensure that the administration of the survey was efficient and ethical. Details of the data analyses for addressing the research questions identified in Section 1.5 have also been discussed in this chapter.

The study involved 221 students from three AISSA (Independent) Schools in the Adelaide metropolitan area. The schools used included a single-sex all-girls school and two coeducational schools. All of the students in the sample were in Year 9 which, in most South Australian schools, is the last year of middle schooling.

The survey used in this study included six scales from the widely-used and frequently-validated What Is Happening In this Class? (WIHIC) to assess students' perceptions of the learning environment of their mathematics classroom. Student attitudes towards mathematics were assessed using three scales from the Test of Mathematics Related Attitudes (TOMRA).

To ensure the confidentiality and well-being of the research participants, approval was obtained from the Human Research Ethics Committee of Curtin University. Ethical considerations at each stage of the study, including informed consent and confidentiality, protected the participating individuals.

Provided that the scales of the WIHIC and TOMRA can be shown to be valid and reliable through rigorous statistical analysis, then it would be justified to analyse the quantitative data collected in order to investigate my other research questions. Two main validation analyses were performed on WIHIC data collected during this study, namely, exploratory factor analysis and confirmatory factor analysis.

Exploratory factor analysis involved a principal axis factor analysis with oblimin rotation and Kaiser normalisation to determine the factorial validity of the WIHIC and TOMRA scales. Items were retained if they had a factor loading of at least 0.3 for their *a priori* scale and a factor loading of less than 0.3 with the other scales.

The Cronbach alpha reliability coefficient was used as a measure of the internal consistency of each WIHIC and TOMRA scale and the ability of the WIHIC to differentiate between different classrooms was checked using ANOVA.

To establish whether a hypothesised measurement model provided a good fit to the data, confirmatory factor analysis methods were used with WIHIC data (Hu & Bentler, 1999). Initially confirmatory factor analysis was used to determine whether the data confirmed the proposed six-scale WIHIC structure. By assessing their convergent validity and discriminant validity, the factor structure of the scales within

the instrument was examined. Confirmatory factor analysis was used to examine construct measurement fit (Bagozzi et al., 1991). The adequacy of the fit between the data and the model was checked using five indices: χ^2 , TLI, CFI, IFI, RMSEA and RMSR.

Associations between students' perceptions of the mathematics learning environment and student attitudes were first examined using simple correlation and multiple regression analyses. Simple correlation analysis provided information about the bivariate association between each learning environment and each attitude scale. Multiple regression analysis identified the multivariate association between the six learning environment scales and each attitude scale, as well as which learning environment scales were independently related to an attitude scale when the other environment scales were held constant.

Using SEM, relationships between students' perceptions of the classroom environment and the three attitude scales in TOMRA also were explored using Structural Equation Modeling (SEM). In this confirmatory approach (Byrne, 2001), a hypothesised model was tested to determine the extent to which it is consistent with the data. The total, direct and indirect effects on a research model were estimated. The theoretical model shown in Figure 3.1 was tested using AMOS Version 22 (Arbuckle, 2013) using the same five fit indices (χ^2 , TLI, CFI, IFI, RMSEA and RMSR).

A one-way MANOVA was performed for the set of nine WIHIC and TOMRA scales to investigate sex differences. If statistically-significant sex differences for the set of

scales as a whole were found, the univariate ANOVA would be interpreted separately for each of the nine scales. Cohen's *d* effect size was calculated to determine the magnitude of the difference between males and females for each scale, as distinct from its statistical significance, in standard deviation units. Chapter 4 describes in detail the data analyses and the findings of my study.

Chapter 4

DATA ANALYSES AND RESULTS

4.1 Introduction

I investigated associations between the perceived learning environment in middle-school (Year 9) classrooms and students' attitudes towards mathematics. Two questionnaires were administered to 221 students in 13 classes from three independent schools in Adelaide, South Australia.

The What Is Happening In this Class? (WIHIC) learning environment survey was used to assess the perceived learning environment in six areas: Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity (Fraser, Fisher & McRobbie, 1996; see Section 3.3.1). Attitudes towards mathematics were measured using three scales from the Test of Mathematics Related Attitudes (TOMRA): Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes (Fraser, 1981; see Section 3.3.2).

This chapter describes analyses used to answer the research questions posed for this study and reports my findings. Validity and reliability for the learning environment and attitude instruments are reported in Section 4.2. A distinctive feature of my study is that the WIHIC was cross-validated using both exploratory factor analysis (Section 4.2.1) and confirmatory factor analysis (Section 4.2.4). The internal consistency reliability for the WIHIC (Section 4.2.2) and its ability to differentiate between classrooms (Section 4.2.3) are reported, together with the consistency of my results

with past research (Section 4.2.5). The factorial validity and internal consistency reliability for TOMRA are reported in Section 4.2.6.

Section 4.3 details associations between classroom learning environments and attitudes. Simple correlation and multiple regression analyses are reported in Section 4.3.1. Section 4.3.2 reports environment–attitude associations from Structural Equation Modeling (SEM), including descriptive statistics (Section 4.3.2.1) and the assessment of the total, direct and indirect effects (Section 4.3.2.2). A comparison of multiple regression and SEM results for associations between attitudes and learning environments is provided in Section 4.3.3.

Finally, sex differences in perceived learning environment and attitudes to mathematics are reported in Section 4.4. A chapter summary is provided in Section 4.5.

4.2 Validity and Reliability of WIHIC and TOMRA

The first aim of this study was to check if the WIHIC for assessing classroom environment and the TOMRA for assessing student attitudes were valid and reliable when used with middle-school mathematics students in Adelaide. The validity and reliability data provide researchers with a certain level of confidence when using these instruments.

The analyses performed on the data collected from the sample are explained in this section. Data collected from administering the WIHIC and TOMRA questionnaires

were analysed by exploratory factor analysis (principal axis factor analysis followed by oblimin rotation and Kaiser normalisation). Eigenvalues and the percentages of variance also are reported. Also internal consistency reliability was checked for each WIHIC and TOMRA scale using Cronbach's alpha coefficient, and ANOVA was employed to check the ability of WIHIC scales to differentiate between classrooms.

Section 4.2.1 reports exploratory factor analysis for the WIHIC and Section 4.2.2 reports the internal consistency reliability for WIHIC scales. A desirable feature of a classroom environment scale is its ability to demonstrate that students in the same classroom hold similar perceptions of the classroom environment, but different perceptions from those held by students in other classrooms. An analysis of variance (ANOVA) was used to investigate this characteristic for each WIHIC scale with class membership as the independent variable. The η^2 statistic provides an estimate of the strength of the relationship between class membership and WIHIC scores (Section 4.2.3). Confirmatory factor analysis for the WIHIC follows in Section 4.2.4, followed by a discussion of the consistency of these findings with past research which has also used the WIHIC. Finally, the factorial validity and internal consistency reliability for the TOMRA are reported in Section 4.2.6.

4.2.1 Exploratory Factor Analysis for WIHIC

A principal axis factor analysis with oblimin rotation with Kaiser normalisation was undertaken for the WIHIC's 48 items in 6 scales for the sample of 221 students in 13 classes in Adelaide. The two criteria for the retention of any item were that it must have a factor loading of at least 0.3 on its *a priori* scale and less than 0.30 on all other

scales. This cut-off criterion of 0.3 for factor loadings is consistent with guidelines suggested by Hair, Black, Babin and Anderson (2010). The exploratory factor analysis results for the WIHIC are shown in Table 4.1, with only factor loadings greater than 0.30 reported. The eigenvalue and percentage of variance for each scale are reported at the bottom of Table 4.1. Items are referred to by their numbers in the questionnaire (as presented to students) and the wording of each item is provided in Appendix A.

Table 4.1 confirms a strong factor structure for the WIHIC consistent with previous research (Aldridge & Fraser, 2000; Chionh & Fraser, 2009; Zandvliet & Fraser, 2005). The *a priori* six-scale structure was supported in that nearly all items had a factor loading of at least 0.30 on their own scale and less than 0.30 on all the other scales. The only exceptions were three Involvement items (Item 21, 23 & 24) with factor loadings smaller than 0.30 on their own scale. These three items were omitted from subsequent consideration. Overall, all 48 WIHIC items had factor loadings of less than 0.30 with all other scales, while 45 of the 48 items had factor loadings greater than or equal to 0.30 with their own scale.

Table 4.1 shows that the six WIHIC scales together accounted for just over 51% of the variance, with the percentage of total variance extracted for the individual scales ranging from 1.74% to 28.3%. The eigenvalue associated with each factor ranged from 1.35 to 14.05 and exceeded the minimum value of one that is recommended by Kaiser (1960) for meaningfulness.

Table 4.1 Factor Loadings, Eigenvalues and Percentages of Variance from Exploratory Factor Analysis for the What Is Happening In this Class? (WIHIC) Questionnaire

Item #	Factor Loading					
	Student Cohesiveness	Teacher Support	Involvement	Task Orientation	Cooperation	Equity
1	0.50					
2	0.48					
3	0.69					
4	0.68					
5	0.65					
6	0.43					
7	0.31					
8	0.31					
9		0.62				
10		0.61				
11		0.49				
12		0.64				
13		0.59				
14		0.54				
15		0.54				
16		0.55				
17			0.71			
18			0.81			
19			0.30			
20			0.62			
22			0.58			
25				0.68		
26				0.74		
27				0.62		
28				0.72		
29				0.66		
30				0.64		
31				0.68		
32				0.64		
33					0.41	
34					0.52	
35					0.65	
36					0.59	
37					0.51	
38					0.58	
39					0.51	
40					0.57	
41						0.71
42						0.67
43						0.63
44						0.71
45						0.77
46						0.74
47						0.77
48						0.73
% Variance	3.12	6.23	1.74	8.26	3.50	28.31
Eigenvalue	1.97	3.46	1.35	4.42	2.09	14.05

Only factor loadings greater than 0.30 are shown.

Sample consisted of 221 students in 13 classes.

Items 21, 23 and 24 were omitted from the Involvement scale.

Overall, the factor loadings, eigenvalues and percentages of variance strongly support the factorial validity of the modified six-scale version of the WIHIC for measuring aspects of the learning environment as perceived by students.

4.2.2 *Internal Consistency Reliability of WIHIC*

Reliability was estimated using Cronbach’s alpha coefficient. The alpha coefficients for the different scales of the WIHIC are shown in Table 4.2. They ranged from 0.79 to 0.92, which satisfies the minimum value of 0.5 suggested for scale scores to be meaningful (Cronbach, 1951). This suggests that the WIHIC was reliable when used with my sample.

Table 4.2 Scale Mean, Standard Deviation, Internal Consistency Reliability (Cronbach Alpha Coefficient) and Ability to Differentiate between Classrooms (ANOVA Results) for WIHIC

Scale	Number of Items	Mean	SD	Alpha Reliability	ANOVA Eta ²
Student Cohesiveness	8	4.17	0.48	0.79	0.19***
Teacher Support	8	3.77	0.71	0.89	0.34***
Involvement	5	3.45	0.80	0.86	0.15***
Task Orientation	8	4.12	0.62	0.88	0.09*
Cooperation	8	3.99	0.60	0.83	0.21***
Equity	8	3.94	0.80	0.92	0.20***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
 $N = 221$ students

4.2.3 *Ability of the WIHIC to Differentiate Between Classrooms*

A desirable characteristic of a classroom environment scale is that students within the same class have similar perceptions of the classroom environment, but different perceptions from those held by students in other classrooms. This characteristic was investigated using a one-way ANOVA for each WIHIC scale with class membership

as the independent variable. The η^2 statistic, which is the ratio of ‘between’ to ‘total’ sum of squares, was used to indicate the strength of the relationship between class membership and WIHIC scores and the proportion of variance explained by class membership. ANOVA results indicate a WIHIC scale’s ability to differentiate significantly between the perceptions of students in different classes.

Table 4.2 shows that there were significant differences between classrooms for the scales of Student Cohesiveness, Teacher Support, Involvement, Cooperation and Equity ($p < 0.001$) and Task Orientation ($p < 0.05$). The range of values for the η^2 statistic was between 0.09 and 0.34 for the six WIHIC scales. These findings support the ability of WIHIC scales to differentiate between the perceptions of students in different classrooms.

4.2.4 Confirmatory Factor Analysis for WIHIC

Confirmatory factor analysis was conducted with the WIHIC data from my sample of 221 students using maximum-likelihood estimation using Analysis of Moment Structure (AMOS) version 22 software (Arbuckle, 2013). The measurement model, which is depicted in Figure 4.1, consisted of the 48 WIHIC learning environment items in the six scales of Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity.

I used five fit indices recommended by Harrington (2009) and Kline (2010) to evaluate model fit. Table 4.3 lists these five model fit indices used and shows, for each index, the value obtained for the index for my data, a minimum cut-off guideline

for the index, and authors proposing that cut-off value. Table 4.3 shows the following results for my five chosen model fit indices for confirmatory factor analysis:

- χ^2/df : The obtained value of 1.64 satisfied the cut-off guideline of < 3 recommended by Hu and Bentler (1999) and Kline (2010).
- Tucker-Lewis Index (TLI): The obtained value of 0.91 satisfied the cut-off guideline of ≥ 0.90 recommended by Hu and Bentler (1999) and Schumacker and Lomax (2004).
- Comparative Fit Index (CFI): The obtained value of 0.92 satisfied the cut-off guideline of ≥ 0.90 recommended by Byrne (2010) and McDonald and Ho (2002).
- Root Mean Square Error of Approximation (RMSEA): The obtained value of 0.05 satisfied the cut-off guideline of < 0.08 recommended by Hair et al. (2010).
- Standardised Root Mean Square Residual (SRMR): The obtained value of 0.06 satisfied the cut-off value of < 0.08 recommended by Hair et al. (2010).

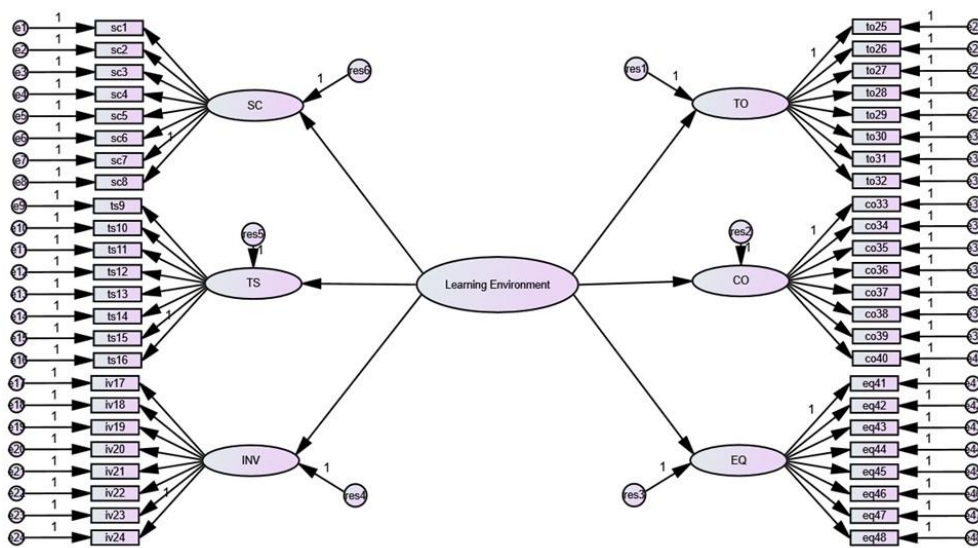


Figure 4.1 Measurement Model for Confirmatory Factor Analysis of 48 WIHIC Items in Six Scales

Overall results for confirmatory factor analysis of WIHIC data in Table 4.3 show acceptable model fit for all of the five criteria (in that obtained values satisfied minimum cut-off guidelines in every case). Therefore, the results in Table 4.3 support the factorial validity of the WIHIC for my sample of mathematics students.

Table 4.3 Model Fit Indices (Obtained Values and Cut-Off Guidelines) for Confirmatory Factor Analysis for WIHIC

Model Fit Index	Obtained Value	Cut-off Guideline	References
χ^2/df	1.64	< 3	Hu & Bentler (1999); Kline (2010)
Tucker-Lewis Index (TLI)	0.91	≥ 0.90	Hu & Bentler (1999); Schumacker & Lomax (2004)
Comparative Fit Index (CFI)	0.92	≥ 0.90	Byrne (2010); McDonald & Ho (2002)
Root Mean Square Error of Approximation (RMSEA)	0.05	< 0.08	Hair et al. (2010)
Standardised Root Mean Residual (SRMR)	0.06	< 0.08	Hair et al (2010)

As proposed by Fornell and Larcker (1981), the reliability and convergent validity of items were assessed in terms of the item reliability, composite reliability (CR) and average variance extracted (AVE). The table in Appendix E shows the composite reliabilities of all the constructs. The CR values shown in Appendix E, ranging from 0.83 to 0.96, all exceed this minimum value of 0.70 recommended by Nunnally and Bernstein (1994).

For AVE, Fornell and Larcker (1981) and Nunnally and Bernstein (1994) recommend a minimum value of 0.5. As shown in the table in Appendix E, the AVE values for all scales were above 0.5. This means that over 50% of the variance observed in the items was explained by their hypothesized factors. Therefore all factors in the measurement model had adequate reliability and convergent validity.

Table 4.4 Inter-construct Correlation Matrix for WIHIC Scales

Construct	Student Cohesiveness	Teacher Support	Involvement	Task Orientation	Cooperation	Equity
Student Cohesiveness	(0.71)					
Teacher Support	0.41**	(0.73)				
Involvement	0.54**	0.55**	(0.73)			
Task Orientation	0.32**	0.41**	0.44**	(0.73)		
Cooperation	0.64**	0.35**	0.61**	0.34**	(0.71)	
Equity	0.34**	0.69**	0.46**	0.30**	0.39**	(0.71)

Note. Diagonal in parentheses: square roots of average variance extracted (AVE) from observed variables.
 ** $p < 0.01$; * $p < 0.05$

Discriminant validity is the degree to which constructs differ from each other. The criterion of discriminant validity was that the square root of the average variance extracted (AVE) for each construct is larger than the inter-construct correlation (Barclay, Higgins & Thompson, 1995). The inter-construct correlation matrix for the six WIHIC constructs is displayed in Table 4.4. The values of the square root of AVE from observed variables are displayed diagonally in parentheses in Table 4.4 and range from 0.71 to 0.73. The values for the shared variances between the factors ranged from 0.16 to 0.69 and were lower than the square root of AVE of the individual factors for all constructs. This suggests little overlap between the constructs, therefore supporting discriminant validity. Therefore the measurement model demonstrated adequate reliability, convergent validity and discriminant validity for the WIHIC.

4.2.5 Consistency with Past Research with WIHIC

The results from this study suggest that the modified version of the WIHIC used with 221 middle-school mathematics students in Adelaide supported the findings of past research using the WIHIC in terms of factorial validity, internal consistency reliability

and ability to differentiate between classrooms. These results replicate considerable past research with diverse samples from around the world including:

- Australia for 1081 junior high-school science students (Aldridge et al., 1999) and 567 students (Fraser et al., 2010)
- India among 1021 middle-school science students (Koul & Fisher, 2005)
- Indonesia with 1188 lower-secondary school science students (Wahyudi & Treagust, 2004)
- Korea with 543 grade 8 science students (Kim, Fisher & Fraser, 2000)
- Singapore with 2310 grade 10 geography and mathematics students (Chionh & Fraser, 2009) and 250 working adults enrolled in computer application courses (Khoo & Fraser, 2008)
- the United Arab Emirates with 90 tertiary-level mathematics students (Afari, Aldridge & Fraser, 2012), 352 college-level mathematics students (Afari, Aldridge, Fraser & Khine, 2013) and 763 college students (MacLeod & Fraser, 2010)
- the United States with 172 kindergarten students in South Florida (Robinson & Fraser, 2013), 520 elementary science students in Miami (Allen & Fraser, 2007), 1434 middle-school science students in New York (Wolf & Fraser, 2008) and 745 high-school mathematics students in California (Taylor & Fraser, 2013)
- Australia and Canada with 1404 students in technology-rich classrooms (Zandvliet & Fraser 2004, 2005)
- Australia, the UK and Canada with 3980 high-school students (Dorman 2003).

4.2.6 Factorial Validity and Internal Consistency Reliability for TOMRA

A similar principal axis factor analysis with oblimin rotation and Kaiser normalisation was undertaken for TOMRA's 15 items in 3 scales for the sample of 221 students in 13 classes in Adelaide. The two criteria for the retention of any item were that it must have a factor loading of at least 0.3 on its own scale and less than 0.30 on all other scales. The exploratory factor analysis results for the TOMRA are shown in Table 4.5, with only factor loadings greater than 0.30 reported.

Table 4.5 Factor Loadings, Eigenvalues and Percentages of Variance for Exploratory Factor Analysis of the Test of Mathematics Related Attitudes (TOMRA)

Item	Factor Loading		
	Enjoyment of Mathematics Lessons	Attitude to Mathematical Inquiry	Adoption of Mathematical Attitudes
49	0.79		
50	0.70		
51	0.79		
52	0.91		
53	0.84		
54		0.68	
55		0.69	
56		0.61	
57		0.81	
58		0.53	
60			0.58
61			0.64
62			0.47
63			0.35
% Variance	40.61	8.85	5.11
Eigenvalue	6.47	1.68	1.33

Only factor loadings greater than 0.30 are shown.

Sample consisted of 221 students in 13 classes.

Item 59 was omitted from the Adoption of Mathematical Attitudes scale.

The exploratory factor analysis results for the 15 items in the TOMRA instrument suggest a factor structure similar to previous research (Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). The *a priori* three-scale structure was replicated, with all but one of the items (Item 59 on the Adoption of Mathematical Attitudes scale) having a factor loading of at least 0.30 on its own scale and less than 0.30 on all of the

other scales. This item was omitted. The eigenvalue and percentage of variance for each scale are reported at the bottom of Table 4.5. Items are identified by their numbers in the questionnaire (as presented to students) and the wording of each item is provided in Appendix A.

Table 4.5 shows that the three TOMRA scales together accounted for just over 54% of the variance, with the percentage of total variance extracted for the individual scales ranging from 5.11% to 40.61%. The eigenvalues associated with each factor were greater than the recommended minimum of one (Kaiser, 1960) for each of the three factors, ranging from 1.33 to 6.47. All 15 items had factor loadings less than 0.30 with all other scales, while 14 of the 15 items had factor loadings greater than or equal to 0.30 with their own scale.

The factor loadings, eigenvalues and percentages of variance strongly support the factorial validity of this modified three-scale version of the TOMRA for assessing student attitudes towards mathematics.

Table 4.6 shows that the alpha reliability coefficients for the three scales of the TOMRA ranged from 0.68 to 0.94, which exceed the meaningful minimum value of 0.5 suggested by Cronbach (1951), thus supporting the TOMRA's reliability when used with my sample.

Table 4.6 Scale Mean, Standard Deviation and Internal Consistency Reliability (Cronbach Alpha Coefficient) for TOMRA

Scale	Number of Items	Mean	SD	Alpha Reliability
Enjoyment of Mathematics Lessons	5	2.46	1.07	0.94
Attitude to Mathematical Inquiry	5	3.48	0.86	0.83
Adoption of Mathematical Attitudes	4	3.63	0.71	0.68

N = 221 students

My findings that the modified version of the TOMRA used in this study showed satisfactory factorial validity and internal consistency reliability for the three attitude scales used (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes) are consistent with other research around the world including:

- Australia with 541 grade 7 and 8 mathematics students (Deieso & Fraser, 2019)
- the United Arab Emirates with 352 college-level mathematics students (Afari et al., 2013)
- the United States for 119 grade 5 mathematics students (Spinner & Fraser, 2005), 661 middle-school mathematics students (Ogbuehi & Fraser, 2007), 600 grade 9 and 10 mathematics students (Hoang, 2008) and 914 middle-school mathematics students (Earle & Fraser, 2017).

4.3 Associations Between Classroom Learning Environment and Student Attitudes

I investigated associations between WIHIC and TOMRA scales using, first, multiple regression analysis (Section 4.3.1) and, second, Structural Equation Modeling (SEM) (Section 4.3.2). A comparison of multiple regression and SEM results is provided in Section 4.3.3.

4.3.1 Simple Correlation and Multiple Regression Analyses

Investigating relationships between the six learning environment scales and the three attitude scales initially involved simple correlation and multiple regression analyses. Historically, the relationships between WIHIC scales and attitudes towards a subject have been investigated in a range of subjects including: science (Fraser et al., 2010; Robinson & Fraser, 2013; Wolf & Fraser, 2008), geography and mathematics (Chionh & Fraser, 2009), Spanish (Adamski, Fraser & Peiro, 2013) and mathematics (Hoang, 2008; Ogbuehi & Fraser, 2007; Taylor & Fraser 2013). In these analyses, the learning environment scales served as the independent variable and the TOMRA scales as the dependent variables.

The simple correlation analysis described bivariate associations between an attitude scale and a learning environment dimension, while the multiple regression analyses provided an economical representation of the joint influence correlated environment scales on attitudes. The magnitude of the relationship between a particular environment scale and an attitude scale, when all of the other environment scales were jointly controlled, is reflected in the regression coefficient from the multiple regression analysis.

The results of the simple correlation and multiple regression analyses of environment–attitude associations are shown in Table 4.7. Interestingly all scales from the WIHIC showed significant simple correlations with all three TOMRA attitude scales. Specifically, for the Enjoyment of Mathematics Lessons scale, Table 4.7 shows significant simple correlations for the WIHIC scales of Teacher Support,

Involvement, Task Orientation and Equity ($p < 0.01$) and for Student Cohesiveness and Cooperation ($p < 0.05$). For the Attitude to Mathematical Inquiry scale, the simple correlation was statistically significant for Equity ($p < 0.05$) and all other WIHIC scales ($p < 0.01$). For the Adoption of Mathematical Attitudes scale, Table 4.7 shows that the simple correlation was statistically significant for Cooperation ($p < 0.05$) and all other WIHIC scales ($p < 0.01$). All of these significant simple correlations were positive, suggesting a positive relationship between student attitudes (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry, Adoption of Mathematical Attitudes) and the learning environment.

The multiple correlation (R) reported in Table 4.7 between the set of six WIHIC scales and each of the three attitude scales was statistically significant ($p < 0.01$). To identify which specific WIHIC scales accounted most for the variance in the attitude scales when the other environment scales were jointly controlled, standardised regression weights (β) were considered.

Table 4.7 Associations between WIHIC Scales and TOMRA Scales in Terms of Simple Correlations (r), Multiple Correlations (R) and Standardised Regression Coefficients (β)

Scale	Enjoyment of Mathematics Lessons		Attitude to Mathematical Inquiry		Adoption of Mathematical Attitudes	
	r	β	r	β	r	β
Student Cohesiveness	0.16*	0.07	0.19**	0.01	0.19**	0.04
Teacher Support	0.40**	0.30**	0.24**	0.01	0.28**	0.03
Involvement	0.35**	0.18*	0.36**	0.27**	0.28**	0.14
Task Orientation	0.49**	0.39***	0.42**	0.34***	0.37**	0.28***
Cooperation	0.15*	0.11	0.18**	0.09	0.16*	0.09
Equity	0.22**	0.11	0.17*	0.01	0.26**	0.12
Multiple Correlation	$R = 0.57^{**}$		$R = 0.48^{**}$		$R = 0.42^{**}$	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

When using Enjoyment of Mathematics Lessons as the dependent variable, the WIHIC scales of Task Orientation ($p < 0.001$), Teacher Support ($p < 0.01$) and

Involvement ($p < 0.05$) were all significantly and independently related to the Enjoyment of Mathematics Lessons (Table 4.7). When using Attitude to Mathematical Inquiry as the dependent variable, the WIHIC scales of Task Orientation ($p < 0.001$) and Involvement ($p < 0.01$) were significantly and independently related to the Attitude to Mathematical Inquiry. Finally, when considering Adoption of Mathematical Attitudes as the dependent variable, the only WIHIC scale that was significantly and independently related to the Adoption of Mathematical Attitudes was Task Orientation ($p < 0.001$).

Although most of the magnitudes of significant correlations were in the small to medium range (Cohen, 1988), these results plainly show a moderate, but still consistent and positive, association between the learning environment and students' attitudes to mathematics for my sample of middle-school mathematics students in South Australia. These results suggest that, in classrooms that have strong task orientation and where students are involved and have the support of a teacher, students enjoyed mathematics lessons. Classrooms with strong task orientation and involvement helped students to develop positive attitudes to mathematical inquiry, while task orientation in the classroom was important for promoting adoption of mathematical attitudes.

The positive relationship found in this study between student attitudes and the learning environment is consistent with past research with students studying elementary-school mathematics (Goh, Young & Fraser, 1995), grade 4 and 5 science (Allen & Fraser, 2007), grade 5 mathematics (Spinner & Fraser, 2005), grade 4–6 Spanish (Adamski et al., 2013), middle-school science (Wolf & Fraser, 2008),

middle-school mathematics (Ogbuehi & Fraser, 2007), high-school mathematics and science (Fraser & Raaflaub, 2013), grade 9 and 10 mathematics (Hoang, 2008), grade 10 geography and mathematics (Chionh & Fraser, 2009) and a university science course for prospective elementary teachers at university (Martin-Dunlop & Fraser, 2007).

4.3.2 Structural Equation Modeling

The data collected from the 221 students were also analysed using Structural Equation Modeling (SEM), which is a wide-ranging method for testing hypotheses about the associations among observed and latent variables (Hoyle, 1995). Using SEM, the relationships between students' perceptions of the classroom environment, Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes involved a confirmatory approach (Byrne, 2001) in which a hypothesised model was tested to determine the extent to which it was consistent with the data.

The three hypotheses tested were outlined in Chapter 3 (Section 3.6.3.2). The hypothesised model used in this study, involving nine scales (six from the WIHIC and three from the TOMRA) and a total of 18 hypothesised relationships for the study (shown in Figure 3.1), was tested using AMOS Version 22 (Arbuckle, 2013). This section reports analyses of the data including descriptive statistics (Section 4.3.2.1), model fit (Section 4.3.2.2), path coefficients (Section 4.3.2.3) and the assessment of total, direct and indirect effects on the research model (Section 4.3.2.4).

4.3.2.1 *Descriptive Statistics*

Descriptive statistics were generated for the WIHIC constructs (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation, and Equity) and for the TOMRA constructs (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry, and Adoption of Mathematical Attitudes). The mean, standard deviation, skewness and kurtosis for each item are provided in Appendix F. With the exception of five items from TOMRA's Enjoyment of Mathematics Lessons scale (Item 49, Item 50, Item 51, Item 52 and Item 53), the means for all individual items were greater than the midpoint of 3.00, suggesting a positive response to the constructs. The standard deviations ranged from 0.52 to 1.27 and suggest a narrow spread of scores around the mean.

A requirement for SEM is that the data are multivariate normal (Byrne, 2010; Kline 2010). Assessing all aspects of multivariate normality can be difficult and many tests have limits (Kline, 2010). Skew and kurtosis are two ways that a univariate distribution can be non-normal. Kline (2010) recommends that skewness and kurtosis indices should be less than 3.0 and 8.0, respectively. Because the skewness indices for my data ranged between -1.92 and 1.38, and the kurtosis indices ranged between -0.956 and 5.056, both indices were within the values recommended by Kline (2010) for univariate normality (Appendix F).

The value of the Mardia's coefficient of multivariate normality in my study was 35.02, which is less than $[p(p + 2)]$ where p = total number of observed indicators (Raykov & Marcoulides, 2008). Therefore the requirement of multivariate normality

was satisfied and the data were suitable for SEM.

4.3.2.2 *Model Fit*

SEM analysis of the relationships between WIHIC learning environment scales and TOMRA attitude scales shown in the research model in Figure 3.1 was conducted for my sample of 221 students. The same five model fit indices recommended by Harrington (2009) and Kline (2010) and used for confirmatory factor analysis of WIHIC data (see Section 4.2.4 and Table 4.3) again were chosen and are listed in Table 4.8.

Table 4.8 Model Fit Indices (Obtained Values and Cut-off Guidelines) for SEM Analysis for Model in Figure 3.1

Model Fit Index	Obtained Value	Cut-off Guideline	References
χ^2/df	1.55	< 3	Hu & Bentler (1999); Kline (2010)
Tucker-Lewis Index (TLI)	0.91	≥ 0.90	Hu & Bentler (1999); Schumacker & Lomax (2004)
Comparative Fit Index (CFI)	0.92	≥ 0.90	Byrne (2010); McDonald & Ho (2002)
Root Mean Square Error of Approximation (RMSEA)	0.04	< 0.08	Hair et al. (2010)
Standardised Root Mean Residual (SRMR)	0.05	< 0.08	Hair et al (2010)

Table 4.8 identifies the five model fit indices and shows for each the value obtained for my data, a recommended minimum cut-off value, and authors recommending that guideline. Table 4.8 shows the following results for model fit indices for SEM analysis of WIHIC and TOMRA scales:

- χ^2/df : The obtained value of 1.55 satisfied the cut-off guideline of < 3 recommended by Hu and Bentler (1999) and Kline (2010).

- Tucker-Lewis Index (TLI): The obtained value of 0.91 satisfied the cut-off guideline of ≥ 0.90 recommended by Hu and Bentler (1999) and Schumacker and Lomax (2004).
- Comparative Fit Index (CFI): The obtained value of 0.92 satisfied the cut-off guideline of ≥ 0.90 recommended by Byrne (2010) and McDonald and Ho (2002).
- Root Mean Square Error of Approximation (RMSEA): The obtained value of 0.04 satisfied the cut-off guideline of < 0.08 recommended by Hair et al. (2010).
- Standardised Root Mean Square Residual (SRMR): The obtained value of 0.05 satisfied the cut-off value of < 0.08 recommended by Hair et al. (2010).

Overall the SEM results in Table 4.8 show acceptable fit of my data to the research model in Figure 3.1 for all of the five criteria (in that obtained values satisfy minimum cut-off guidelines). Therefore the results in Table 4.8 support the hypothesised conceptual model of relationships between students' perceptions of the learning environment and mathematics-related attitudes proposed in Figure 3.1.

4.3.2.3 *Path Coefficients*

Three endogenous variables (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry, Adoption of Mathematical Attitudes) were tested in the research model. The coefficient of determination (R^2) of the endogenous variables was used in evaluating the explanatory power of the research model (refer to Figure 3.1). The R^2 values in Table 4.9 indicate that Enjoyment of Mathematics Lessons was

predicted by classroom climate with an R^2 of 0.47. This means that students' perceptions of their classroom environment explained 47% of the variance in Enjoyment of Mathematics Lessons. Also students' perceptions of their classroom environment explained 31% of the variance in Attitude to Mathematical Inquiry and 74% of the variance in Adoption of Mathematical Attitudes.

Table 4.9 Coefficient of Determination (R^2) of the Endogenous Variables

Endogenous Variables	Coefficient of Determination (R^2)
Enjoyment of Mathematics Lessons	0.47
Attitude to Mathematical Inquiry	0.31
Adoption of Mathematical Attitudes	0.74

The resulting path coefficients and t -values for statistically-significant paths of the proposed model are shown in Table 4.10. Overall, 8 out of 21 possible relationships were statistically significant ($p < 0.05$) and the resulting path coefficient for each statistically-significant path is shown in Figure 4.2.

The statistically-significant relationships between learning environment and attitude scales from SEM and depicted in Figure 4.2 can be summarised as follows:

- Teacher Support was related directly to Enjoyment of Mathematics Lessons and indirectly to Adoption of Mathematical Attitudes via other attitude scales.
- Involvement was directly related to Attitude to Mathematical Inquiry and indirectly to Enjoyment of Mathematics Lessons and Adoption of Mathematical Attitudes via other attitude scales.
- Task Orientation was related directly to Enjoyment of Mathematics Lessons and Attitude to Mathematical Inquiry and indirectly to Adoption of Mathematical Attitudes via other scales.

- Equity was directly related to Adoption of Mathematical Attitudes.
- Student Cohesiveness was related neither directly nor indirectly to any of the three TOMRA attitude scales.

Table 4.10 Standardized Path Coefficients and *t*-values

Hypothesized Relationship	Standardized Path Coefficient	<i>t</i> -value
Student Cohesiveness → Enjoyment of Mathematics Lessons	-0.03	-0.25
Student Cohesiveness → Attitude to Mathematical Inquiry	0.13	- 0.91
Student Cohesiveness → Adoption of Mathematical Attitudes	-0.03	-0.23
Teacher Support → Enjoyment of Mathematics Lessons	0.39	3.00**
Teacher Support → Attitude to Mathematical Inquiry	-0.09	-0.57
Teacher Support → Adoption of Mathematical Attitudes	-0.27	-1.78
Involvement → Enjoyment of Mathematics Lessons	0.11	- 1.00
Involvement → Attitude to Mathematical Inquiry	0.35	- 2.55*
Involvement → Adoption of Mathematical Attitudes	-0.04	-0.35
Task Orientation → Enjoyment of Mathematics Lessons	0.26	- 3.13**
Task Orientation → Attitude to Mathematical Inquiry	0.42	- 4.33***
Task Orientation → Adoption of Mathematical Attitudes	0.02	0.17
Cooperation → Enjoyment of Mathematics Lessons	-0.13	-0.91
Cooperation → Attitude to Mathematical Inquiry	-0.30	-1.75
Cooperation → Adoption of Mathematical Attitudes	0.04	- 0.24
Equity → Enjoyment of Mathematics Lessons	-0.20	-1.82
Equity → Attitude to Mathematical Inquiry	0.04	- 0.31
Equity → Adoption of Mathematical Attitudes	0.32	- 2.53*
Attitude to Mathematical Inquiry → Enjoyment of Mathematics Lessons	0.34	-4.26***
Attitude to Mathematical Inquiry → Adoption of Mathematical Attitudes	0.47	-4.27***
Enjoyment of Mathematics Lessons → Adoption of Mathematical Attitudes	0.53	-4.85***

Note: * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$.

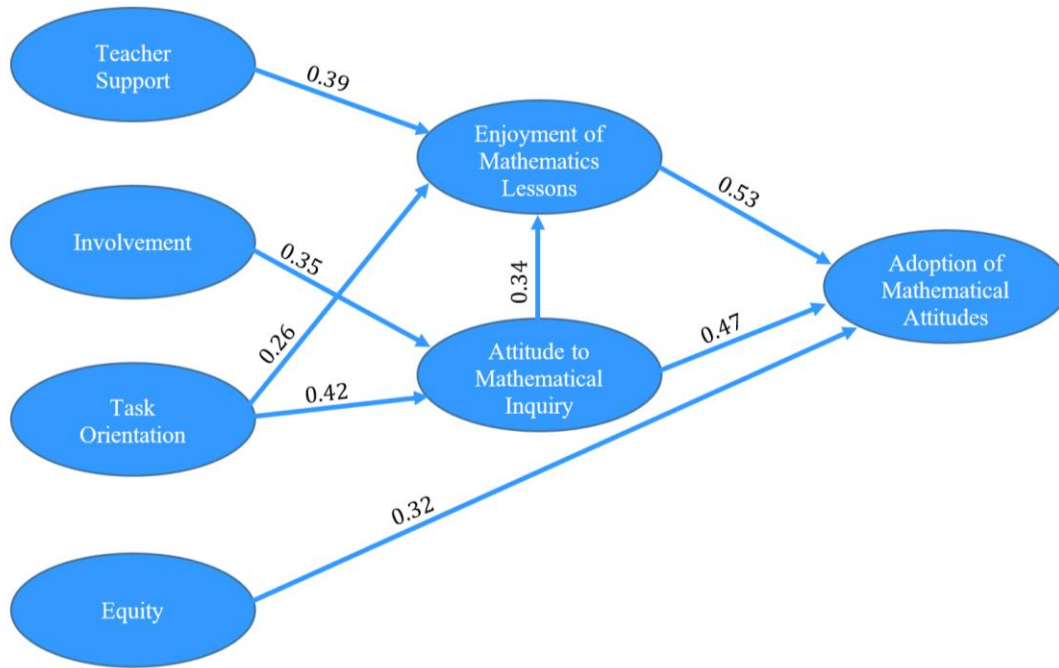


Figure 4.2 Structural Model of Statistically-Significant Standardized Path Coefficients for Relationships between Students' Perceptions of Learning Environment and Mathematics-Related Attitudes

4.3.2.4 Assessment of Direct, Indirect and Total Effects on the Research Model

The standardized total effect, direct effect and indirect effect associated with each of the three attitude constructs were examined to assess the extent to which each exogenous variable had an impact on the endogenous variables (see Table 4.11). In terms of total effects, Task Orientation was the most dominant determinant of all the endogenous variables in the model with a small to medium total effect for Attitude to Mathematical Inquiry ($d = 0.42$), Enjoyment of Mathematics Lessons ($d = 0.40$) and Adoption of Mathematical Attitudes ($d = 0.42$). This suggests that students benefit from mathematics classrooms where they understand the importance of the activities planned, know what they need to do, stay on task and complete the tasks.

Table 4.11 Direct, Indirect and Total Effects on the Research Model

Outcome	Determinant	Standardised Estimates		
		Direct	Indirect	Total
Enjoyment of Mathematics Lessons	Student Cohesiveness	-0.03	0.04	0.02
	Teacher Support	0.39*	-0.03	0.36
	Involvement	0.11	0.12	0.23
	Task Orientation	0.26*	0.14	0.40
	Cooperation	-0.13	-0.10	-0.23
	Equity	-0.20	0.01	-0.19
Attitude to Mathematical Inquiry	Student Cohesiveness	0.13	0.00	0.13
	Teacher Support	-0.09	0.00	-0.09
	Involvement	0.35*	0.00	0.35
	Task Orientation	0.42*	0.00	0.42
	Cooperation	-0.30	0.00	-0.30
	Equity	0.04	0.00	0.04
Adoption of Mathematical Attitudes	Student Cohesiveness	-0.03	0.07	0.04
	Teacher Support	-0.27	0.15	-0.12
	Involvement	-0.04	0.28	0.24
	Task Orientation	0.02	0.41	0.42
	Cooperation	0.04	-0.26	-0.22
	Equity	0.32*	-0.08	0.25

* $p < 0.05$

In terms of direct effects, Table 4.11 and Figure 4.2 show that: Teacher Support ($d = 0.39$) and Task Orientation ($d = 0.26$) were the largest statistically-significant determinants of Enjoyment of Mathematics Lessons; Involvement ($d = 0.35$) and Task Orientation ($d = 0.42$) were the largest statistically-significant determinants of Attitude to Mathematical Inquiry; and Equity ($d = 0.32$) was the largest statistically-significant determinant of Adoption of Mathematical Attitudes. It is not surprising that the perceived support of the teacher was most important in students' enjoyment of their mathematics lessons.

Generally, most indirect effects in Table 4.11 are small except for Adoption of Mathematical Attitudes. Table 4.11 and Figure 4.2 show that, although the direct effects of Involvement and Task Orientation on Adoption of Mathematical Attitudes were small and nonsignificant, they had indirect effects on Adoption scores ($d = 0.28$

for Involvement and $d = 0.41$) via their relationship with Attitude to Mathematical Inquiry.

4.3.3 Comparison of Multiple Regression and SEM Results for Associations Between Learning Environment and Student Attitudes

For associations between TOMRA and WIHIC scales, Table 4.12 compares the statistically-significant coefficients found in the multiple regression analysis with the direct effects on the research model found using structural equation modeling (SEM). With some noteworthy exceptions, there is relatively high similarity between the multiple regression and SEM findings.

For Enjoyment of Mathematics Lessons, regression results (β coefficients) and SEM results for direct effects in Table 4.12 were identical for five out of 6 WIHIC scales: both coefficients were significant for Teacher Support and Task Orientation and both coefficients were nonsignificant for Student Cohesiveness, Cooperation and Equity. The only difference between results from the two methods was that the regression coefficient was significant for Involvement but the SEM coefficient was not. For Attitude to Mathematical Inquiry, multiple regression and SEM results were identical for every WIHIC scale (i.e. both methods yielded significant coefficients for the two scales of Involvement and Task Orientation and nonsignificant coefficients for the other WIHIC scales). For Adoption of Mathematical Attitudes in Table 4.12, regression analysis and SEM yielded identical and nonsignificant results for the four WIHIC scales of Student Cohesiveness, Teacher Support, Involvement and Cooperation, but differing results for the other two WIHIC scales. For Task Orientation, the regression coefficient was significant but the SEM coefficient was

not. For Equity, the SEM coefficient was significant but the regression coefficient was not.

Table 4.12 Comparison of Results of Multiple Regression and SEM Analyses for Associations between WIHIC and TOMRA Scales

Scale	Enjoyment of Mathematics Lessons		Attitude to Mathematical Inquiry		Adoption of Mathematical Attitudes	
	Regression	SEM	Regression	SEM	Regression	SEM
Student Cohesiveness						
Teacher Support	0.30**	0.39**				
Involvement	0.18*		0.27**	0.35**		
Task Orientation	0.39***	0.26**	0.34***	0.42***	0.28***	
Cooperation						
Equity						0.32*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

To summarise, the direct effects on the research model found using SEM show high similarity with the statistically-significant coefficients found using multiple regression analysis. Task Orientation was significant in both methods of analysis for two out of the three TOMRA scales used in my study. SEM only identified one significant relationship (Equity with Adoption of Mathematical Attitudes) that was not identified using multiple regression analysis and regression analysis only identified two statistically-significant relationships (Involvement with Enjoyment of Mathematics Lessons and Task Orientation with Adoption of Mathematical Attitudes) that were not identified by SEM.

Table 4.12 shows that, for the six statistically-significant associations found using multiple regression analysis, four were also found to be significant using SEM analysis. Only one statistically-significant association was identified by SEM analysis that was not identified by multiple regression analysis. All of the significant associations identified by either method were positive, therefore suggesting practical implications for the mathematics classroom. My finding that Task Orientation was

related to all three mathematics attitude scales suggests that the extent to which the completion of classroom activities and productivity are seen as important is positively linked with the Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and the Adoption of Mathematical Attitudes. It is not surprising that students' perceptions of the level of Teacher Support significantly predicted students' Enjoyment of Mathematics Lessons. It also makes sense that student Involvement was positively associated with Attitude to Mathematical Inquiry because, by its very nature, inquiry requires students to be active participants in the generation of mathematical solutions.

It is interesting to note that there were no statistically-significant associations found between the WIHIC scales of Student Cohesiveness or Cooperation and the attitude scales used in this study. This could suggest that that the interactions between students are less important than the individual or the relationship with the teacher for the development of mathematical attitudes. A further interesting result is that the WIHIC scale Equity was identified as statistically-significantly related to Adoption of Mathematical Attitudes using the SEM analysis only.

As a result of this study, teachers could gain a better understanding of associations between mathematics classroom learning environment and mathematical attitudes. In turn, this could lead to teachers adopting specific classroom practices that are likely to promote more positive attitudes to mathematics among their students.

4.4 Sex Differences in Learning Environment Perceptions

My last research question involved sex differences in perceptions of the classroom learning environment and attitudes to mathematics for the sample of 221 students. To reduce the Type I error rate, MANOVA for the set of nine WIHIC and TOMRA scales was initially conducted and, because Wilks' lambda criterion revealed statistically-significant sex differences for the set of scales as a whole, the univariate ANOVA was interpreted separately for each of the nine scales. Table 4.13 shows the ANOVA results obtained.

In addition to reporting statistical significance, the magnitude of the male–female difference for each scale is also described in Table 4.13 in terms of Cohen's *d* effect size or the difference in the means divided by the pooled standard deviation (Cohen, 1988; Thompson, 1998a, 1998b). The effect size reflects the magnitude of a difference between two groups, rather than its statistical significance, and describes the importance of a difference in terms of the number of standard deviations.

As shown in Table 4.13, there were statistically significant sex differences for the WIHIC scales of Student Cohesiveness ($p < 0.001$), Cooperation ($p < 0.01$) and Teacher Support ($p < 0.05$). The effect sizes for these three significant sex differences were 0.61 standard deviations for Student Cohesiveness, 0.49 standard deviations for Cooperation to 0.37 standard deviations for Teacher Support, which would be described by Cohen (1988) as medium to large effect sizes. The female average item mean was higher than the male average item mean for these three scales, with females scoring 4.25 for Student Cohesiveness, 4.07 for Cooperation and 3.87

for Teacher Support, while male students recorded means of 3.97, 3.78 and 3.64, respectively. This suggests that female students had more favourable perceptions of the learning environment than males.

Table 4.13 Average Item Mean, Average Item Standard Deviation, and Sex Difference (ANOVA Results and Effect Size) for Each WIHIC and TOMRA Scale

Scale	Mean		SD		Difference	
	Male	Female	Male	Female	<i>F</i>	Effect Size <i>d</i>
WIHIC						
Student Cohesiveness	3.97	4.25	0.42	0.49	1.95 ^{***}	0.61
Teacher Support	3.64	3.87	0.58	0.65	1.53 [*]	0.37
Involvement	3.41	3.51	0.79	0.79	0.93	0.14
Task Orientation	4.12	4.13	0.51	0.66	0.26	0.01
Cooperation	3.78	4.07	0.59	0.59	1.76 ^{**}	0.49
Equity	3.93	4.01	0.67	0.75	0.82	0.11
TOMRA						
Enjoyment of Mathematics Lessons	2.55	2.44	1.13	1.05	-0.80	-0.10
Attitude to Mathematical Inquiry	3.73	3.39	0.88	0.84	-1.57 [*]	-0.39
Adoption of Mathematical Attitudes	3.83	3.57	0.72	0.65	-1.56 [*]	-0.38

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

$N = 221$ students, Males = 57, Females = 148

d is Cohen's effect size

Taylor and Fraser (2013) suggested that it is plausible that female students would hold more favourable perceptions of the mathematics learning environment for WIHIC scales which measure motivation and interaction among students because female teenagers are known to be more socially active and exhibit greater academic motivation than their male counterparts. These patterns were also identified by Deieso and Fraser (2019) in a study that used scales from three questionnaires including the WIHIC and the TOMRA. Females had more favourable perceptions for all four learning environment scales used by Deieso and Fraser (Student Cohesiveness, Teacher Support, Involvement and Cooperation) but, just as in my study, males had somewhat more favourable attitude scores on both scales from the TOMRA (Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons).

This replicates the findings of previous studies of sex differences using the WIHIC in science (Aldridge et al., 1999; den Brok et al., 2006; Fraser, Giddings & McRobbie, 1995; Wahyudi & Treagust, 2004), mathematics (Hoang, 2008; Taylor & Fraser, 2012; 2013), both science and mathematics classrooms (Fraser & Raaflaub, 2013) and English classrooms (Liu & Fraser, 2013).

Also, as shown in Table 4.13, there were statistically significant sex differences occurring for the TOMRA scales of Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes ($p < 0.05$), but not for Enjoyment of Mathematics Lessons. The effect sizes for these two significant sex differences can be described as modest with values of 0.39 standard deviations for Attitude to Mathematical Inquiry and 0.38 standard deviations for Teacher Support. The female average item mean was lower than the male average item mean for these two scales, with female scoring a mean of 3.39 for Attitude to Mathematical Inquiry and 3.75 for Adoption of Mathematical Attitudes, while male students recorded means of 3.73 and 3.83, respectively. These findings suggest that the attitudes of females towards mathematics were less positive than their male classmates for these two scales, reproducing the findings of Kaiser-Messmer (1993) and Hoang (2008). These findings are also consistent with those of Fraser and Raaflaub (2013), who reported that female students had less favourable attitudes to science and mathematics than their male peers.

Figure 4.3 illustrates the sex differences for the WIHIC and TOMRA scales used in my study. For each of the six WIHIC scales used, the average item mean for female students was higher than that of their male classmates and sex differences were largest

in magnitude for the scales of Student Cohesiveness, Cooperation and Teacher Support. As previously noted, the average item means for female students for the scales from the TOMRA were smaller than those of their male classmates, particularly for the Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes scales. Interestingly, for both male and female students, the lowest average item mean for all scales was for the TOMRA scale of Enjoyment of Mathematics Lessons, with sex differences being nonsignificant for this scale.

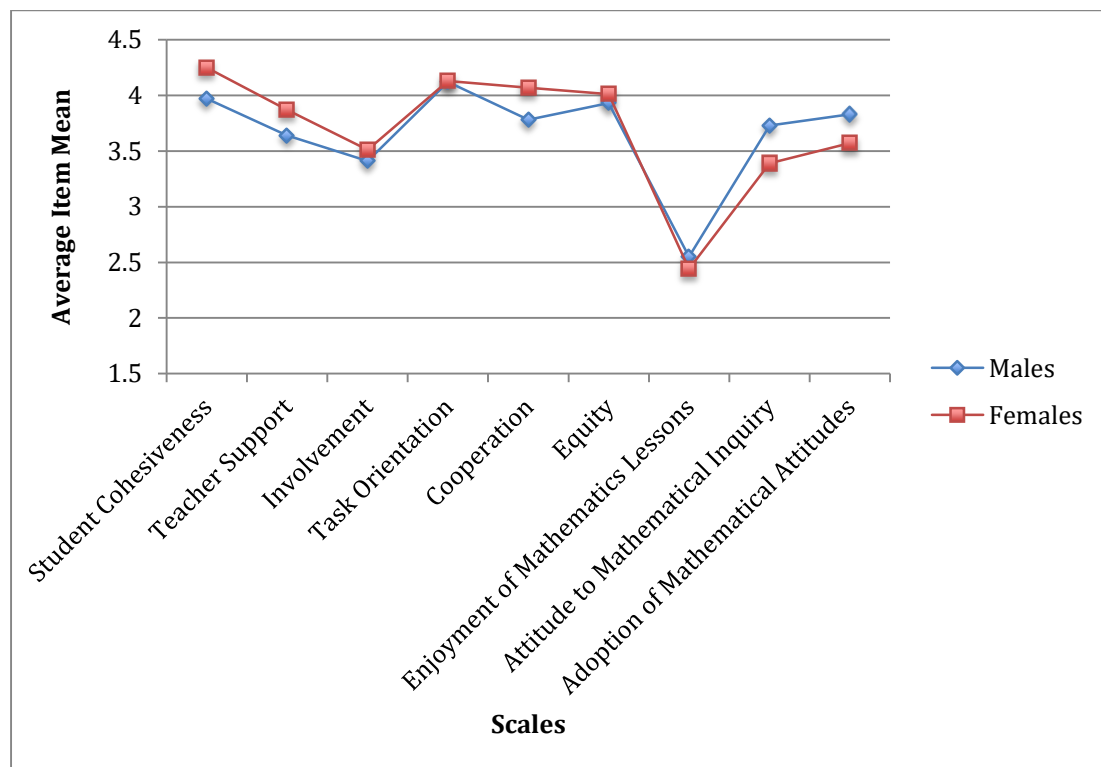


Figure 4.3 Sex Differences for Classroom Environment Perceptions and Attitudes to Mathematics

An interesting pattern can be identified in Table 4.13 and Figure 4.3. The average item mean for all six WIHIC scales was higher for female students than for male students, but the average item mean for all three TOMRA scales was higher for male students than for female students.

4.5 Summary of Analyses and Results

A sample of 221 Year 9 students from three schools in Adelaide completed the WIHIC and TOMRA questionnaires to provide quantitative data for validating the questionnaires and investigating associations between students' perceptions of the learning environment and their attitudes to mathematics. Sex differences in learning environment perceptions and attitudes to mathematics were also investigated.

A noteworthy feature of this study was that the validation of the WIHIC involved both exploratory and confirmatory factor analyses. Both of these types of factor analysis suggested that the WIHIC was factorially valid and therefore able to measure the multiple components of the learning environment. The WIHIC scales together accounted for just over 51% of the total variance, while Cronbach alpha reliability coefficients for each scale exceeded 0.79. ANOVA results showed that all of the six WIHIC scales used were able to differentiate significantly between classrooms. Confirmatory factor analysis showed that my data fitted the measurement model according to fit indices (χ^2/df , TLI, CFI, RMSEA and SRMR).

Exploratory factor analysis supported the structure of the three scales from the TOMRA, which accounted for just over 54% of the total variation. Cronbach alpha reliability coefficients exceeded 0.68 for every TOMRA scale.

When simple correlation and multiple regression analyses were used to identify possible relationships between the learning environment and attitude scales, moderate and positive associations were found. Students enjoyed mathematics lessons in

classrooms that had strong task orientation, involvement and teacher support. Positive attitudes to mathematical inquiry were held in classrooms with strong task orientation and involvement, while task orientation in the classroom was important for promoting adoption of mathematical attitudes.

SEM was also used to analyse the relationships between the learning environment and students' attitudes to mathematics and to assess the total, direct and indirect effects on the research model. Interestingly, relatively similar patterns of relationships between the learning environment and student attitudes emerged from both multiple regression and SEM.

The investigation of sex differences via MANOVA revealed that females perceived the learning environment in mathematics classrooms in a more positive way than males, while males had more positive attitudes towards mathematics than did females.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this chapter, I provide a summary of the material presented in my thesis (Section 5.2), before summarising the major findings of this study (Section 5.3) and discussing its limitations (Section 5.4). The significance and implications of this study (Section 5.5) and recommendations for further research (Section 5.6) are then discussed before final comments (Section 5.7) are made.

5.2 Summary Chapters 1–3 of Thesis

Contextual and background information for this study was presented in Chapter 1, together with its rationale and aims. The Australian participation rate for most mathematics and science subjects fell from 1992 to 2012 despite the total student enrolment increasing (Kennedy, Lyons & Quinn, 2014). Concerns have been raised about the decline in Australia's international ranking in mathematics and science (ACER, 2016a, 2016b; Australian Academy of Science, 2009; Office of the Chief Scientist, 2014) while, at the same time, reports from the Office of the Chief Scientist (2016) suggests that Australia's future relies on STEM disciplines.

A history of the development of the learning environments field was briefly introduced in Chapter 1, because my study drew concepts and methods from it, and a review of many historically-important and contemporary instruments was given. By

bringing together the two fields of learning environments and attitudes to mathematics, this study adds to the growing body of knowledge involving mathematics and learning environments. The intentions of the study were explained in Chapter 1 and the specific research questions posed were:

1. Are modified versions of the WIHIC and the TOMRA questionnaires valid when used with middle-school students in Adelaide?
2. Are there associations between the classroom learning environment and student attitudes?
3. Is sex a determinant of students':
 - a. perceptions of the mathematics learning environment;
 - b. attitudes towards mathematics?

The hypothesised structural model for the study was presented in Figure 1.1.

A literature review was presented in Chapter 2 that considered areas relevant to this study, especially learning environments, attitudes and sex differences in mathematics education. Various learning environment questionnaires, including the CES, LEI, MCI, ICEQ, QTI, CUCEI, CLES and SLEI, were reviewed. Major lines of learning environments research, such as evaluation of educational initiatives, associations between student outcomes and classroom environment, and the use of learning environment scales as dependent variables, were reviewed. Similarly, literature about attitudes and their assessment, especially attitudes to mathematics, was reviewed. Particular attention was paid to the What Is Happening In this Class? (WIHIC) questionnaire and the Test of Mathematics-Related Attitudes (TOMRA) because they were used to measure the central constructs in this study.

Chapter 3 outlined the research methodology used in this study. This included a detailed description of the research sample of 221 students across 13 year 9 middle-school mathematics classes. I chose the WIHIC and TOMRA questionnaires, both of which have been widely used and extensively validated previously. A total of 48 items from six WIHIC scales (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity) and 15 items from three TOMRA scales (Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes) were included in the final survey administered to students. Descriptions were provided of methods for collecting data and ethical considerations.

Methods of data analysis also were detailed in Chapter 3. In particular, techniques for validating questionnaires included both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Also approaches for investigating associations between the WIHIC and TOMRA scales were described as involving and comparing two different methods of analysis: multiple regression analysis and Structural Equations Modeling (SEM). In evaluating model fit for both the CFA and SEM, the five cut-off guidelines employed were that the normed chi-square (the ratio of χ^2 to its degree of freedom) was less than 3 (Hu & Bentler, 1999; Kline, 2010), the Tucker-Lewis Index was greater than 0.90 (Hu & Bentler, 1999; Schumacker & Lomax, 2004), the Comparative Fit Index was greater than 0.90 (Byrne, 2010; McDonald & Ho, 2002), the Root Mean Square Error of Approximation (RMSEA) was less than 0.08 (Hair, Black, Babin & Anderson, 2010) and the Standardised Root Mean Square Residual was less than 0.08 (Hair et al., 2010).

The data analyses and main findings of the study were detailed in Chapter 4 and are summarised in Section 5.3 below.

5.3 Major Findings of this Study

A summary and discussion of the results relating to the three research questions posed in Chapter 1 are presented below including: the validity and reliability of the instruments (Section 5.3.1); associations between the classroom learning environment and student attitudes (Section 5.3.2); and sex as a determinant of students' perceptions of the mathematics learning environment and attitudes towards mathematics (Section 5.3.3).

5.3.1 Validity and Reliability of the Instruments

The first research question involved whether modified versions of the WIHIC and TOMRA questionnaires were valid when used with middle-school students in Adelaide. Data collected from 221 middle-school students from three independent schools in Adelaide, South Australia were used to validate the modified version of the WIHIC using both exploratory factor analysis and confirmatory factor analysis. As well, the WIHIC's internal consistency reliability and ability to differentiate between classrooms were reported in Section 4.2, which also included validation of the TOMRA in terms of its factorial validity and internal consistency reliability. Validity results are summarised in Section 5.3.1.1 for the WIHIC and in Section 5.3.1.2 for the TOMRA.

5.3.1.1 *Validity and Reliability of the WIHIC*

Principal axis factor analysis with oblimin rotation and Kaiser normalisation was performed to examine the internal structure of the 48 items of the modified WIHIC for the sample of 221 Year 9 students. Internal consistency reliability was estimated using Cronbach's alpha coefficient. An ANOVA for each WIHIC scale, with class membership as the independent variable, was performed to ensure the ability of scales to differentiate between classrooms. A summary of the key findings for the validity and reliability of the WIHIC include:

- The modified version of the WIHIC (48 items in 6 scales) displayed satisfactory factorial validity using exploratory factor analysis. All 48 WIHIC items had factor loadings of less than 0.30 with all other scales, while 45 of the 48 items had factor loadings greater than or equal to 0.30 with their own scale; only these 45 items were subsequently considered. The eigenvalues for different scales ranged from 1.35 to 14.05, with just over 51% of the total proportion of variance being accounted for.
- Internal consistency reliability using Cronbach's alpha coefficient ranged from 0.79 to 0.92 for different WIHIC scales.
- Significant ANOVA results suggested that all WIHIC scales were capable of differentiating between classrooms.

Using the same WIHIC data, confirmatory factor analysis (CFA) was conducted using maximum-likelihood estimation using Analysis of Moment Structure (AMOS) version 22 software (Arbuckle, 2013). The measurement model consisted of 48 WIHIC items from six scales. Key findings include:

- The values obtained for the five fit indices were: $\chi^2/df = 1.64$, TLI = 0.91, CFI = 0.92, RMSEA = 0.05 and SRMR = 0.06, therefore confirming that the data provided a good fit for the measurement model.
- Composite reliability values for all constructs ranged from 0.83 to 0.96.
- The average variance extracted for all scales was above 0.5.
- The square root of average variance extracted from observed variables ranged from 0.71 to 0.73 and the values for the shared variances between factors ranged from 0.16 to 0.69 and were lower than the square root of the average variance of the individual factors for all constructs.

The WIHIC has been used in educational research for well over a decade. During this time, it has been widely used and frequently validated by educational researchers (Fraser, 2007, 2012, 2014, 2018). The WIHIC provides a foundational questionnaire for learning environment researchers to modify and tailor to suit their particular studies (Fraser, 2007). The results of the exploratory factor analysis strongly support the factorial validity of the modified six-scale version of the WIHIC for measuring aspects of the learning environment. The results from the CFA for the WIHIC supported satisfactory fit to the measurement model, reliability, convergent validity and discriminant validity. These findings suggest that the WIHIC is a valid, robust and economical survey for assessing the classroom learning environment for use in South Australia.

5.3.1.2 *Validity and Reliability of the TOMRA*

Principal axis factor analysis with oblique rotation and Kaiser normalisation was also used to test the factorial validity of the modified TOMRA questionnaire using the same sample described above. Internal consistency reliability was again estimated using Cronbach's alpha coefficient. A summary of the key findings for the validity and reliability of the TOMRA include:

- The modified version of the TOMRA (15 items in 3 scales) used in this study displayed satisfactory factorial validity. Only one item was omitted from subsequent consideration because it did not meet the criteria previously outlined in Section 5.2.1.1. The eigenvalues for different scales ranged from 1.33 to 6.47, with just over 54% of the total proportion of variance being accounted for.
- Internal consistency reliability using Cronbach's alpha coefficient for the three TOMRA scales ranged from 0.68 to 0.94.

These results provided support for the factorial validity of the TOMRA when used with my sample of middle-school students from metropolitan Adelaide. The WIHIC and TOMRA have been used and validated in the same study before (Hoang, 2008; Ogbuehi & Fraser, 2007), but not with middle-school students from South Australia. This gap in past research was filled by my study.

5.3.2 *Associations between the Classroom Learning Environment and Student Attitudes*

To answer my second research question concerning associations between the classroom learning environment and student attitudes, I first used simple correlation

and multiple regression analyses (Section 5.3.2.1) and then Structural Equation Modelling (SEM) (Section 5.3.2.2). Comparisons between the results of the different methods of analysis (multiple regression analysis and SEM) are provided in Section 5.3.2.3.

5.3.2.1 *Simple Correlation and Multiple Regression Analyses*

Associations between the six learning environment scales and the three attitude scales were investigated using simple correlation and multiple regression analyses. Key findings include:

- All six scales from the WIHIC showed significant, positive simple correlations with each of the three TOMRA scales.
- The set of six scales from the WIHIC showed a significant multiple correlation with each of the three TOMRA scales.
- Regression coefficients revealed the following significant and independent associations between a WIHIC scale and an attitude scale:
 - Enjoyment of Mathematics Lessons with the WIHIC scales of Task Orientation, Teacher Support and Involvement.
 - Attitude to Mathematical Inquiry with the WIHIC scale of Task Orientation and Involvement.
 - Adoption of Mathematical Attitudes with the WIHIC scale of Task Orientation.

5.3.2.2 *Structural Equation Modelling*

The research model (see Figures 1.1 and 3.1) was tested to determine the extent to which it was consistent with the data. The results supported the hypothesised conceptual model of relationships between students' perceptions of the learning environment and mathematics-related attitudes proposed in Figure 3.1. Three hypotheses tested were:

- Hypothesis 1 – Students' perceptions of the six WIHIC scales measuring classroom environment (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation, Equity) are related to the three TOMRA scales measuring student attitudes to mathematics (Enjoyment of Mathematics Lessons, Attitude to Mathematics Inquiry and Adoption of Mathematical Attitudes).
- Hypothesis 2 – Attitude to Mathematical Inquiry is related to Enjoyment of Mathematics Lessons and Adoption of Mathematical Attitudes.
- Hypothesis 3 – Enjoyment of Mathematics Lessons is associated with Adoption of Mathematical Attitudes.

SEM analysis identified 8 out of 21 possible relationships that were statistically significant and that are summarised below and represented in Figure 4.2:

- Teacher Support was related directly to Enjoyment of Mathematics Lessons and indirectly to Adoption of Mathematical Attitudes via other attitude scales.
- Involvement was directly related to Attitude to Mathematical Inquiry and indirectly to Enjoyment of Mathematics Lessons and Adoption of Mathematical Attitudes via other attitude scales.

- Task Orientation was related directly to Enjoyment of Mathematics Lessons and Attitude to Mathematical Inquiry and indirectly to Adoption of Mathematical Attitudes via other scales.
- Equity was directly related to Adoption of Mathematical Attitudes.
- Student Cohesiveness was related neither directly nor indirectly to any of the three TOMRA attitude scales.

When standardised the total effect, direct effect and indirect effect associated with each of the three attitude constructs were examined to assess the extent to which each exogenous variable had an impact on the endogenous variables, the findings can be summarised as follows:

- Task Orientation was the most dominant determinant in terms of total effects of all the endogenous variables in the model, with a small to medium total effect for Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes.
- In terms of direct effects, Teacher Support and Task Orientation were the largest statistically-significant determinants of Enjoyment of Mathematics Lessons; Involvement and Task Orientation were the largest statistically-significant determinants of Attitude to Mathematical Inquiry; and Equity was the largest statistically-significant determinant of Adoption of Mathematical Attitudes.
- Although the direct effects of Involvement and Task Orientation on Adoption of Mathematical Attitudes were small and nonsignificant, they had indirect effects on Adoption scores via their relationship with Attitude to Mathematical Inquiry.

5.3.2.3 *Comparison of Multiple Regression and SEM Results for Associations Between Learning Environment and Student Attitudes*

The relatively high similarity between the statistically-significant regression coefficients and the direct effects in the research model found using SEM can be summarised as follows:

- For both methods of analysis, Task Orientation was significantly related to two of the three TOMRA scales.
- SEM only identified one significant relationship (Equity with Adoption of Mathematical Attitudes) that was not identified using multiple regression analysis.
- Regression analysis only identified two statistically-significant relationships (Involvement with Enjoyment of Mathematics Lessons and Task Orientation with Adoption of Mathematical Attitudes) that were not identified by SEM.

Interestingly, all statistically significant regression and SEM coefficients for associations between an environment scale and an attitude scale were positive, thus replicating the results from many past studies in numerous countries reviewed by Fraser (2007, 2018). This suggests that generally more positive learning environments as assessed by WIHIC scales are associated with more-positive student outcomes, especially attitudes.

5.3.3 *Sex as a Determinant of Students' Perceptions of Mathematics Learning Environment and Attitudes Towards Mathematics*

The third research question involved whether sex was a determinant of students' perceptions of the mathematics learning environment and attitudes towards

mathematics. To answer this question, a one-way MANOVA for the set of nine scales from the WIHIC and TOMRA scales was conducted. When Wilks' lambda criterion revealed a statistically significant sex difference for the set of scales as a whole, the univariate ANOVA was interpreted separately for each of the nine scales to identify:

- Statistically-significant sex differences for the WIHIC scales of Student Cohesiveness, Cooperation and Teacher Support, with female students holding more favourable perceptions of the learning environment than males for these scales
- Statistically-significant sex differences for the TOMRA scales of Attitude to Mathematical Inquiry and Adoption of Mathematical Attitudes, but not for Enjoyment of Mathematics Lessons, with the attitudes of females towards mathematics being less positive than their male classmates.

5.4 Limitations of the Study

Careful preparation during the design phase of this study helped to reduce errors and bias in the data collected but, as in all research, my study invariably had some limitations. It is important to outline these limitations associated with instruments, hypotheses and methods before generalising any results.

The two closed questionnaires (WIHIC and TOMRA) used did not offer the participants the opportunity to answer questions as they might wish, to make suggestions, or to expand or add to the statements to which they were asked to respond. Instead students were asked to respond to statements using a five-point

frequency scale (Almost Never, Seldom, Sometimes, Often, Almost Always). A closed questionnaire, like the one used in this study, reduced the complexity and specific detail of responses. Students remained anonymous, which encouraged them to be honest in their responses. Because questionnaires that are well written can be administered in a timely, economical, non-threatening way and are easy to score, they can provide objective responses to students across a physically-large area without huge amounts of effort (Anderson & Arsenault, 1998). Students also could have different interpretations of the five-point frequency scale that could have introduced bias and errors into the data collected. Previous research has identified gender and ethnic background as key factors in the differing interpretations of respondents (Bolt & Johnson, 2009; Hui & Triandis, 1989; Watkins & Cheung, 1995).

A limitation of using questionnaires is in the selection and appropriateness of the constructs included. Where relationships have been identified, there could be other unidentified factors that caused the effect. The items selected might have missed other aspects pertinent to the research or failed to provide sufficient detail, thereby decreasing the adequacy of the research data. To reduce the impact of this limitation, time and consideration were given to the selection of the questionnaires, scales and items to include in the survey.

Despite the survey being anonymous, it is possible that students still might have deliberately given misleading answers because they felt somehow embarrassed about giving away certain information (Bradburn, Sudman, Blair & Stocking, 1978). Similarly, student might have answered in the way that they believe was expected of them, rather than in a way that reflected their true perception. It is also possible that

students answered the questions based on their misinterpretation of the wording rather than the way in which the researcher intended (Bourhis, Roth & MacQueen, 1989; Hadlow & Pitts, 1991). It is virtually impossible to know if students gave misleading answers, modified their answers or misinterpreted any questions in my survey.

In the hypothesised model used in this study, the influence of student perceptions of the learning environment on attitudes towards mathematics was in one direction. To gain further insight into associations between student perceptions of the learning environment and attitudes to mathematics, the model could have included the influence of students' attitudes on their perceptions of the learning environment.

The sample was taken from year 9 classes in three independent schools from different geographical and social-economic regions of Adelaide, but it was not highly representative of the range of students and schools in Adelaide. A more diverse and representative sample, including students from the Catholic and State Government Schools and students from outside metropolitan Adelaide, would have improved the generalisability of findings. Caution is needed in generalising any findings from the present study to wider groups of students.

Another limitation of this study is that only quantitative methods were used and therefore possible explanations for the relationships identified in the quantitative data could not be explored. Numerous authors claim that the use of both quantitative and qualitative methods together give a more complete understanding than either of the individual methods alone (Creswell, 2008; Tobin & Fraser, 1998). A positive aspect of collecting only quantitative data is that the disruption caused to school programmes

and students was kept to a minimum. Although high external validity can be achieved in studies using only quantitative data, Lowhorn (2007) suggests that the inclusion of qualitative data provides greater opportunity to understand the relationships between factors. Triangulation of findings using qualitative and quantitative methods could then enable a fuller and deeper understanding of the learning environment (Aldridge et al., 1999). Future studies should involve a mixed-method approach in order to provide a deeper understanding of the relationships between the factors.

There always are limitations related to the size and composition of a sample. The relatively small sample size of 221 students in my study limited the statistical power of analyses. While this sample size was acceptable for the purposes of this research, Creswell (2008) suggests that larger sample sizes add to the validity of the conclusions drawn from any study.

Robust debate surrounds the use of exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) (Hurley, Scandura, Schriesheim, Brannick, Seers, Vandenberg & Williams, 1997). As with all analyses, there are advantages and disadvantages to each approach. Cabrera-Nguyen (2010) suggests that EFA and CFA both should be undertaken using different samples. They recommend that EFA is conducted and that this is then followed by CFA in order to assess the *a priori* theory about the measure's factor structure and psychometric properties formed from the EFA (Cabrera-Nguyen, 2010). For studies involving large sample sizes, data could be split into one subsample for EFA and the other subsample for CFA. Brown (2006, p. 168) suggests that EFA can be used in a CFA framework "as an intermediate step between EFA and CFA". Cabrera-Nguyen (2010) and Worthington and Whittaker

(2006) also recommend beginning with EFA with one sample and following this with CFA using a different sample. A potential limitation of my study was that both EFA and CFA were completed using the same sample because of its somewhat limited size (221 students).

For the analysis of sex difference, the male subgroup was small and included only 57 students, therefore reducing the statistical power of analyses for sex differences. While one single sex-girls school was included, the addition of a single-sex boys school would have improved the gender balance of the sample and would be desirable in future research.

5.5 Significance and Implications of Study

While the WIHIC has been widely used and validated, the inclusion of both WIHIC and TOMRA scales in the same study is less common. Because this is the first time that the WIHIC has been validated using middle-school students in Adelaide, South Australia, my research has addressed a small gap in the body of knowledge. Middle-school mathematics teachers might find these economical instruments valuable for assessing their students' perceptions of learning environment and their attitudes towards the subject. The WIHIC and TOMRA could also be used to evaluate the effectiveness of initiatives designed to improve students' motivation to study mathematics in the school and their adoption of mathematics attitudes, thereby improving the chance that the students continue to study mathematics at tertiary level.

This research is methodologically significant because the WIHIC was validated using two different methods of statistical analysis, namely, exploratory and confirmatory factor analyses. Also two different methods of statistical analyses were undertaken to investigate associations between WIHIC and TOMRA scales: multiple regression analysis and using Structural Equation Modeling (SEM). This allowed the results of these two methods of analysis to be compared and reveal relatively high similarity between the findings from the two types of analysis.

The positive and statistically-significant relationships between environment scales and student attitudes replicate the findings of other studies in numerous countries (Fraser, 2007). However investigating possible relationships between students' learning environment perceptions and their attitudes has been more common in science rather than mathematics classrooms. The development of the TOMRA has facilitated the quantification of attitudes specifically to mathematics in a few past studies (Afari, Aldridge & Fraser, 2012; Afari, Aldridge, Fraser & Khine, 2013; Deieso & Fraser, 2019; Hoang, 2008; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005).

The results of this study suggest that female students perceived the mathematics learning environment more positively than their male peers, but that their attitudes towards mathematics were less positive than their male counterparts. These results are consistent with past research (Fraser & Raaflaub, 2013; Hoang, 2008; Kaiser-Messmer, 1993; Taylor & Fraser, 2012; 2013). This information could be used by mathematics teachers to change their teaching practices in an attempt to improve the mathematics learning environment. This study suggests that working to improve the

perceived levels of Student Cohesiveness, Teacher Support and Cooperation are likely to improve male students' perceptions of the learning environment and female students' Attitudes to Mathematical Inquiry and Adoption of Mathematical Attitudes. Suggestions about how teachers can use assessments of their students' actual and preferred environment to guide improvements in classrooms have been reviewed by Fraser and Aldridge (2017).

5.6 Suggestions for Further Research

Many suggestions for future research emerge from the above discussion of limitations in Section 5.4. The quantitative nature of this study limited the opportunity to provide explanations for observed relationships between perceptions of the learning environment and attitudes to mathematics. Further research involving qualitative methods could enhance the findings of my study and provide some insight into the reasons for these relationships. As suggested by Creswell (2008) and Tobin and Fraser (1998), research using both quantitative and qualitative methods can provide a more comprehensive understanding than either method alone.

The small sample size (221 year 9 students) in this study was a limitation that leads to suggestions for future research. A larger sample size would provide greater statistical power, as well as permitting exploratory factor analysis and confirmatory factor analysis to be conducted with separate subsamples. Recruiting a sample from a more-diverse range of schools would improve the generalisability of findings. Because more female than male students participated in this study, the inclusion of a single-sex male school would help the gender balance.

Also this study involved only year 9 students in their last year of middle school. Given that students' perceptions of the learning environment and their attitudes to mathematics are likely to change throughout their schooling, future research could include longitudinal data in order to track students' perceptions of mathematics over their time in the middle school or even over their time in secondary education. Such an investigation could identify critical points in time when students form attitudes that could influence their decisions to study mathematics in the future. This could provide further insights for schools and administrators on how to improve mathematics learning environments in order to encourage students to continue with their studies of mathematics.

Another suggestion for future research into outcome–environment associations in mathematics classrooms is to include a wider range of important student outcomes, such as achievement, academic efficacy, satisfaction, self-esteem and well-being. Also different learning environment scales could be included to assess dimensions that are not included in the WIHIC, such as Differentiation from the Individualised Classroom Environment Inventory, Personal Relevance from the Constructivist Learning Environment Scale, Responsibility for Own Learning from the Outcomes-Based Learning Environment Questionnaire, or Formative Assessment and Assessment Criteria from the Constructivist-Oriented Learning Environment Survey. Similarly, the TOSRA attitude scales used in my study could be supplemented by scales from the Fennema-Sherman Attitude Scale, Sandman's Attitude Inventory or the Revised Mathematics Anxiety Rating Scale.

This study investigated sex as a determinant of students' perceptions of the mathematics learning environment and attitudes towards mathematics. Future research could include other determinants such as socioeconomic status, grade-level, cultural background, ethnicity, level of anxiety, stream, confidence, motivation or perceived usefulness of mathematics.

5.7 Final Comments

This study has cross-validated modified versions of the WIHIC and TOMRA questionnaires with middle-school mathematics students in Adelaide. Also associations between students' perceptions of the mathematics learning environment and their attitudes towards mathematics were identified, with a high degree of similarity between the results of multiple regression analysis and Structural Equation Modeling. This study revealed that females perceived the learning environment in mathematics classrooms in a more positive way than males, while males had more positive attitudes towards mathematics than females.

The WIHIC and TOMRA questionnaires used in this study allow both teachers and researchers to economically and practically assess middle-school students' perceptions of their learning environment and attitudes towards mathematics. The environment–attitude associations found in this study have implications for mathematics teachers about developing more positive attitudes among their students by emphasising those classroom environment dimensions found to be linked empirically with positive student attitudes.

The results of my study, in conjunction with the suggestions outlined for future investigations, are likely increase understanding of associations between the learning environment and student attitudes towards mathematics, which could inspire teachers to create positive classroom environments that could motivate students to choose mathematics subjects and continue to learn mathematics after they are no longer required to do so.

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Every reasonable effort has been made to acknowledge the owners of copyright material. I would be pleased to hear from any copyright owner who has been omitted or incorrectly acknowledged.

APPENDIX A

What Is Happening In this Class? (WIHIC) Learning Environment Questionnaire

Test of Mathematics-Related Attitudes (TOMRA)

Items 1–48 in this questionnaire are from the What Is Happening In this Class? (WIHIC) questionnaire (Aldridge, Fraser & Huang, 1999) and Items 49–63 are based on items selected from the Test of Science Related Attitudes (TOSRA, Fraser, 1981a). These questionnaire scales and items were used in my study and included in this thesis with the permission of their authors.

What Is Happening In this Class? (WIHIC) Questionnaire and Test Of Mathematics-Related Attitudes (TOMRA)

Directions for Students

This questionnaire contains a number of statements about your mathematics classroom and mathematics. You will be asked what you yourself think about these statements.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted. Think about how well each statement describes what your mathematics class and mathematics are like for you.

For each statement, draw a circle around:

- 1 if you think the statement **ALMOST NEVER** occurs in your classroom
- 2 if you think the statement **SELDOM** occurs in your classroom
- 3 if you think the statement **SOMETIMES** occurs in your classroom
- 4 if you think the statement **OFTEN** occurs in your classroom
- 5 if you think the statement **ALMOST ALWAYS** occurs in your classroom

If you change your mind about an answer, cross it out and circle another one.

Although some statements in this questionnaire are fairly similar to other statements, you are asked to indicate your opinion about all statements.

Practice Item

Suppose you were given the statement shown below. You would need to choose between 'Never', 'Seldome', 'Sometimes', 'Often' or 'Almost Always'.

If you select 'Often', then you would need to circle the number 4 on your questionnaire, as indicated below.

		Almost Never	Seldom	Sometimes	Often	Almost Always
1.	I choose my partners for group discussion.	1	2	3	(4)	5

Please circle your gender: Male Female

Student Cohesiveness		Almost Never	Seldom	Sometimes	Often	Almost Always
1.	I make friends among students in this class.	1	2	3	4	5
2.	I know other students in the class.	1	2	3	4	5
3.	I am friendly to members of this class.	1	2	3	4	5
4.	Members of the class are my friends.	1	2	3	4	5
5.	I work well with other class members.	1	2	3	4	5
6.	I help other class members who are having trouble with their work	1	2	3	4	5
7.	Students in this class like me.	1	2	3	4	5
8.	In this class, I get help from other students.	1	2	3	4	5
Teacher Support		Almost Never	Seldom	Sometimes	Often	Almost Always
9.	The teacher takes a personal interest in me.	1	2	3	4	5
10.	The teacher goes out of his/her way to help me.	1	2	3	4	5
11.	The teacher considers my feelings.	1	2	3	4	5
12.	The teacher helps me when I have trouble with the work.	1	2	3	4	5
13.	The teacher talks with me.	1	2	3	4	5
14.	The teacher is interested in my problems.	1	2	3	4	5
15.	The teacher moves about the class to talk with me.	1	2	3	4	5
16.	The teacher's questions help me to understand.	1	2	3	4	5

Involvement		Almost Never	Seldom	Sometimes	Often	Almost Always
17.	I discuss ideas in class.	1	2	3	4	5
18.	I give my opinions during class discussions.	1	2	3	4	5
19.	The teacher asks me questions.	1	2	3	4	5
20.	My ideas and suggestions are used during classroom discussions.	1	2	3	4	5
21.	I ask the teacher questions.	1	2	3	4	5
22.	I explain my ideas to other students.	1	2	3	4	5
23.	Students discuss with me how to go about solving problems.	1	2	3	4	5
24.	I am asked to explain how I solve problems.	1	2	3	4	5
Task Orientation		Almost Never	Seldom	Sometimes	Often	Almost Always
25.	Getting a certain amount of work done is important to me.	1	2	3	4	5
26.	I do as much as I set out to do.	1	2	3	4	5
27.	I know the goals for this class.	1	2	3	4	5
28.	I am ready to start this class on time.	1	2	3	4	5
29.	I know what I am trying to accomplish in this class.	1	2	3	4	5
30.	I pay attention during this class.	1	2	3	4	5
31.	I try to understand the work in this class.	1	2	3	4	5
32.	I know how much work I have to do.	1	2	3	4	5

Cooperation		Almost Never	Seldom	Sometimes	Often	Almost Always
33.	I cooperate with other students when doing assignment work.	1	2	3	4	5
34.	I share my books and resources with other students when doing assignments.	1	2	3	4	5
35.	When I work in groups in this class, there is teamwork.	1	2	3	4	5
36.	I work with other students on projects in this class.	1	2	3	4	5
37.	I learn from other students in this class.	1	2	3	4	5
38.	I work with other students in this class.	1	2	3	4	5
39.	I cooperate with other students on class activities.	1	2	3	4	5
40.	Students work with me to achieve class goals.	1	2	3	4	5
Equity		Almost Never	Seldom	Sometimes	Often	Almost Always
41.	The teacher gives as much attention to my questions as to other students' questions.	1	2	3	4	5
42.	I get the same amount of help from the teacher as do other students.	1	2	3	4	5
43.	I have the same amount of say in this class as the other students.	1	2	3	4	5
44.	I am treated the same as other students in this class.	1	2	3	4	5
45.	I receive the same encouragement from the teacher as other students do.	1	2	3	4	5
46.	I get the same opportunity to contribute to class discussions as other students.	1	2	3	4	5
47.	My work receives as much praise as other students' work.	1	2	3	4	5
48.	I get the same opportunity to answer questions as other students.	1	2	3	4	5

Enjoyment of Mathematics Lessons		Almost Never	Seldom	Sometimes	Often	Almost Always
49.	Mathematics lessons are fun.	1	2	3	4	5
50.	School should have more mathematics lessons each week.	1	2	3	4	5
51.	Mathematics is one of the most interesting school subjects.	1	2	3	4	5
52.	I really enjoy going to mathematics lessons.	1	2	3	4	5
53.	I look forward to mathematics lessons.	1	2	3	4	5
Attitude to Mathematical Inquiry		Almost Never	Seldom	Sometimes	Often	Almost Always
54.	I would prefer to find out why something happens by doing a problem rather than being told.	1	2	3	4	5
55.	I would prefer to do problems than to read about them.	1	2	3	4	5
56.	I would prefer to solve my own problems than to find out information from a teacher.	1	2	3	4	5
57.	I would rather solve a problem by performing calculations than be told the answer.	1	2	3	4	5
58.	I would prefer to solve problems on a topic than to read about it in mathematics magazines.	1	2	3	4	5
Adoption of Mathematical Attitudes		Almost Never	Seldom	Sometimes	Often	Almost Always
59.	I enjoy reading about things which disagree with my previous ideas.	1	2	3	4	5
60.	I am curious about the world in which we live.	1	2	3	4	5
61.	I like to listen to people whose opinions are different to mine.	1	2	3	4	5
62.	When solving problems in mathematics, I like to use new methods which I have not tried before.	1	2	3	4	5
63.	In solving problems, I report unexpected results as well as expected ones.	1	2	3	4	5

APPENDIX B

Ethics Approval

Memorandum

To	Rhiannon Giles, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval SMEC-41-11
Date	9 June 2011
Copy	Barry Fraser, 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 "*Learning environments and student attitudes in middle-school mathematics*". On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **7th June 2011 to 6th June 2012**.

The approval number for your project is **SMEC-41-11**. *Please quote this number in any future correspondence.* If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.



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 by the Curtin University Human Research Ethics Committee (Approval Number SMEC-41-11). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or hrec@curtin.edu.au

APPENDIX C

Participant Information Sheet and Consent Form for Parents

Curtin University
Science and Mathematics Education Centre

Participant Information Sheet for Parents

My name is Rhiannon Giles and I am a science and mathematics teacher at Wilderness School, located in Medindie, Adelaide. I am currently conducting research for my Master of Philosophy (Mathematics Education) at Curtin University.

Purpose of Research

I am using questionnaires to investigate the perceptions of mathematics learning environments and attitudes among middle-school students.

Your Role

You would need to agree to allow your child to complete a questionnaire in class which will take approximately 30 minutes. This questionnaire will be administered by either your child's teacher or me.

Consent to Participate

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

Confidentiality

All information provided by your child will be kept confidential. The name of the school, teacher or student will not be included in any form in the published report. I will keep the responses from the survey in a locked cabinet for five years and then I will destroy them. Digital records will be stored at Curtin University of Technology in Perth, Australia.

Further Information

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval number SMEC-41-11). If you would like further information about the study, please feel free to contact me on my mobile on 0417 869 222 or by email: rgiles@wilderness.com.au.

Alternatively, you can contact my supervisor, Professor Barry Fraser, at B.Fraser@curtin.edu.au.

I would like to thank you for your involvement in this research and your participation is greatly appreciated.

CONSENT FORM FOR PARENTS

- I understand the purpose and the procedures of the study.
 - I have been provided with the participant information sheet.
 - I understand that my child's involvement in this study itself might not benefit him/her.
 - I understand that my child's involvement is voluntary and he/she can withdraw from it at any time without a problem.
 - I understand that no personal identifying information will be used and that all information will be securely stored for 5 years before being destroyed.
 - I agree to allow my child to participate in the study outlined to me.
-

Signature : _____

Date: _____

APPENDIX D

Participant Information Sheet and Consent Form for Students

**Curtin University
Science and Mathematics Education Centre**

Participant Information Sheet for Students

My name is Rhiannon Giles and I am a science and mathematics teacher at Wilderness School, located in Medindie, Adelaide. I am currently conducting research for my Master of Philosophy (Mathematics Education) at Curtin University.

Purpose of Research

I am using questionnaires to investigate the perceptions of mathematics learning environments, attitudes and achievement among middle-school students.

Your Role

You would need to complete a questionnaire which will take approximately 30 minutes, which will be administered by either your teacher or me.

Consent to Participate

Your involvement in the research is entirely voluntary and 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

All information provided by you will be kept confidential. The name of the school, teacher or student will not be included in any form in the published report. I will keep the responses from the survey in a locked cabinet for five years and then I will destroy them. Digital records will be stored at Curtin University of Technology in Perth, Australia.

Further Information

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval number SMEC-41-11). If you would like further information about the study, please feel free to contact me on my mobile on 0417 869 222 or by email: rgiles@wilderness.com.au.

Alternatively, you can contact my supervisor, Professor Barry Fraser, at B.Fraser@curtin.edu.au.

I would like to thank you for your involvement in this research and your participation is greatly appreciated.

CONSENT FORM FOR STUDENT PARTICIPANTS

- I understand the purpose and the procedures of the study.
 - I have been provided with the participant information sheet.
 - I understand that my involvement in this study itself might not benefit me.
 - I understand that my involvement is voluntary and I can withdraw from it at any time without a problem.
 - I understand that no personal identifying information will be used and that all information will be securely stored for 5 years before being destroyed.
 - I have been given the opportunity to ask questions.
 - I agree to participate in the study outlined to me.
-

Signature : _____

Date: _____

APPENDIX E

Standardized Item Loading, Composite Reliability and Average Variance Extracted for WIHIC

Latent Variable	Item	Standardized loading	Average Variance Extracted (AVE)	Composite Reliability (CR)
Student Cohesiveness	sc1	0.75	0.50	0.89
	sc2	0.65		
	sc3	0.77		
	sc4	0.73		
	sc5	0.71		
	sc6	0.74		
	sc7	0.67		
	sc8	0.65		
Teacher Support	ts9	0.73	0.53	0.90
	ts10	0.72		
	ts11	0.75		
	ts12	0.74		
	ts13	0.77		
	ts14	0.79		
	ts15	0.65		
	ts16	0.65		
Involvement	iv17	0.75	0.54	0.90
	iv18	0.78		
	iv19	0.70		
	iv20	0.79		
	iv21	0.69		
	iv22	0.77		
	iv23	0.68		
	iv24	0.70		
Task Orientation	to25	0.72	0.53	0.90
	to26	0.78		
	to27	0.74		
	to28	0.75		
	to29	0.68		
	to30	0.69		
	to31	0.76		
	to32	0.72		

Latent Variable	Item	Standardized loading	Average Variance Extracted (AVE)	Composite Reliability (CR)
Cooperation	co33	0.65	0.51	0.89
	co34	0.69		
	co35	0.73		
	co36	0.68		
	co37	0.65		
	co38	0.74		
	co39	0.75		
	co40	0.79		
Equity	eq41	0.73	0.51	0.90
	eq42	0.69		
	eq43	0.71		
	eq44	0.77		
	eq45	0.84		
	eq46	0.80		
	eq47	0.80		
	eq48	0.77		
Enjoyment	enj49	0.88	0.75	0.96
	enj50	0.75		
	enj51	0.84		
	enj52	0.96		
	enj53	0.89		
Inquiry	inq54	0.72	0.53	0.85
	inq55	0.73		
	inq56	0.69		
	inq57	0.83		
	inq58	0.65		
Adoption	adop59	0.73	0.50	0.83
	adop60	0.59		
	adop61	0.67		
	adop62	0.78		
	adop63	0.75		

AVE = $\sum \lambda^2 / n$; Composite reliability (CR) is computed by $(\sum \lambda^2 / \sum \lambda^2) + (\sum \delta)$ where λ = standardized loading.

APPENDIX F

Descriptive Statistics, Skewness and Kurtosis for Individual Items for WIHIC

Items	Mean	Standard Deviation	Skewness	Kurtosis
sc1	4.25	0.72	-0.93	1.66
sc2	4.70	0.52	-1.92	5.056
sc3	4.38	0.62	-0.92	2.830
sc4	4.24	0.71	-0.68	0.376
sc5	4.11	0.80	-0.96	1.543
sc6	3.97	0.94	-0.99	0.822
sc7	3.70	0.81	-0.34	0.766
sc8	4.00	0.92	-0.92	0.684
ts9	3.50	0.95	-0.31	-0.096
ts10	3.69	0.97	-0.45	-0.366
ts11	3.54	0.97	-0.53	0.128
ts12	4.37	0.72	-1.35	2.789
ts13	4.02	0.81	-1.17	2.268
ts14	3.47	1.08	-0.33	-0.385
ts15	3.71	0.99	-0.55	-0.254
ts16	3.93	0.90	-0.80	0.561
iv17	3.39	0.98	-0.34	-0.595
iv18	3.39	1.13	-0.25	-0.956
iv19	3.81	0.85	-0.91	1.076
iv20	3.14	0.97	-0.22	-0.425
iv21	4.10	0.96	-1.33	1.794
iv22	3.51	1.08	-0.62	-0.232
iv23	3.81	0.97	-0.82	0.376
iv24	3.71	0.99	-0.80	0.338
to25	4.20	0.87	-1.28	1.853
to26	3.96	0.95	-0.70	-0.059
to27	3.77	0.88	-0.50	0.012
to28	4.14	0.87	-0.96	0.638
to29	4.03	0.89	-0.97	1.038
to30	4.01	0.90	-0.93	1.007

Items	Mean	Standard Deviation	Skewness	Kurtosis
to31	4.48	0.68	-1.57	3.725
to32	4.35	0.72	-1.30	2.749
co33	4.08	0.85	-1.17	2.043
co34	3.99	0.97	-1.12	1.168
co35	4.06	0.81	-1.01	1.879
co36	3.61	1.08	-0.68	-0.114
co37	4.14	0.89	-1.25	1.881
co38	4.19	0.73	-0.67	0.333
co39	4.23	0.67	-0.67	1.381
co40	3.66	0.97	-0.37	-0.316
eq41	3.98	1.02	-0.97	0.488
eq42	3.90	1.05	-1.00	0.511
eq43	3.85	1.03	-0.88	0.320
eq44	3.97	1.00	-0.99	0.568
eq45	4.05	0.96	-1.13	1.279
eq46	4.04	0.90	-0.91	0.762
eq47	3.76	1.06	-0.67	-0.151
eq48	3.95	0.99	-1.12	1.248
enj49	2.94	1.23	-0.10	-1.095
enj50	1.83	1.02	1.38	1.631
enj51	2.48	1.27	0.49	-0.861
enj52	2.64	1.25	0.22	-1.009
enj53	2.43	1.24	0.45	-0.814
inq54	3.37	1.17	-0.34	-0.752
inq55	3.61	1.10	-0.46	-0.558
inq56	3.18	1.13	-0.10	-0.675
inq57	3.59	1.09	-0.62	-0.287
inq58	3.68	1.05	-0.53	-0.090
adop59	3.05	0.89	-0.09	0.013
adop60	4.11	0.94	-1.19	1.450
adop61	3.85	0.94	-0.98	1.268
adop62	3.18	1.11	-0.22	-0.638
adop63	3.40	0.97	-0.25	0.034