Science and Mathematics Education Centre

Laboratory Classroom Environment, Sex and Frequency of Practical Work as Determinants of Middle-School Science Students' Attitudes and Aspirations

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DECLARATION

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

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ABSTRACT

This study was undertaken to investigate sex and frequency of practical work as determinants of middle-school science students' perceptions of their learning environment, attitudes and aspirations. Associations between laboratory classroom environment and students' attitudes and aspirations were also investigated. The Science Laboratory Environment Inventory (SLEI), Students' Adaptive Learning Engagement in Science (SALES) questionnaire, and a new scale developed from the Career Interest in Science scale from the Test Of Science-Related Attitudes (TOSRA) formed the survey.

The structures of the questionnaires containing SLEI, SALES and Future Intentions scales were examined using principal axis factor analysis with varimax rotation and Kaiser normalisation. The internal consistency reliability of each scale (to provide a measure of the extent to which its items contribute to the same underlying construct) was measured using Cronbach's alpha coefficient. To investigate the statistical significance of differences based on the independent variables of sex and frequency of practical work, MANOVA was conducted with the set of dependent variables being the five SLEI scales, the Future Intentions scale and the four scales from the SALES questionnaire. Because the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, univariate two-way ANOVAs were interpreted for each individual scale. In addition, effect sizes were used to provide information about the magnitude of differences between sexes or different frequencies of practical work. Associations between students' perceptions of the laboratory environment and students' attitudes towards science were examined using simple correlation and multiple regression analyses. Simple correlation analysis provided information about the bivariate association between each attitude and learning environment scale. Multiple regression analysis was used to investigate the multivariate association between the set of learning environment scales and each attitude scale.

The sample consisted of 431 Year 9 and 10 science students from two typical Catholic and two typical Independent schools across metropolitan Adelaide. The schools were coeducational and students were of mixed abilities.

The survey exhibited sound factorial validity and reliability. MANOVA revealed that the interaction effect was statistically non-significant, suggesting that the frequency of practical work was not differentially effective for males and females. Statistically significant results for frequency of practical work were found for the environment scales of Open-Endedness, Integration and Material Environment and the attitude scales of Task Value and Self-Regulation. More frequent practical work was found to be associated with more favourable environment and attitude scores on these scales. In terms of sex differences, there were statistically significant differences for the attitude scales of Future Intentions and Self-Efficacy, with males expressing more positive attitudes, and for the environment scales of Integration and Rule Clarity, with females expressing more positive attitudes than males. The absence of any statistically-significant frequency–by–sex interaction suggests that the findings for different laboratory work frequencies apply equally well to male and female students.

A series of simple correlation and multiple regression analyses revealed strong and positive associations between each laboratory environment scale and each attitude scale. Overall, Integration was a strong, independent predictor of all five attitude scales, and Open-Endedness was a strong, independent predictor of four of the five attitude scales (with the exception of Goal Orientation).

The questionnaires validated and used in this study can be used by other researchers and teachers to assess middle-school science students' perceptions of the science laboratory learning environment and attitudes towards science in an economical and practical manner. The results reported in this thesis have implications for teachers of science who are interested in using practical work in improving their students' classroom environments, attitudes and science-related aspirations in their students.

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INTRODUCTION

1.1 INTRODUCTION

The declining numbers of students undertaking the study of physics, chemistry and biology in Years 11 and 12 in Australia is well documented (Ainley, Kos & Nicholas, 2008; Dekkers & de Laeter, 2001, 1997; Goodrum, Druhan & Abbs, 2012; Lyons & Quinn, 2010; Tytler, 2007). There is evidence among many students not choosing science subjects in Year 11 that they made this decision because they found middle-school science uninteresting (Goodrum et al., 2012; Lyons & Quinn, 2010). The views of science and non-science students reported by Goodrum et al. (2012) suggest that students could find science more engaging through more interactive, investigative and practical lessons. Because the classroom learning environment affects both the cognitive and affective outcomes of students, the provision of a suitable learning environment is important (Aldridge & Fraser, 2008; Fraser, 2007, 2012). The overarching aim of this study was to examine sex and frequency of practical work as determinants of science students' perceptions of their learning environment, as well as their attitudes and aspirations. Associations between the laboratory classroom environment and students' attitudes and aspirations were also investigated in this study. The terms 'practical work', 'laboratory work' and 'experiments' are often used interchangeably, yet "not all practical work is carried out in a laboratory, and not all laboratory work comprises experiments" (Hodson, 1988, p. 53). For the purpose of this study, 'practical work' is defined as a method for learning the processes and skills involved in the development of scientific literacy (Bradley, 2005). It can include: teacher demonstrations, during which students make observations about phenomena and good laboratory practice; traditional laboratory exercises, in which students follow sets of instructions to practise laboratory skills; practical design tasks, in which students are required to design and implement an experimental method to answer a research question; investigations in the field, in which students collect and analyse data from external environments; and open-ended exercises in which students determine their own line of inquiry from their individual interests, research question and method of data collection.

This chapter briefly provides the background to the study (Section 1.2), the nature of past and contemporary classroom environment research (Section 1.3), a rationale for the study (Section 1.4), a listing of the research questions (Section 1.5), some limitations of the study (Section 1.6) and the structure of the thesis (Section 1.7).

1.2 BACKGROUND TO THE STUDY

Being part of a modern, technologically-advancing society calls for a higher degree of scientific literacy among citizens than at any time in the past. National education policy includes the explicit goal of improving the scientific and technological literacy of all Australians (DEST, 2003). Reviews of contemporary science education around the world highlight the current crisis of low student achievement and enrolments in science courses and call for reforms focussed on engaging young people in science learning (Osborne & Dillon, 2008; Sjøberg & Schreiner, 2010;

Tytler, 2007). According to these reviews, the failure of school science is mainly attributed to the inability of science curricula and classroom practices to ignite the interest of students in science. Ainley et al. (2008) concluded that enhancement of the curriculum in science involves relating content and process more strongly to the experience of young people and connecting what is studied in schools to the emergent fields of science.

Goodrum et al. (2012) completed a survey of Year 11 and 12 students. Of the 363 non-science students surveyed, 61% did not choose science subjects because they either disliked science or found it boring. Of the 1157 science students surveyed, 68% chose senior school science subjects because they had an interest in science or found science relevant to their lives. When students were asked what they liked about their science classrooms, 47% liked the content of the lessons, 35% liked the general atmosphere of the classroom and 27% liked science practicals, excursions and investigations (Goodrum et al., 2012).

The provision of a suitable learning environment is important because it influences the outcomes of students (Aldridge & Fraser, 2008; Fraser, 2007, 2012). Contemporary research on learning environments builds upon the theoretical foundations of Lewin's (1936) seminal recognition that both the environment and its interaction with characteristics of the individual are potent determinants of human behaviour, Stern's (1970) notion of person-environment fit, and Walberg's model for educational productivity (1981) in which the educational environment is one of the determinants of student outcomes. Since the late 1960s, significant research has been carried out which involved the conceptualisation, development, validation and application of classroom environment instruments (Fraser 2007, 2012). The history of learning environments research is discussed in greater detail in Chapter 2, particularly Section 2.2.1.

One outcome of this research has been the finding of relationships between students' perceptions of science classroom learning environments and students' attitudes and achievement (Fraser, 2012; Fraser, Walberg, Welch, & Hattie, 1987; McRobbie & Fraser, 1993a). Research indicates that students' successful learning engagement in science is primarily determined by their level of motivation and self-regulation in science learning (Boekaerts & Cascallar, 2006; Hanrahan, 2002; Zimmerman, 2000). Much research has involved the use of classroom environment instruments to determine relationships between the classroom environment and student attitudes towards science (Fraser, 1981, 1994; Lee, Fraser & Fisher, 2003; McRobbie & Fraser, 1993a; Wong & Fraser, 1996).

Researchers investigating the effect of factors such as teacher personality, class size, grade level, subject matter, the nature of the school environment and type of school have used classroom environment dimensions as criterion variables (Fraser, 1994). Much past classroom environment research has examined sex differences and has indicated that, generally, females have more favourable perceptions of the learning environment than their male counterparts (Goh & Fraser, 1998; Quek, Wong & Fraser, 2005). Sex has been shown to be a strong predictor of science subject choice, with physics classes being dominated by boys, biology classes by girls and chemistry classes being fairly evenly balanced in terms of student sex (Ainley et al., 2008; Fullarton, Walker, Ainley & Hillman, 2003). One of the most promising explanations for the sex imbalance in physics enrolments concerns students' self-efficacy in science and the interaction of this with their conceptions of the relative difficulty of physics (Lyons & Quinn, 2010).

Relevant to my study is whether sex and frequency of practical work are determinants of middle-school students' perceptions of their learning environments and their attitudes towards science. Investigation of aspects of laboratory learning environments enables the researcher to elicit from students the ways in which they perceive their learning environments, as well as associations between students' perceptions and their attitudes towards science.

1.3 PAST CLASSROOM ENVIRONMENT RESEARCH

Research into classroom environments began over 40 years ago. Numerous instruments have been developed to measure specific or general aspects of the learning environment, including: the Learning Environment Inventory (LEI) (Walberg & Anderson, 1968) and the Classroom Environment Scale (CES) (Moos, 1974), which were independently developed at approximately the same time; the My Class Inventory (MCI), which is a modified form of the LEI for use among children between the ages of 8 and 12 years (Fisher & Fraser, 1981); the Individualised Classroom Environment Questionnaire (ICEQ), developed by Rentoul and Fraser (1979) for use in individualised, open and inquiry-based classrooms; the Questionnaire on Teacher Interaction (QTI) for assessing student perceptions of interpersonal relationships between students and teachers (Wubbels, 1993); the Science Laboratory Environment Inventory (SLEI), which was created in response to the need to assess the learning environment specific to science laboratory classes (Fraser, Giddings & McRobbie, 1995); the Constructivist Learning Environment Survey (CLES), developed by Taylor, Fraser and Fisher (1997) for assessing the constructivist emphasis in classrooms; the What Is Happening In this Class? (WIHIC) questionnaire (Fraser, Fisher & McRobbie, 1996), which is the most frequently-used classroom instrument around the world today (Fraser, 2012); and the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), which includes three new scales in addition to the seven assessed by the WIHIC questionnaire to assess learning environments that provide an outcomes focus and integrate information communication technology (Aldridge & Fraser, 2008).

Studies into classroom environments have been useful in deepening understanding of participants' perceptions of the environment and interpreting important influences on teaching and learning that affect perceptions of the environment (Hine, 2001). A review of the above learning environment instruments and the field of contemporary learning environment research is provided in greater depth in Chapter 2, particularly Section 2.2.

1.4 RATIONALE FOR THE STUDY

Much past research on learning environments has focussed on associations between students' learning outcomes, both cognitive and affective, and their perceptions of psychosocial characteristics of their classrooms. Studies have involved a variety of outcome measures, classroom environment instruments and samples, and have replicated associations between outcome measures and classroom environment perceptions (Fraser, 2002, 2007, 2012).

Laboratory work is integral to most science courses and offers a learning environment that is quite different from the traditional classroom setting. The Science Laboratory Environment Inventory (SLEI) was developed in response to the need for a learning environment instrument that addresses the specific nature of science laboratory classes (Fraser, McRobbie, & Giddings, 1993). Relatively few studies in the field of learning environments have been conducted in middle-school science laboratory classes worldwide, and the SLEI has not previously been validated with middle-school students in Adelaide, South Australia. Therefore, one of the aims of my study was to address this gap in the research by validating the SLEI with middle-school students in South Australia and using it to examine associations between middle-school science students' perceptions of their laboratory learning environment and their attitudes towards science.

Velayutham, Aldridge and Fraser (2011) developed the Students' Adaptive Learning Engagement in Science (SALES) questionnaire to assess four aspects of students' motivation and self-regulation in science learning: Learning Goal Orientation (students' adaptive motivational belief in science learning), Task Value (the value that students place on the science tasks given to them), Self-efficacy (students' self-belief that they can achieve the desired outcomes) and Self-regulation (the degree to which students engage in their learning and evaluate their progress). The SALES is a new instrument that, apart from its validation study with 1360 middle-school students, has not been used in other published research. Koren and Fraser (2013) used the SALES and the What Is Happening In this Class? (WIHIC) questionnaires in their study that investigated differences between gifted and non-gifted middle-school students' perceptions of classroom learning environment and attitudes. Their sample consisted of 495 middle-school students from within the large, urban school district of Miami-Dade County, Florida. The SALES was selected for use in my study because it has been validated for use with middle-school students for assessing students' learning goal orientation, self-efficacy, task value and self-regulation, which collectively contribute towards adaptive learning engagement in science. Also, I developed a Future Intentions scale for my study to assess student aspirations to study science at the senior secondary level. The Future Intentions scale was added to the SALES questionnaire to form a modified SALES questionnaire.

Although involvement in practical work is advocated in reviews of contemporary science education as one of the solutions to increasing student engagement in science and enrolment in science courses (Goodrum et al., 2012; Lyons & Quinn, 2010), little research evidence supports this widespread belief. Therefore, one of the aims of this study was to address this gap in the research by investigating frequency of practical work as a determinant of middle-school students' perceptions of their laboratory learning environments, their attitudes and their future intentions to study science at the senior secondary level.

Much past classroom environment research has examined sex differences and has indicated that, generally, females have more favourable perceptions of the learning environment than their male counterparts (Goh & Fraser, 1998; Quek et al., 2005).

The Programme for International Student Achievement 2006 study (OECD, 2007) revealed that, despite achieving similar scores for scientific literacy, Australian girls reported lower levels of self-efficacy and self-concept in science than boys. Also males reported more favourable attitudes than females for enjoyment of science, instrumental motivation, future orientation to study or work in science, science self-efficacy and science self-concept. Females reported more favourable attitudes to the importance of doing well in science and there was no difference between males and females in their general interest in science (Thomson & DeBortoli, 2008). My study aimed to build on this research by investigating sex differences in students' perceptions of their learning environments, their attitudes towards science and their future intentions to study science at the senior-secondary level.

1.5 RESEARCH QUESTIONS AND INTENTIONS

The intentions of my study were: to validate modified versions of the SLEI and SALES questionnaire with a sample of middle-school students from Adelaide, South Australia; to determine if sex and the frequency of practical work are determinants of middle-school students' perceptions of their learning environment, their motivation towards science and their intentions to study science at the senior secondary level; and to investigate associations between middle-school students' perceptions of their laboratory learning environment and their attitudes towards science. Specific research questions are listed below:

1. Are modified versions of the SLEI and the SALES questionnaire valid when used with middle-school students in Adelaide?
2. Are (i) the frequency of practical work and (ii) sex determinants of students':

    a. perceptions of the science laboratory environment;
    b. motivation towards science;
    c. aspirations to study science in Year 11 and 12?
3. Are there relationships between middle-school students' perceptions of their science laboratory environment and students':
    a. motivation towards science;
    b. aspirations to study science in Year 11 and 12?

1.6 SOME LIMITATIONS OF THIS STUDY

Limitations of this study are discussed in detail in Chapter 5, but the main limitations are briefly considered here. Because the selected sample for this study was limited to co-educational middle-school students from four schools in Adelaide, South Australia, findings should not be generalised to all students in Years 9 and 10. A concerted effort was made to include typical schools from both the Independent and Catholic Education sectors so that different school sectors were included in the sample, but schools from the State Department of Education were not involved in this study. South Australian Independent Schools educate students within a curriculum underpinned by a diverse range of religious beliefs including Anglican, Baptist, Christian, Christadelphian, Greek Orthodox, Islamic, Lutheran, Seventh-day Adventist and Uniting (AISSA, nd). It is important, therefore, to confine findings to the types of schools involved and not to extrapolate findings to others. The schools in my sample were from different geographical and socio-economic regions, but not all regions were represented. Extrapolation of the findings should not be made to different regions in Adelaide.

The number of students included in my study was not large relative to some classroom environment studies conducted in the past. The larger the size of a representative sample, the greater the validity of the inferences that can be drawn (Creswell, 2008).

The research methods for my study were limited in that a wholly-quantitative design was used. Qualitative data can provide additional insights to students' perceptions (Tobin & Fraser, 1998), but qualitative information was not collected as part of my study except for a pilot study involving 20 Year 9 students conducted to determine the suitability of the wording of the items, the wording of the five-point agreement scale and the length of time it took students to answer the survey. The study was quantitative in design because this design was highly suitable for investigating sex and frequency of practical work as determinants of students' attitudes and aspirations towards learning science. Better external validity can be achieved in quantitative research studies compared to qualitative research studies (Lowhorn, 2007). In addition, qualitative data were not collected because care was taken to ensure that disruption to the students' usual school programme was minimised. Quantitative data collection was the best way to minimise adverse impacts on students' class time. Nevertheless, combining quantitative and qualitative research methods in future research is recommended.

1.7 OVERVIEW OF THE THESIS

Chapter 1 describes the purposes of the study and provides background information which contextualises the study. Chapter 2 contains a review of the literature relating to learning environment research, with particular attention being paid to studies which have used the SLEI to measure students' perceptions of their laboratory learning environments, studies which have investigated associations between learning environment variables and cognitive and attitudinal student outcomes in science, and studies of sex differences in learning environment perceptions. A brief overview of the history of the use of practical work in secondary school science classrooms and a summary of some studies of practical work are also included in Chapter 2.

In Chapter 3, the methodology utilised in this study is outlined, with particular emphasis on describing the questionnaires used in my study (the SLEI and SALES). Details of the data-collection process and data analyses conducted are also provided in Chapter 3. Because this study used two instruments that have not been widely used with middle-school students, Chapter 3 describes the extensive statistical analysis that was undertaken to ensure that the instruments conformed to standards of reliability and validity.

Chapter 4 reports the findings from the analyses conducted with the data to address the research questions outlined in Section 1.5. The validity and reliability of the modified SLEI and SALES are reported in Section 4.2; student sex and the frequency of practical work as determinants of students' perceptions of the laboratory environment, their motivation in science lessons and their intention to study science at the senior secondary school level are reported in Section 4.3; and associations between students' perceptions of the laboratory learning environment, four aspects of their motivation towards science, and their aspirations are reported in Section 4.4.

Chapter 5 discusses the findings of the study, outlines its significance, addresses limitations, provides recommendations for further research and makes concluding remarks.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

My study had three main purposes. The first was to modify and validate the SLEI and SALES questionnaires. The second purpose was to determine if the frequency of practical work and student sex are determinants of students' perceptions of their science laboratory environment (SLEI), their motivation towards science (SALES) and their intention to study science at the senior secondary level (based on the Career Interest in Science scale from the TOSRA). The third purpose was to investigate associations between students' perceptions of their laboratory learning environment and their attitudes towards science.

This chapter reviews literature related to the above aims of my study under four main sections: Learning Environments Research (Section 2.2); Attitudes (Section 2.3); Sex Differences (Section 2.4); and Frequency of Practical Work (Section 2.5).

2.2 LEARNING ENVIRONMENTS RESEARCH

This section is organised using the following headings:

- 2.2.1 Introduction and Historical Background
- 2.2.2 Overview of Classroom Environment Instruments
- 2.2.3 Science Laboratory Environment Inventory

- 2.2.4 Past Learning Environment Research.

2.2.1 Introduction and Historical Background

Because the classroom learning environment affects both the cognitive and affective outcomes of students, the provision of a suitable learning environment is important (Aldridge & Fraser, 2008; Fraser, 2007). Contemporary research on learning environments builds upon theoretical foundations laid down by Lewin's (1936) seminal recognition that both the environment and its interaction with characteristics of the individual are potent determinants of human behaviour. Lewin's work stressed the need for new research strategies to consider human behaviour as a function of both the environment and the person. Drawing on Murray's (1938) work, Stern's (1970) notion of person-environment fit involved a theory of congruence of the person and the environment, in which he recognised that student outcomes are enhanced by complementary combinations of personal needs and environmental factors. Research specifically on classroom learning environments took off about 40 years ago when the independent work of Walberg and Anderson (1968) and Moos (1974) spawned diverse research programmes around the world (Aldridge & Fraser, 2008; Fisher & Khine, 2006; Fraser, 1998b, 2007, 2012).

Walberg's work in the field of learning environments spans several decades. In the late 1960s, Walberg worked with Anderson in the initial development of the Learning Environment Inventory (LEI), in conjunction with evaluation and research related to Harvard Project Physics (Walberg & Anderson, 1968). Walberg's work in 1981 included the psychosocial learning environment as one factor in a multifactor psychological model of educational productivity. Other factors include student age, ability, motivation and the quality and quantity of instructions. These factors are multiplicative in that any factor that is a zero results in zero learning. When the educational productivity model was tested by Fraser et al. (1987), both student achievement and attitudes were strongly linked to classroom and school environment, even when a comprehensive set of other factors was held constant.

The Classroom Environment Scale (CES) was independently developed at approximately the same time by Moos. The CES grew out of a programme of research involving measures of a variety of human environments, including psychiatric hospitals, prisons, university residences and work settings (Moos, 1974; Moos & Trickett, 1974). Moos (1979) developed three basic categories for describing human environments. Relationship dimensions identify the nature and intensity of personal relationships within the environment. Personal Development dimensions assess personal growth and self-enhancement. System Maintenance and Change dimensions assess the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change. The three basic categories of human environments developed by Moos (1979) led to the development of many new instruments for the assessment of different dimensions of the classroom learning environment (Fraser, 2012).

Over the past several decades, much research has been conducted in the field. The earlier decades focussed on the assessment of students' perceptions of their classroom learning environment in Western countries, but the last couple of decades have seen research in Asian countries (Fraser, 2002). Many classroom environment instruments were developed during this time.

2.2.2 Overview of Classroom Environment Instruments

The LEI and CES (discussed in Section 2.2.1) were among the earliest learning environment questionnaires developed. This section provides an overview of classroom environment instruments using the following organisation:

- 2.2.2.1 My Class Inventory (MCI)
- 2.2.2.2 Individualised Classroom Environment Questionnaire (ICEQ)
- 2.2.2.3 Questionnaire on Teacher Interaction (QTI)
- 2.2.2.4 Science Laboratory Environment Inventory (SLEI)
- 2.2.2.5 Constructivist Learning Environment Survey (CLES)
- 2.2.2.6 What is Happening In This Class? (WIHIC)
- 2.2.2.7 Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI).

2.2.2.1 My Class Inventory (MCI)

The My Class Inventory (MCI) was developed from the LEI for use among children between the ages of 8 and 12 years (Fisher & Fraser, 1981). The MCI was developed to minimise fatigue among younger children, so it only contains five of the LEI's original 15 scales (Cohesiveness, Friction, Satisfaction, Difficulty and Competitiveness). Originally the MCI had a Yes–No response, but this was later modified by Goh, Young and Fraser (1995) in their study of 1512 primary mathematics students in Singapore to a three–point response format: Seldom, Sometimes and Most of the Time. Some of the items on the MCI have been written so that reverse scoring is required. In addition, the MCI has two forms – one which measures perceptions of the actual environment and the other which measures the preferred environment (Fraser, 1989). The LEI, CES and MCI were all designed for conventional teacher-centred classrooms (Fraser, 2002).

The MCI is still used today because of its low reading level. In Brunei Darussalam, Majeed, Fraser and Aldridge (2002) validated and used a refined, three-scale English-language version of the MCI among 1565 lower-secondary mathematics students in 81 classes in 15 government schools. They removed the Satisfaction scale and measured Cohesiveness, Difficulty and Competition. These researchers reported sex differences in learning environment perceptions and associations between students' satisfaction and the nature of the classroom environment.

Scott Houston, Fraser and Ledbetter (2008) used the MCI in an evaluation of science kits among a sample of 588 Grade 3–5 students in Texas. Their research confirmed the validity of the MCI and suggested that using science kits was associated with greater classroom Satisfaction and Cohesiveness.

The MCI was used by Mink and Fraser (2005) in a small-scale evaluation of a K–5 mathematics programme that integrates children's literature with mathematics and science (Science and Mathematics Integrated with Literature Experiences, SMILE). The researchers found that the implementation of SMILE had a positive impact for their sample of 120 Grade 3–5 students in Florida, in that there was congruence between students' actual and preferred classroom environment.

Also in 2005, Sink and Spencer used the MCI with a large sample of 2835 Grade 4–6 students in an urban school district in Washington State. They found that an 18-item revision of the MCI (assessing cohesiveness, competitiveness, friction and satisfaction) was psychometrically sound.

2.2.2.2 Individualised Classroom Environment Questionnaire (ICEQ)

Rentoul and Fraser (1979) developed the Individualised Classroom Environment Questionnaire (ICEQ) as the first learning environment instrument to focus on dimensions which distinguish individualised classrooms from conventional ones (Fraser, 1990). The initial design of the ICEQ was guided by the literature on individualised open and inquiry-based education. Teachers and secondary school students were interviewed and reactions to draft versions of the ICEQ were sought from selected experts, teachers and junior high school students. The final published version of the ICEQ (Fraser 1990) contains five scales, each with ten items. The scales are Personalisation, Differentiation, Participation, Independence and Investigation. Each item is responded to on a five-point frequency scale (Almost Never, Seldom, Sometimes, Often and Very Often).

2.2.2.3 Questionnaire on Teacher Interaction (QTI)

In the Netherlands, the Questionnaire on Teacher Interaction (QTI) was developed to assess student perceptions on eight behaviour aspects. Teacher behaviour has a ‘proximity dimension’ ranging from cooperation to opposition and an ‘influence dimension’ ranging from dominance to submission. Its eight dimensions (Leadership, Helpfulness, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviours) are represented in a coordinate system divided into eight equal sectors. Each item is scored on a five-point scale. The higher a teacher scores on a particular scale, the more a teacher shows behaviours from that sector (Wubbels, 1993; Wubbels & Brekelmans, 2012; Wubbels & Levy, 1993). The original Dutch version consists of 77 items. A 64-item American version was constructed in 1988. To make the QTI more accessible to teachers, a short 48-item version was developed with a hand-scoring procedure (Wubbels & Brekelmans, 2012).

Den Brok, Brekelmans and Wubbels (2006) used a multi-level design to compare the structure of the traditional QTI and a form developed to measure teachers’ relations with individual students. They concluded that, on average, teachers were perceived to have more Influence and more Proximity in their relationships with individual students than in their relationship with the class as a whole.

Several studies of the associations between teacher–students relationships and student outcomes have been conducted in science classrooms using the QTI. The results of these studies indicate medium to strong associations between student outcomes and student perceptions of teacher–students relationships (Wubbels, Brekelmans, den Brok & van Tartwijk, 2006). Brekelmans, Wubbels and Créton (1990) investigated Grade 9 physics students' perceptions of the interpersonal behaviour of their teachers. Data were collected in 65 classrooms, with 21 classrooms using a new curriculum and 44 classrooms using the traditional curriculum. The researchers found that the relationship between teacher interpersonal behaviour and the affective outcome was stronger than the relationship between teacher interpersonal behaviour and the cognitive outcome.

Although research with the QTI began with senior high school students in The Netherlands, it has been cross-validated with various grade levels in numerous countries, including in the USA (Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995) and Singapore (Goh & Fraser, 1996). In Brunei Darussalam, Scott and Fisher (2004) validated a version of the QTI in Standard Malay with 3104 students in 136 elementary-school classrooms. They showed that achievement was related positively to cooperative behaviours and negatively to submissive behaviours. Quek et al. (2005) validated an English version of the QTI with 497 gifted and non-gifted secondary-school chemistry students in Singapore. They reported some stream and sex differences in QTI scores also.

The QTI has been translated, validated and used in studies in Korea and Indonesia. In Korea, a translated version of the QTI was validated by Lee et al. (2003) among 439 science students and also by Kim, Fisher and Fraser (2000) among 543 students. In Indonesia, Fraser, Aldridge and Soerjaningsih (2010) validated a translated version of the QTI with a sample of 422 university students.

2.2.2.4 Science Laboratory Environment Inventory (SLEI)

In response to the need to assess the learning environment specific to science laboratory classes, particularly in upper-secondary and higher-education contexts, the Science Laboratory Environment Inventory (SLEI) was created (Fraser, Giddings & McRobbie, 1995). It measures the five dimensions of Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment in both actual and preferred forms. The actual form of the SLEI directs the student to answer the questions in response to the current learning environment, whereas the preferred form directs the student to give their responses regarding their preferred learning environment (Fraser, Giddings & McRobbie, 1992). Because the SLEI was used in my study, a more extensive review of the literature about the SLEI is provided in Section 2.2.3.

2.2.2.5 Constructivist Learning Environment Survey (CLES)

Developments in education towards constructivist teaching practices and student learning led to the need for learning environment instruments to reflect these trends. The Constructivist Learning Environment Survey (CLES) was developed to assist researchers and teachers to assess the degree to which constructivist ideologies within the learning environment are present (Taylor, Fraser & Fisher, 1997). The CLES is comprised of five scales: Personal Relevance, Uncertainty of Science, Critical Voice, Shared Control and Student Negotiation.

A comparative form of the CLES was developed for students to reflect, not only on what happens in the class of focus, but also on what happens in other classes (Nix, Fraser & Ledbetter, 2005). A sample of 1079 students in 59 science classes in North Texas was involved in an evaluation of an innovative science teacher professional development programme. Strong factorial validity and reliability were reported. The study revealed that the students of the teachers involved in this programme perceived their classrooms more favourably than the students of teachers not involved in the programme.

The CLES was used by Aldridge, Fraser, Taylor and Chen (2000) in a cross-national study of junior high school science classroom learning environments in Australia and Taiwan. The English version of the CLES was administered to 1081 students in 50 classes in Australia and a Mandarin translation was administered to 1879 students in 50 classes in Taiwan. These researchers reported sound validity (factor structure, reliability and ability to differentiate between classrooms) for both the English and Mandarin versions of the CLES. They also reported that Australian classes were perceived as being more constructivist than Taiwanese classes.

Peiro and Fraser (2009) modified the CLES, translated it into Spanish and administered the English and Spanish versions to 739 Grade K–3 science students in Miami, USA. Strong positive associations were found between students' attitudes and the nature of the classroom environment. The CLES has also been translated into Korean (Kim, Fisher & Fraser, 1999) and administered to a sample of 1083 students in 25 Grade 10 classes. These two studies supported the reliability and factor structure of the Spanish and Korean versions of the CLES, and revealed statistically significant relationships between classroom environment and students' attitudes to science.

In South Africa, the English version of the CLES was administered by Aldridge, Fraser and Sebela (2004) to a sample of 1864 mathematics students in 43 classes in Grades 4–6. The researchers cross-validated this version of the CLES in terms of: factorial validity, internal consistency reliability and the ability to differentiate between classrooms. The primary focus of this study was to assist South African teachers to become more reflective in their daily classroom teaching practices. Some improvements in the constructivist orientation of classrooms were achieved during a 12-week intervention.

2.2.2.6 What Is Happening In this Class? (WIHIC)

The What Is Happening In this Class? (WIHIC) questionnaire was developed by combining modified versions of relevant scales from a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns, such as equity and constructivism (Fraser, 2007). Its original 90 item, 9-scale form was modified once data from 355 junior high school science students was statistically analysed, and interviews regarding students' views about their classroom environments conducted, into a 56 item, 7-scale form (Fraser et al., 1996).

The WIHIC questionnaire is the most frequently-used classroom instrument around the world today (Fraser, 2012). The WIHIC has been used in several cross-national studies and has been translated into numerous other languages and cross-validated.

The seven dimensions of the classroom environment assessed by the WIHIC are Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity (Aldridge, Fraser & Huang, 1999). A personal form of the WIHIC was developed in conjunction with the class form. The personal form uses the same scales as the class form, but instead of seeking student perceptions of the class as a whole, it is worded to extract the student's perceptions of his or her individual role within the classroom (Fraser, 1998a, 1998b; Fraser et al., 1996).

Dorman (2003) reported a large cross-national study with a sample of 3980 high school students from Australia, the UK and Canada. Factor analysis supported the seven-scale a priori structure of the WIHIC, and the invariant factor structures for the three grouping variables of country, grade level and student sex were also substantiated by the use of multi-sample analyses within structural equation modelling. In a second study, Dorman (2008) confirmed the factor structure and validated both the actual and preferred forms of the WIHIC with a sample of 978 secondary school students from Australia. This research provided "strong evidence of the sound psychometric properties of the WIHIC" (p. 179).

The WIHIC has been widely used in the USA, including three studies in California with samples of 665 middle-school science students in 11 schools (den Brok, Fisher, Rickards & Bull, 2006), 525 female university science students in 27 classes (Martin-Dunlop & Fraser, 2008) and 661 middle-school mathematics students (Ogbuehi & Fraser, 2007). Other studies in the USA include: one study in New York involving a sample of 1434 middle-school science students in 71 classes (Wolf &

Fraser, 2008) and four studies in Florida, with samples of 120 parents and 520 Grade 4 and 5 students (Allen & Fraser, 2007), 924 students in 38 Grade 8 and 10 science classes (Helding & Fraser, 2013), 573 Grade 3–5 students (Pickett & Fraser, 2009), and 78 parents and 142 kindergarten science students (Robinson & Fraser, in press).

The English version of the WIHIC was used by Zandvliet and Fraser (2004, 2005) in a study involving 1404 students in Australia and Canada and by Aldridge, Fraser and Ntuli in their study of 1077 Grade 4–7 students in South Africa.

The WIHIC has been translated into and validated in: Mandarin, in a cross-national study involving 1081 Australian junior high school science students in 50 classes and 1879 Taiwanese junior high school science students in 50 classes (Aldridge et al., 1999); Bahasa, in a cross-national study of 567 Australian students and 594 Indonesian students in 18 secondary science classes (Fraser, Aldridge & Adolphe, 2010); Spanish, in a study involving 520 Grade 4 and 5 students and 120 parents (Allen & Fraser, 2007); Korean, when it was used with a sample of 543 Grade 8 science students in 12 schools (Kim et al., 2000); and Arabic, with a sample of 352 college students in 33 classes (Afari, Aldridge, Fraser & Khine, 2013) and a sample of 763 college students in 82 classes (MacLeod & Fraser, 2010).

2.2.2.7 Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)

The WIHIC questionnaire was used as a starting point in the development of an instrument that could be used to monitor the development and effectiveness of learning environments that provide an outcomes focus and integrate information communication technology (ICT). The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) includes three new scales in addition to the seven assessed by the WIHIC questionnaire: Differentiation, Computer Usage and Young Adult Ethos. The TROLFLEI, like the WIHIC, has two versions – actual and preferred (Aldridge & Fraser, 2008).

Aldridge, Dorman and Fraser (2004) used multitrait–multimethod modelling with a sample of 1249 students (772 of the students were from Western Australia and 477 of the students were from Tasmania) to support the construct validity and sound psychometric properties of the TROFLEI. Welch, Cakir, Peterson and Ray (2012) used the TROFLEI in establishing cross-cultural reliability and validity for a sample of 980 students in Grades 9–12 in Turkey and 130 students in Grades 9–12 in the USA. The factor structure of the TROFLEI was confirmed across both samples, for both the actual and preferred responses. Koul, Fisher and Shaw's (2011) study in New Zealand involved a sample of 1027 high-school students from 30 classes in pursuing three main aims: to validate the TROFLEI for use in New Zealand; to investigate differences between students' perceptions of their actual and preferred learning environments, their year levels and their sex; and to investigate associations between science classroom learning environment, attitudes and self-efficacy.

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2.2.3 Science Laboratory Environment Inventory

Laboratory work is integral to most science courses and offers a learning environment that is very different from the traditional classroom setting. The SLEI was developed in response to the need to have a learning environment instrument that addresses the specific nature of science laboratory classes (Fraser et al., 1993). The initial development of the SLEI began with a review of the literature in order to identify relevant dimensions that were important in the laboratory setting. The scales that were developed within the SLEI cover the three dimensions identified by Moos (1974) of Relationship, Personal Development and System Maintenance and System Change (Henderson, Fisher & Fraser, 2000). Science teachers and senior high school students were interviewed to provide feedback on draft versions of sets of items in an attempt to ensure that the SLEI's dimensions and individual items were considered important by them. The SLEI was designed to be economical with a relatively small number of scales and items (Fraser et al., 1992).

The SLEI was simultaneously field tested and validated cross-nationally in six countries (Australia, United States, Canada, England, Israel, and Nigeria) with a sample of 5447 students in 269 classes (Fraser et al., 1992). It was cross-validated with a sample of 3,727 senior high school and university students (Fraser et al., 1995). From these studies, it was confirmed that researchers and teachers can use the SLEI with confidence.

Fraser and Tobin (1991) identified that there is potentially a major problem with nearly all existing classroom environment instruments at the time in that they were worded to obtain an individual's perception of the class as a whole as distinct from the student's perception of his or her own role within the classroom. This presents problems for research into differences between subgroups within a class. A personal version of the SLEI was developed to overcome this problem. The personal version parallels the class version (Fraser et al., 1992). "The work of the class is difficult" and “I find the work of the class difficult” are examples of the contrasting wording between the class and individual forms of the instrument.

The SLEI was used in the first investigation of associations between student outcomes and classroom environment, specifically in science laboratory settings (McRobbie & Fraser, 1993a). Students’ perceptions of classroom psychosocial environment accounted for appreciable amounts of variance in student outcomes beyond that attributable to student characteristics such as general ability. Integration of laboratory classes with science theory classes showed the strongest positive association between any SLEI scale and students’ outcomes.

McRobbie and Fraser (1993b) also used the SLEI with a sample of 4593 students in 240 classes across four countries to determine a typology of science laboratory learning environments. This study showed that students’ attitudinal outcomes varied according to the typology of the class, and that over 90% of the classes examined could be assigned to one of eight different typologies. The types included: laboratory classrooms which were above average on each of the environment scales and could be said to have a moderately positive or supportive environment; laboratory classrooms in which the environment was moderately negative; laboratory environments with a high degree of Integration and a low level of Rule Clarity and Material Environment support; and environments which were labelled as supportive open-ended.

Many studies have investigated links between dimensions of the SLEI and student attitude and achievement outcomes. Wong and Fraser (1995) modified the SLEI to form the Chemistry Laboratory Environment Inventory (CLEI) and used it to investigate students' perceptions of the chemistry laboratory environment with a sample of 1592 high school chemistry students in 56 classes in Singapore. The CLEI consisted of the same 35 items as the SLEI, but was applied specifically to the chemistry laboratory environment, rather than the general science laboratory environment. They found that all scales of the SLEI, apart from Open-Endedness, were positively related to students' attitudinal outcomes. Females were found to have more favourable perceptions of their learning environment than males, with the exception of Open-Endedness, which was perceived more favourably by males. This study also provided cross-cultural validation of the SLEI. Later, in Singapore, Quek et al. (2005) used the CLEI among 497 gifted and non-gifted chemistry students, providing further cross-validation.

Fisher, Henderson and Fraser (1997) used the SLEI among 489 biology students in 28 senior high school classes in Tasmania, Australia. Fraser et al. (1995) studied links between students' perceptions of the laboratory learning environment and students' attitudes to laboratory work. It was found that all five dimensions of the SLEI were related positively with students' attitudes. Although Open-Endedness was related positively to attitudes overall, it was related negatively to attitudes for some student samples.

Aladejana and Aberibigbe (2007) completed a study of the effect of the laboratory environment on students' learning outcomes in Nigerian schools. The sample of 328 senior secondary school chemistry students was carefully selected to ensure that students included in the sample had adequate exposure to laboratory classes. In particular, Integration, Material Environment and Student Cohesiveness were strongly correlated with student achievement.

Henderson et al. (2000) used the QTI and SLEI together in a study of 489 students from 28 senior biology classes in Australia. They concluded that it would be worthwhile to use both instruments together in the same study in future research because each instrument made an appreciable, independent contribution to the variance in students' achievement outcomes and in attitudes to laboratory work.

Lightburn and Fraser (2007) used the SLEI in an evaluation of the effectiveness of using anthropometry activities. Their results, using a sample of 761 high-school biology students in 25 classes in south-eastern USA, confirmed the validity of the SLEI in terms of factor structure, internal consistency reliability and ability to differentiate between classrooms. They also reported a positive impact of the use of anthropometric activities on both classroom learning environment and student attitudes.

The SLEI has been cross-validated in both its original English form and translated versions. A research programme using a Korean-language version of the SLEI was initiated by Kim and built upon by Lee (Kim & Kim, 1995; Kim & Lee, 1997; Fraser & Lee, 2009). Fraser and Lee (2009) translated the SLEI into the Korean language for their study of differences between the classroom environments of three streams (science-independent, science-orientated and humanities). The sample of 439 high school students was divided among these three streams. The Korean version of the SLEI exhibited sound factorial validity and internal consistency reliability, and was able to differentiate between the perceptions of students in different classes. Generally, students in the science-independent stream perceived their laboratory environments more favourably than the students in either of the other two streams.

The SLEI has been found to be valid and reliable in numerous studies around the world. Therefore I chose to use it for my study about the laboratory environment.

2.2.4 Past Learning Environment Research

Fraser (2002, 2007, 2012) reviewed many studies to illustrate the variety of applications of classroom environment instruments. Six types of past research were summarised: associations between student outcomes and environment; evaluation of educational innovations; differences between students' and teachers' perceptions of the same classrooms; determinants of classroom environment; use of qualitative research methods; and cross-national studies were summarised. My study focussed on associations between student attitudes and environment, and determinants of classroom environment (namely, student sex and frequency of practical work).

This section outlines the types of past research and is organised in the following manner:

- 2.2.4.1 Associations between Students' Learning Outcomes and their Perceptions of their Learning Environments
- 2.2.4.2 Evaluation of Educational Innovations
- 2.2.4.3 Other Studies.

2.2.4.1 Associations between Students' Learning Outcomes and their Perceptions of their Learning Environments

Much of the research that has been conducted has focussed on the investigation of the association between students' learning outcomes, both cognitive and affective, and their perceptions of psychosocial characteristics of their classrooms. Studies have involved a variety of outcome measures, classroom environment instruments and samples, and have consistently replicated associations between outcome measures and classroom environment perceptions (Fraser, 2002, 2007, 2012). For example, associations with students' cognitive and affective outcomes have been established using the SLEI for samples of: approximately 80 senior high school chemistry classes in Australia (Fraser & McRobbie, 1995; McRobbie & Fraser, 1993a); 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997); and 1592 Grade 10 chemistry students in Singapore (Wong & Fraser, 1996).

Some studies have utilised more than one classroom environment questionnaire to assess the unique and joint contributions made by each questionnaire to the variance in student outcomes (Fraser, 2002, 2007, 2012). For example, the QTI was used by Fisher et al. (1997) in conjunction with the SLEI in their study of associations between student outcomes and perceived patterns of teacher–student interactions for a sample of 489 senior high school biology students in Australia. They found that associations with students' perceptions of the learning environment were stronger for the attitudinal outcomes than for the cognitive or practical skill outcomes. They also found some commonality between the QTI and SLEI in their contributions to the variance in attitudinal outcomes, but not in their contributions to the variance in the cognitive or practical skill outcomes. Khine (2001) used scales from both the WIHIC and QTI with a sample of 1188 Form 5 students in 54 science classrooms in a study of outcome–environment associations.

The range of studies of associations between environments and outcomes has included both English-language questionnaires and versions of questionnaires translated into Spanish, Arabic and Greek. Translations into Asian languages have included Standard Malay, Korean, Chinese and Indonesian. For example for studies of outcome–environment associations, the WIHIC was translated into: Mandarin for a sample of 1879 Taiwanese junior high science students in 50 classes (Aldridge et al., 1999); Bahasa, in a cross-national study of 567 Australian students and 594 Indonesian students in 18 secondary science classes (Fraser, Aldridge & Adolphe, 2010); and Korean, when it was used with a sample of 543 Grade 8 science students in 12 schools (Kim, Fisher & Fraser, 2000).

Because classroom environment data are typically derived from students in intact classes, there is the potential for problems to arise such as aggregation bias (within-group homogeneity) and imprecision. Many past learning environment studies have used techniques such as multiple regression analysis, but few have used the multilevel analysis that takes into account the hierarchical nature of classroom settings. Two studies of outcome-environment associations compared the results obtained from multiple regression analysis with those obtained from an analysis involving the hierarchical linear model. Goh, Young and Fraser's (1995) study involving 1512 Grade 5 mathematics students in 39 classes in Singapore related scores on a modified version of the MCI to student achievement and attitude. Wong, Young and Fraser's (1997) study of 1592 Grade 10 students in 56 chemistry classes in Singapore investigated associations between three student attitude measures and a modified version of the SLEI. Most of the significant results from the multiple regression analyses were replicated in the hierarchical linear model analyses, as well as being consistent in direction.

2.2.4.2 Evaluation of Educational Innovations

Educational innovations, such as new curricula or the use of technology, can be evaluated using classroom environment instruments. Early research in this area included an evaluation of the Australian Science Education Project (ASEP), which revealed that ASEP students perceived their classrooms as being more satisfying and individualised, and having a better material environment when compared to a comparison group (Fraser, 1979). The CLES was used in a study in Korea (Oh & Yager, 2004) in assessing the effectiveness of constructivist approaches to instruction. It was found that the students' perceptions on the CLES became more positive with time, and that changes in the CLES scale of Personal Relevance were associated with improvements in student attitudes to science. A Canadian study used classroom environment dimensions to evaluate the use of laptop computers in science and mathematics classrooms (Raaflaub & Fraser, 2002). Aldridge and Fraser (2008) reported that the implementation of an outcomes-focussed, technology-rich learning environment led to more positive student perceptions of Student Cohesiveness, Task Orientation, Investigation, Cooperation and Young Adult Ethos, but less Classroom Differentiation.

Martin-Dunlop and Fraser (2008) evaluated an innovative science course for prospective elementary teachers in a large urban university in California. They selected learning environment scales from the WIHIC and SLEI and administered them to 525 females in 27 classes. Very large differences (of over 1.5 standard deviations) were found on all scales between students' perceptions of the innovative course and their previous courses.

Lightburn and Fraser (2007) investigated the use of anthropometric activities with a sample of 761 high-school biology students in south-eastern USA. They reported that the anthropometry group, relative to a comparison group, scored significantly higher on some SLEI and attitude scales.

Wolf and Fraser (2008) evaluated the effectiveness of using inquiry-based laboratory activities in terms of learning environment, attitudes and achievement. When they administered the WIHIC to a sample of 1434 middle-school science students in 71 classes in New York, they found that inquiry-based instruction promoted more Student Cohesiveness than non-inquiry instruction.

Helding and Fraser (2013) administered the WIHIC to a sample of 924 Grade 8 and 10 science students in 38 classes in Florida. They reported that students of National Board Certified teachers had more favourable classroom environment perceptions.

2.2.4.3 Other Studies

Fisher and Fraser (1983) reported that students preferred a more positive classroom environment than was actually present. Furthermore, teachers perceived a more positive classroom environment than their students. This result has been replicated with the use of the WIHIC and QTI by Wong and Fraser (1996) with 1592 Year 10 chemistry students in Singapore, and the WIHIC among 2498 university students in Indonesia by Margianti, Fraser and Aldridge (2001).

Research aimed at identifying the effect of factors such as teacher personality, class size, grade level, subject matter, the nature of the school environment and the type of school has used classroom environment dimensions as criterion variables (Fraser, 1994, 2012). Studies have included differences between the perceptions of at-risk and normal students in Japan (Hirata & Sako, 1998), cultural differences in perceptions based on whether the teacher is Asian or Western in Dubai (Khine & Fisher, 2002) and the investigation of differences between streams in classroom environment perceptions (Fraser & Lee, 2009).

Some studies have involved the comparison of student perceptions of their learning environments between countries. Aldridge et al. (1999) undertook a cross-national learning environment study involving six Australian and seven Taiwanese science education researchers working together. The WIHIC was administered to 50 junior high school science classes in Taiwan (1879 students) and a further 50 junior high school science classes in Australia (1081 students). The qualitative data collected during this study provided valuable insights into the perceptions of students in each of the countries, helped to explain some of the differences in the means between countries, and highlighted the need for caution when interpreting differences between the questionnaire results between different cultures. Fraser, Aldridge and Adolphe (2010) completed cross-national research involving 594 students from Indonesia and 567 students from Australia in a total of 18 secondary science classes. Sex has been the most studied determinant of classroom environment, with females typically reporting more favourable perceptions of the learning environment than males (Fraser, 2002, 2007). One of the aims of my study was to investigate sex as a determinant of students' perceptions of their laboratory environment and their attitudes towards science. Section 2.4 describes some of the past studies involving sex differences.

Qualitative research methods can help researchers to determine the suitability of a learning environment questionnaire and to modify it before using it in a large-scale study (Margianti et al., 2001). Tobin and Fraser (1998) claim that there is merit in combining quantitative and qualitative research methods. Qualitative research is also useful for researchers for obtaining greater insights into students' perceptions of their classroom environments (Khoo & Fraser, 2008). Aldridge et al. (1999) combined quantitative and qualitative methods in their cross-national study of students' perceptions of their learning environments in Taiwan (1879 students) and Australia (1081 students). The qualitative information complemented and clarified the differences that emerged between countries in the quantitative results. Khine and Fisher (2002) used qualitative interviews of students who experienced difficulties with surveys.

The last major area of study discussed in this literature review is that of cross-national studies. Cross-national studies are significant because they usually provide greater variation in variables of interest, such as teaching methods and student attitudes and, secondly, the more familiar educational practices, beliefs and attitudes in one country can be exposed and questioned (Fraser, 1997). Examples of cross-national studies include: Aldridge, Fraser and Huang's (1999) study of 50 junior high school science classes in Taiwan (1879 students) and 50 junior high school science classes in Australia (1081 students); and Fraser, Aldridge and Adolphe's (2010) study involving 567 Australian students and 594 Indonesian students in 18 secondary science classes.

2.3 ATTITUDES

Two of the aims of my study were to investigate: students' sex and frequency of practical work as determinants of students' motivation and future aspirations to study science; and associations between students' perceptions of their laboratory learning environment and their attitudes towards science. Therefore, this section reviews literature on attitudes using the following organisation:

- 2.3.1 Introduction
- 2.3.2 Students' Adaptive Learning Engagement in Science (SALES) Questionnaire
- 2.3.3 Learning Goal Orientation
- 2.3.4 Self-efficacy
- 2.3.5 Task Value
- 2.3.6 Self-regulation.

2.3.1 Introduction

Because attitude is a non-observable psychological construct that can only be inferred from the behaviour shown (Eccles, 2006), agreement on any one definition of attitude is difficult. Shrigley (1983) maintains that attitude is central to human activity, yet educational researchers have had difficulty in understanding it. Thurstone (1928), who was instrumental in the formulation and popularisation of methods for measuring attitudes, defined attitude as:

> …the sum total of a person's inclinations and feelings, prejudice and bias, preconceived notions, ideas, fears, threats and convictions about any specified topic. (Eccles, 2006, p. 42)

It is generally agreed that attitude is not innate, but learned as part of culture (Shrigley, 1983).

In a study aimed at revising and validating a science attitude scale that employed a Likert (1932) response format, Misiti, Shrigley and Hanson (1991) stated that "during the middle school years attitudes are formed that influence science course selections in the high school and college" (p. 25). If students do not have a positive attitude towards science, then career choices will probably not be science-related (Lowe, 2004). It is therefore important to develop and validate a range of attitude measuring instruments so that research into attitudes can be continued.

Gardner (1975) proposed that attitudes to science can be divided into two main categories: attitudes towards science and scientific attitudes. The Test Of Science-Related Attitudes (TOSRA, Fraser, 1981) includes scales which assess both categories of attitudes to science, and it is scored using a five-point Likert (1932) scale. The theoretical basis for TOSRA came from Klopfer's (1971) categories for the affective domain in science education. Fraser (1981) distinguished seven distinct school science-related attitude 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 was validated in 1977 with a sample of 1337 Years 7–10 students in 44 classes from 11 schools in the Sydney metropolitan area (Fraser, 1981). The Career Interest in Science was used as the basis for developing the Future Intentions scale used in my study.

Velayutham, Aldridge and Fraser (2011) developed the Students' Adaptive Learning Engagement in Science (SALES) questionnaire to assess students' motivation and self-regulation in science learning. The ability of students to self-regulate their learning has been identified as a central construct that influences students' engagement in learning and their achievement in school (Boekaerts & Cascallar, 2006). Zimmerman (2000) argues that this is of little value if students cannot motivate themselves to use self-regulation skills. The term 'adaptive' is used in educational psychology to describe characteristics that promote students' engagement in learning (Ames, 1992; Dweck, 1986; Kaplan & Maehr, 2007; Midgley, 2002; Pintrich, 2000). Pintrich (2000) argued that students' engagement in classroom tasks is influenced by both adaptive motivational beliefs and adaptive self-regulated learning.

Research indicates that students' level of motivation and self-regulation in science learning primarily determine their successful learning engagement in science (Boekaerts & Cascallar, 2006; Hanrahan, 2002; Zimmerman, 2000). In studying students' motivation to learn science, researchers have examined "why students strive to learn science, how intensively they strive, and what beliefs, feelings, and emotions characterize them in this process" (Glynn, Taasoobshirazi & Brickman, 2009, p. 128).

Much research has involved the use of classroom environment instruments to determine relationships between the classroom environment and student attitudes towards science (Fraser, 2012; Wong & Fraser, 1996; Lee et al., 2003; McRobbie & Fraser, 1993a). My study built on and extended past research by examining the relationships between students' perceptions of the science laboratory environment, their motivation towards learning science and their aspirations to study science in Years 11 and 12. My study also investigated sex and frequency of practical work as determinants of students' perceptions of their laboratory environment, motivation towards learning science, and aspirations to study science in Years 11 and 12.

2.3.2 Students' Adaptive Learning Engagement in Science (SALES) Questionnaire

Velayutham, Aldridge and Fraser (2011) developed the Students' Adaptive Learning Engagement in Science (SALES) questionnaire to assess students' motivation and self-regulation in science learning. It consists of four scales: Learning Goal Orientation (which measures the students' adaptive motivational belief in science learning), Task Value (the value the students place on the science tasks given to them), Self-efficacy (the students' self believe that they can achieve the desired outcomes) and Self-regulation (which measures the degree to which students engage in their learning and evaluate their progress). Each of the four scales of the SALES questionnaire has 8 items, making 32 items in total.

The SALES was validated with a sample of 1360 Grade 8 to 10 students in 78 classes from five different public schools in the Perth metropolitan area. In-depth qualitative information was also gathered from 10 experienced science teachers and 12 Grade 8 students. Convergent and discriminant validity was determined through exploratory factor analysis and internal consistency reliability. The factor analysis results supported the four-scale structure of the SALES questionnaire and the internal consistency reliability values were all high, at above 0.9. A correlation matrix, obtained through oblique rotation, indicated that each scale measured a different dimension. In addition, the ability of all scales in the SALES questionnaire to differentiate between classes was established using ANOVA. The researchers developed this instrument to be used to provide instructors with a reliable, valid and convenient tool for gathering information about science student motivation and self-regulation.

The SALES is a new instrument that, apart from its validation study with 1360 middle-school students, has not been used in other published research. Koren and Fraser (2013) used the SALES in their study of 495 gifted and non-gifted middle-school students within the Miami-Dade County in Florida. In order to reflect the scope of their study, the SALES questionnaire was renamed Students' Adaptive Learning Engagement in School. The word 'School' replaced the word 'Science' in order to apply the SALES to subjects beyond science. Within the individual items, the word ‘science’ was replaced with the word ‘lessons’ to enable the use of the instrument to assess academic subjects other than science. In their study, the SALES questionnaire was found to be valid, reliable and able to differentiate between classrooms.

The original Students Adaptive Learning Engagement in Science (SALES) questionnaire was selected for use in my study because it has been validated for use with middle-school students for assessing students’ learning goal orientation, self-efficacy, task value and self-regulation, which collectively contribute towards adaptive learning engagement in science. A summary of each of these four constructs is outlined below.

2.3.3 Learning Goal Orientation

Goal orientation provides important theoretical perspectives to help to explain the reasons for students’ engagement with a task (Pintrich, 2000). In addition, researchers have attempted to understand and enhance students’ patterns of learning engagement based on the framework provided by goal orientation theory (Kaplan & Maehr, 2007). According to achievement goal theory, there are two types of goal orientation: learning goal orientation and performance goal orientation. Learning goal orientation refers to the purpose of developing proficiency. It focuses on learning and understanding tasks, and gaining a high skill level. Performance goal orientation refers to the purpose of demonstrating competence (especially managing the impressions of others) (Ames, 1992).

Research evidence (Urdan & Schoenfelder, 2006) indicates that performance goal orientation has the potential to undermine both student motivation and achievement. It is not considered to be an adaptive motivational belief. Past research has indicated that students' learning goal orientation is likely to influence positively a range of learning outcomes including student achievement (Kaplan & Maehr, 2007).

Tuan, Chin and Shieh (2005) reported that goal orientation was an important influence on students' attitudes towards science and science achievement. Kaplan and Maehr (2007, p. 170) found solid theoretical research evidence indicating that learning goal orientation is "an adaptive motivational orientation". Based on theoretical and research evidence, Velayutham et al. (2011) chose to include learning goal orientation as a motivational construct in their study.

2.3.4 Self-efficacy

According to social cognitive theory, students are more likely to be encouraged to learn if they believe that they can achieve success (Bandura, 1986). Self-efficacy beliefs are strong predictors of student choices, effort and persistence (Velayutham et al., 2011). According to Schunk and Pagares (2005), students with high efficacy are more likely to put in additional effort, consistently appraise their progress and select and use self-regulatory strategies. At the high-school level, self-efficacy has been shown to be a stronger predictor of achievement and engagement in science than sex, ethnic background or parental background (Kupermintz, 2002).

2.3.5 Task Value

Expectancy-value theory highlights the central role of academic task value beliefs in shaping students' motivation to learn (Eccles, 1983; Pintrich & De Groot, 1990). Theoretically, students who are convinced that their learning activity is important, interesting and useful are more likely to expend greater effort and persevere when completing a task (Wolters & Rosenthal, 2000). Even when students lack self-efficacy, they are likely to persist on the activity if they value the task (Schunk & Zimmerman, 2007). Pintrich and De Groot (1990) concluded that students who believe that their learning activity is interesting and important were more engaged in attempting to learn and understand the materials presented to them. Tuan et al. (2005) reported that task value significantly influenced students' attitudes towards science and science achievement.

2.3.6 Self-regulation

Students' self-regulation in academic settings has been identified as a pivotal construct that influences students' engagement in learning and their achievement in school (Boekaerts & Cascallar, 2006). Self-regulation skills are of little value if students are not motivated to use them (Zimmerman, 2000). The three components of motivation that have been consistently linked to self-regulation are learning goal orientation, self-efficacy and task value, as described above (Zimmerman, 2002).

The key feature of self-regulation is that the student uses cognitive and motivational strategies to achieve learning goals (Boekaerts & Cascallar, 2006). Pintrich and De

Groot (1990) identified three components of self-regulated learning that are relevant for classroom performance: strategies used by students in planning, monitoring and modifying their cognition; students' use of cognitive strategies; and management and monitoring of effort in academic tasks. Zimmerman (2008) reiterates that the self-regulated learner must have personal initiative, perseverance and adaptive skills. Therefore, students not only must be motivated through assigning goals and values to the learning activity, but they also need to sustain effort until the task is completed (Boekaerts & Cascallar, 2006).

A review of past research has established that students with higher self-regulation skills are more likely to be academically motivated (Pintrich, 2003). Perels, Gurtler and Schmitz (2005) found that even relatively short interventions to improve student self-regulation can result in sustained benefits, including raising students' self-efficacy beliefs.

Two instruments have been regularly used to assess students' self-regulated learning: the 80-item self-report Learning and Study Strategies Inventory (LASSI, Weinstein Schylte & Palmer, 1987); and the 81-item Motivated Strategies for Learning Questionnaire (MSLQ, Pintrich, Smith, Garcia & McKeachie, 1991). These general surveys were designed for college students and use words and concepts with which middle-school students might not be familiar. The SALES questionnaire, which I chose for my study, was developed to address this gap in the instruments available (Velayutham et al., 2011).

2.4 SEX DIFFERENCES

Research aimed at identifying the effect of factors such as teacher personality, class size, grade level, subject matter, nature of the school environment and type of school have used classroom environment dimensions as criterion variables (Fraser, 1994). Much past classroom environment research has examined sex differences and has indicated that, generally, females have more favourable perceptions of the learning environment than their male counterparts (Goh & Fraser, 1998; Quek et al., 2005; Riah & Fraser, 1998). Sex has been shown to be a strong predictor of science subject choice, with physics classes being dominated by boys, biology classes by girls and chemistry classes being fairly evenly balanced in terms of student sex (Ainley et al., 2008; Fullarton et al., 2003). One of the most promising explanations for the sex imbalance in physics enrolments concerns students' self-efficacy in science and the interaction of this with their conceptions of the relative difficulty of physics (Lyons & Quinn, 2010).

The Programme for International Student Achievement (PISA) (2006) revealed that, despite achieving similar scores for scientific literacy, Australian girls reported lower levels of self-efficacy and self-concept in science than boys. The study revealed that males reported more favourable attitudes than females for enjoyment of science, instrumental motivation, future orientation to study or work in science, science self-efficacy and science self-concept. Females reported more favourable attitudes to the importance of doing well in science and there was no difference between males and females in their general interest in science (Thomson & DeBortoli, 2008).

From early adolescence, girls typically express less interest in mathematics or science careers than boys do (Lapan, Adams, Turner & Hinkelman, 2000; Turner et al., 2008). The National Science Foundation (2006) in America also reported that attitudes towards science begin to differ by the 8th grade, with boys more frequently agreeing with statements such as "I like math/science" and "I am good in math/science" than girls in 8th grade. The differences are even more pronounced in the 12th grade.

Fouad et al. (2010) researched sex differences in the barriers and supports for pursuing coursework and/or careers in mathematics and science domains. Sex differences were found in perceptions of the barriers and supports, although there was no difference in the number of supports and barriers between the sexes. Males and females both reported that the most important support was the teacher wanting them to do well. The teacher was the most important barrier (lack of inspiration or advice) for females, whereas the lack of interest among friends in the subject was the most important barrier for males.

Williams et al. (2003) researched sex differences in attitudes to practical work and found that physics and biology students considered practical work interesting, but that males valued practical exercises more than females, whereas females valued the relevance of physics more than males.

2.5 FREQUENCY OF PRACTICAL WORK

2.5.1 Introduction

The literature highlights a number of reviews of science education, but these reviews provide minimal insights into the factors that contribute towards the frequently-observed decline in student interest in science (Velayutham et al., 2011). Although increasing the frequency of practical work is reported through these reviews as one of the solutions to increasing student engagement and enrolment in science (Lyons & Quinn, 2010), little research has been conducted to support this belief. A brief overview of the development of practical work as an instructional approach in secondary science education in Australia is provided, followed by a summary of recent studies of the use of practical work in the teaching of science.

2.5.2 Development of Practical Work as an Instructional Tool in Secondary Science Education in Australia

The scientific method was credited with building modern science through its unique qualities that distinguish it from other methods of gaining knowledge. Enthusiasm for the scientific method could be seen in Australia, as it had been discussed at a meeting of some of the State associations of science teachers; sections of textbooks published at the time included descriptions of the scientific method; and, in some States, understanding the scientific method was included among the objectives of the course listed in the science syllabus (Bradley, 2005).

The scientific method was described as a series of steps as follows:

1. Observing and defining the problem.
2. Gathering reliable data relevant to the problem.
3. Consideration of various hypotheses and the selection of the most satisfactory hypothesis to explain the data.
4. Planning and execution of experiments or observations to test the selected hypothesis.
5. Drawing a conclusion about the support or otherwise of the tested hypothesis.
6. Publication of the procedure in such a way as to allow anyone who desires to repeat and test any step. (Doherty, 1955, p. 13)

In 1955, while addressing the fifth Conference of the Australian Science Teachers' Association, Smith (1955) recognised the importance of practical work in the teaching of science as something about which science teachers agreed. But there was a difference of opinion about the relative importance of teaching by demonstration or by an extensive course of laboratory work. He considered that experiments took a long time to perform, that students were already familiar with the principles or results which the experiments were designed to discover, and that the elementary nature of the experiments resulted in little training in useful practical techniques (Bradley, 2005). Teacher demonstrations could take a fraction of the time and a series of questions and answers would eventually reveal the principle that the experiment was designed to discover. Smith also argued that the purpose of the experiment should be broadened to be less prescriptive (Bradley, 2005). Reimann (1955) advocated experiments in the form of investigations, or problems, for which the student is given as little help as possible.

During the 1970s, expert resources from the scientific and larger education community were used to develop new courses and support materials with the aim of updating the content and placing an emphasis on the processes of science and experimentation as an integral part of science education programmes (Owen, 1977). The major effort to improve secondary science education during the 1950s through to the 1970s fell short of expectations because there was a reliance on inquiry and investigation in the discovery methods used in many of the projects (Novak, 1988). Although science skills, such as observing and collecting and recording data accurately, are important in themselves, a prior conceptual framework is needed before discovery methods lead to meaning and understanding (Hodson, 1988).

In the 1980s, the focus of attention in science education was on skill development and the importance of a student's prior knowledge. The focus of many studies has been to clarify the objectives of practical work in science learning (Beatty & Woolnough, 1982; Gould, 1978; Gunning & Johnstone 1976).

Since the 1990s, learning often has been considered to be a personal construction by the learner, with the learner central to and involved in the process of learning (Bradley, 2005). Learners construct their own knowledge and understandings based on their previous knowledge and experience and on the socio-cultural milieu in which they find themselves (Goodrum, Hackling & Rennie, 2001). Because the search for understanding is part of the human condition, the study of science as a way of knowing and a way of doing can provide a means by which students can deepen their understanding of the world (Bradley, 2005).

2.5.3 Recent Research on the Use of Science Practicals in the Classroom

Rennie, Goodrum and Hackling (2001) reported open investigations, that engage students in planning and conducting investigations so that they are both minds-on and hands-on, have not penetrated the traditional curriculum as implemented in many Australian schools. The dominance of traditional closed laboratory exercises appears to be common in many secondary schools, although some secondary schools have adopted more student-centred approaches to practical work. For Rennie et al.'s sample of 2802 students, 33% of students stated that they never planned and completed their own experiments, and a further 25% of students stated that they completed their own experiments once a term or less. 70% of the students surveyed reported that they completed an experiment by following instructions about once a week or more.

Bradley (2005), in his study of 537 students in Years 8–10 in Tasmania and Western Australia, found that students generally perceive that science practicals are essential to science learning. Students involved in this study wanted an increase in the amount of practical work, more responsibility for their science practical work and less teacher direction.

Chen and Howard (2010) completed a study of the effect of live simulation on students' science learning and attitudes. 311 middle school students participated in the simulation, which allowed them to access and interpret satellite data and images and to design investigations. The findings included positive changes in students' attitudes and perceptions towards scientists. Male students also adopted more positive scientific attitudes than female students.

A study of the effect of an integrated, project-based science course on biology students' attitudes towards science classes and science revealed that the provision of opportunities for students to collect and analyse their own data resulted in a change in students' ideas about science classrooms (Stratford & Finkel, 1996). Students who completed the integrated course no longer described their science experience as one of memorisation, textbook reading and test taking. Instead, they saw science classes as involving collecting data, drawing conclusions, and formulating and solving problems.

Shepardson and Pizzini (1994), in their study of 268 Year 7 and 8 students, established an association between the nature of classroom activities and student perceptions of science classes. Students were more positive about learning science when teachers used a project, inquiry-based approach rather than workbook or traditional structured laboratory-based methods of instruction.

A cross-national study (House, 2005) of 15,696 students from three countries (Japan, Hong Kong and Chinese Taipei) examined several instructional strategies including active learning, cooperative learning and computer-based instruction. A number of significant relationships between the nature of instructional activities and science achievement were noted. Students who more frequently used things from everyday life when solving problems tended to earn higher test scores. Similarly, students who completed an experiment or practical investigation in class were more likely to earn higher test scores.

An interpretive study involving 29 students from three secondary schools in England sought views about the role that practical work plays in school science lessons (Toplis, 2012). The students, aged between 13 and 16 years, reported that practical work is important for three reasons: for activity, including social and personal features such as participation; as an alternative to other forms of science teaching that involve pedagogies of transmission; and as a way of learning. Toplis concluded that practical work can provide students with the opportunity to engage with and influence their own learning, but the complex issue of practical work needs further research into its use and effectiveness.

Matz, Rothman, Krajcik and Banaszak Holl (2012) studied the effect of completing practical work concurrently with a lecture series on the enrolment retention and learning gains of 9,438 university chemistry students attending the University of Michigan. They found a positive correlation between the concurrent completion of practical work and a lecture series with the retention of the lecture material and the lecture grades at the end of the programme, when compared to non-concurrent completion of the laboratory programme and lecture material.

From these studies, it can be concluded that there are positive associations between practical work and student attitudes towards studying science. Respondents in some of the above studies suggest that increasing the frequency of practical work is a solution to increasing student engagement and motivation in science lessons. My study attempted to provide evidence to support the belief that more frequent practical work is associated with more positive student attitudes towards science.

2.6 CHAPTER SUMMARY

The purpose of this chapter was to review literature relevant to this study in four main sections: learning environment research, attitudes towards studying science, sex differences and practical work.

The chapter began with an overview of the historical background to learning environment research. Research specifically on classroom learning environments took off about 40 years ago when the work of Walberg and Anderson (1968) and Moos (1974) spawned diverse research programmes around the world (Aldridge & Fraser, 2008; Fraser, 2007, 2012). A review of literature pertaining to some of the main classroom environment instruments followed. The instruments reviewed were the MCI, ICEQ, QTI, SLEI, CLES, WIHIC and TROFLEI.

Because I chose to use the Science Laboratory Environment Inventory (SLEI) for my study, a more detailed review of the literature was included for this instrument. The SLEI was created in response to the need to assess the learning environment specific to science laboratory classes, particularly in upper-secondary and higher-education contexts (Fraser et al., 1995). It measures the five dimensions of Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment and consists of 35 items in total. The SLEI was simultaneously field tested and validated cross-nationally in six countries with a sample of 5447 students in 269 classes (Fraser et al., 1995). Several studies have shown the SLEI is a reliable and valid instrument (Fraser & Lee, 2009; Lightburn & Fraser, 2007, Quek et al., 2005; Wong & Fraser, 1996). My study contributes to the field of learning environments research by extending the use of the SLEI to middle-school classrooms, where it has had minimal use.

In order to provide further background for my study, some past learning environment research was reviewed. Because my research questions focussed on associations between student attitudes and environment, and determinants of classroom environment (namely, student sex and frequency of practical work), particular emphasis was given to past studies involving associations between students' learning outcomes and their perceptions of their learning environments, evaluation of educational innovations including laboratory work programmes, and a brief overview of other learning environment studies.

Much research has involved the use of classroom environment instruments to determine relationships between the classroom environment and student attitudes towards science (Fraser, 2012; McRobbie & Fraser, 1993a). Because the assessment of student attitudes formed part of my study, the next section of my literature review focussed on the theoretical background to the development of my chosen instrument, the SALES questionnaire. Velayutham et al. (2011) developed the Students' Adaptive Learning Engagement in Science (SALES) questionnaire to assess students' motivation and self-regulation in science learning. It consists of four scales: Learning Goal Orientation, Task Value, Self-efficacy and Self-regulation. The

SALES questionnaire was validated by Velayutham et al. with a sample of 1360 middle-school students.

Investigating sex differences as a determinant of students' perceptions of their laboratory learning environment, their attitudes towards studying science and their aspirations was one of the intentions of my study. Past classroom environment research indicates that females typically have more favourable perceptions of the learning environment than males (Fraser, 2007). The Programme for International Student Achievement (OECD, 2007) revealed that, despite achieving similar scores for scientific literacy, Australian girls reported lower levels of self-efficacy, self-concept, enjoyment of science, instrumental motivation, and future orientation to study or work in science than boys. Females expressed more favourable attitudes to the importance of doing well in science than males (Thomson & DeBortoli, 2008).

Finally, one of the main foci of my study was investigation of the frequency of laboratory work as a determinant of students' perceptions of their laboratory learning environment, their attitudes towards studying science, and their aspirations to study science at the senior-secondary level. Increasing the frequency of practical work is reported through some reviews of science education as one of the solutions to increasing student engagement and enrolment in science (Lyons & Quinn, 2010), but little research has been conducted to support this belief. A brief overview of the development of practical work as an instructional approach in secondary science education in Australia and a summary of recent studies of the use of practical work in the teaching of science was included in my literature review.

In the next chapter, the methodology used in collecting, analysing and interpreting data for the study is discussed.

Chapter 3

METHODOLOGY

3.1 INTRODUCTION

In this study, I investigated student sex and the frequency of practical work as determinants of classroom environment, attitudes towards science and intentions to study science at the senior secondary school level. I also explored associations between students' perceptions of their laboratory environment and their attitudes towards science and their intentions to study science further. 'Practical work' is defined as a method for learning the processes and skills involved in the development of scientific literacy (Bradley, 2005). This study included teacher demonstrations, closed laboratory exercises, practical design tasks, open-ended student-choice investigations and field work within the scope of the term 'practical work'.

Chapter 2 presented a review of relevant literature, including the theoretical bases of previous studies into learning environment research and the use of practical work in science classes. A particular focus was the development of the two instruments used in this study – the SLEI and the SALES.

This chapter outlines the methodology used in this study to collect and analyse data in relation to the objectives outlined in Chapter 1. It includes a description of the sample (Section 3.2), the development of the questionnaires (Section 3.3), the process of data collection (Section 3.4), the methods of data analysis (Section 3.5) and a summary of the chapter (Section 3.6).

3.2 SAMPLE

The study was undertaken in metropolitan Adelaide, South Australia with a sample of 431 students from four coeducational schools. Year 9 and 10 students were selected for this study because subject selection is influenced by students' most recent experiences. Lyons and Quinn (2010), in their study involving 3759 Year 10 students, found that around 80% of the students believed that their most recent experiences (Years 9 and 10) had the greatest influence on their decisions about subject selections for Year 11.

The sample was deliberately chosen to incorporate different school sectors. Two of the schools were typical Independent schools and the other two schools were typical Catholic schools. South Australian Independent Schools educate students within a curriculum underpinned by a diverse range of religious beliefs including Anglican, Baptist, Christian, Christadelphian, Greek Orthodox, Islamic, Lutheran, Seventh-day Adventist and Uniting (AISSA, nd). Schools within the Catholic sector of the education system in South Australia operate within the Archdiocese of Adelaide and the Diocese of Port Pirie to meet the needs of families who choose an education based on Christian principles in the Catholic tradition (Catholic Education, nd). The Catholic schools selected in this study were both in the Archdiocese of Adelaide.

All schools selected were coeducational and they provided a typical sample of students from a range of socioeconomic backgrounds. The word “typical” is used to describe the sample because care was taken to ensure that the schools and the classes within the schools were representative of the range of student abilities and socioeconomic statuses in South Australia. The sample included a wide range of student abilities.

The average size of the classes across all of the schools in the sample did not vary much. The average class size was 25 students. Convenience sampling, based on participants’ willingness and availability to be involved in the study (Creswell, 2008), was the method of sampling used. All 431 participants included in the final sample completed the survey accurately. Additional students were involved in the data collection process, but surveys with missing responses were excluded from the sample prior to analysis. Table 3.1 provides information about the composition of the sample in terms of numbers of males and females and numbers of Year 9 and Year 10 students.

Table 3.1 Composition of the Sample

School	Sample Size				
	Girls	Boys	Year 9	Year 10	Total
1	40	47	48	39	87
2	55	51	53	53	106
3	55	47	53	49	102
4	71	65	74	62	136
Total	221	210	228	203	431

3.3 DEVELOPMENT OF THE SURVEY

Data collection involved the administration of a survey made up of two questionnaires, the Science Laboratory Environment Inventory (SLEI) and the Student Adaptive Learning Engagement in Science (SALES) questionnaire. The SLEI (Section 3.3.1) was created in response to the need to assess the learning environment specific to science laboratory classes, particularly in upper-secondary and higher-education contexts (Fraser et al., 1995). It has had relatively little use in middle-school laboratory classrooms. The SALES questionnaire (Section 3.3.2) was developed to assess students' motivation and self-regulation in science learning. It is a new questionnaire and therefore needed to be further validated in this study. A Future Intentions scale (Section 3.3.3) was developed for my study to assess student aspirations to study science at the senior secondary level. The Future Intentions scale was added to the SALES questionnaire to form a modified SALES questionnaire.

The survey used in my study is provided in Appendix 1. The survey contained three main sections. The first page of the survey sought information about the student's sex and estimation of the frequency of practical work in science classes. It also outlined the instructions for the remainder of the survey. The modified SLEI (titled 'Science Laboratory Environment') followed. The next section of the survey contained the modified SALES questionnaire. It asked students to respond to statements about their future career intentions, followed by the SALES questionnaire.

3.3.1 Science Laboratory Environment Inventory (SLEI)

All five scales (Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment) from the original SLEI were used in this study. Each scale consists of seven items, making 35 items in total. Although the SLEI has both actual and preferred forms, only the actual version of the SLEI was used in my study.

Student Cohesiveness is the extent to which students help each other in the classroom and was assessed by rating statements such as “Members of this laboratory class help me”. Open-Endedness measures student perceptions of whether activities allow for investigation and experimentation. Statements such as “I decide the best way to proceed during laboratory experiments” were rated. The Integration dimension assesses whether or not the laboratory sessions are relevant to the theory lessons. Statements include “What I do in laboratory sessions helps me to understand the theory covered in regular science classes”. Because student safety is extremely important in laboratory sessions, student behaviour needs to be guided by formal rules to assist in making the environment as safe as possible. Rule Clarity assesses this dimension. The original version of the SLEI included statements such as “There are few fixed rules for me to follow in laboratory sessions”. The final dimension, Material Environment, assesses whether or not the equipment and materials available are adequate. Statements from the original version of the SLEI such as “I find that the laboratory is crowded when I am doing experiments” were used in the assessment of this dimension.

Section 2.2.3 reviewed literature about the development and use of the SLEI in detail. The SLEI was simultaneously field tested and validated cross-nationally in six countries (Australia, United States, Canada, England, Israel, and Nigeria) with a sample of 5447 students in 269 classes (Fraser et al., 1992). The SLEI also has been found to be valid and reliable in numerous studies around the world, including Korea (Fraser & Lee, 2009), the USA (Lightburn & Fraser, 2007), Singapore (Wong & Fraser, 1995) and Australia (Fraser et al., 1993; McRobbie & Fraser, 1993a). Therefore I chose to use the SLEI for my study about the laboratory environment.

The original version of the SLEI was developed for use with senior secondary and university students. Some of the items in the original version of the SLEI were worded in the negative sense, thus requiring reverse scoring. The items in the original version of the SLEI were arranged in blocks of five in cyclic order (Fraser et al., 1992).

The actual version of the SLEI was modified for use with middle-school students in my study to minimise possible confusion. Velayutham et al. (2011) stated that negatively-worded items in questionnaires that are appropriate for university students could prove confusing for secondary school students. Schriesheim, Eisenbach and Hill (1991) studied the effect of negatively-worded and polar opposite items on questionnaire reliability and validity with a sample of 280 business undergraduate students. They found that positively-worded items such as “I am happy…” and negated regularly-worded items (“I am not happy…”) are more reliable than the polar opposite, negative items (“I am sad…”) and negated polar opposite items (“I am not sad…”). Their findings also suggest that regularly-worded items are the most reliable of the four types of item wording. Therefore, any negatively-worded items were reworded for my study.

The cyclic arrangement of the items in the original SLEI was altered so that all seven items for each scale were presented together in blocks to ensure that the survey took minimal class time to administer. The block structure of the modified SLEI follows the structure of recent instruments including the CLES, WIHIC and TROFLEI.

The SLEI's five-point frequency scale (Almost Never, Seldom, Sometimes, Often and Very Often) was changed to the same five-point Likert scale that is used in the SALES questionnaire (Strongly Disagree, Disagree, Not Sure, Agree, Strongly Agree) so that a consistent response scale was used across the entire survey. The consistent response scale was used in order to prevent confusion as students moved from the SLEI section of the survey to the SALES section, and to ensure that the survey took minimal lesson time to complete.

Table 3.2 provides a summary of the scale name, a description and a sample item for each scale in the SLEI (Fraser et al., 1992; McRobbie & Fraser, 1991). The survey presented to the students, which includes the modified SLEI, is in Appendix 1.

Table 3.2 Description and a Sample Item for Each Scale in the SLEI

Scale Name	Description of Scale	Sample Item
Student Cohesiveness	Extent to which students help each other in the classroom	I get on well with students in this laboratory class.
Open-Endedness	Extent to which activities allow for personal investigation and experimentation	In this laboratory class, I am required to design my own experiments to solve a given problem.
Integration	Extent to which laboratory sessions are relevant to the theory lessons	I use theory from my regular science class sessions during laboratory sessions.
Rule Clarity	Extent to which formal laboratory rules are outlined and reinforced	There is a recognised way of doing things safely in this laboratory.
Material Environment	Extent to which equipment and materials available are suitable and in good order	The equipment and materials I need for laboratory activities are readily available.

Items are scored 1, 2, 3, 4 & 5, respectively, for the responses Strongly Disagree, Disagree, Not Sure, Agree and Strongly Agree

This table is based on Fraser et al. (1992) and McRobbie and Fraser (1991)

3.3.2 Students' Adaptive Learning Engagement in Science (SALES) Questionnaire

The SALES questionnaire was developed to assess students' motivation and self-regulation in science learning. Section 2.3.2 describes the development and validation of the SALES questionnaire in more detail. The SALES questionnaire consists of four scales: Learning Goal Orientation (which measures the students' adaptive motivational belief in science learning), Task Value (the value the students place on the science tasks given to them), Self-Efficacy (the students' self belief that they can achieve the desired outcomes) and Self-Regulation (which measures the degree to which students engage in their learning and evaluate their progress). Each of the four scales of the SALES questionnaire has 8 items, making 32 items in total.

The SALES was validated with a sample of 1360 Grade 8 to 10 students in 78 classes from five different public schools in the Perth metropolitan area. The factor analysis results supported the four-scale structure of the SALES questionnaire and the scale internal consistency reliability values were all high, at above 0.9. A correlation matrix, obtained through oblique rotation, indicated that each scale measured a different dimension. In addition, the ability of all scales in the SALES questionnaire to differentiate between classes was established using ANOVA (Velayutham et al., 2011).

Koren and Fraser (2013) validated the SALES with a sample of 495 gifted and non-gifted middle-school students from within the large, urban school district of Miami-Dade County, Florida. In order to reflect the scope of their study, the SALES questionnaire was renamed Students' Adaptive Learning Engagement in School. The word 'School' replaced the word 'Science' in order to apply the SALES to subjects beyond science. Within the individual items, the word 'science' was replaced with the word 'lessons' to enable the use of the instrument to assess academic subjects other than science.

Because the original SALES questionnaire was validated with a sample of 1360 middle-school science students (Velayutham et al., 2011), it was not modified for use in my study involving 431 middle-school science students.

Table 3.3 provides a summary of the scale name, a description and a sample item for each scale in the SALES questionnaire (Velayutham et al., 2011). A copy of the SALES questionnaire is in Appendix 1.

Table 3.3 Description and a Sample Item for Each Scale in the SALES Questionnaire

Scale Name	Description of Scale	Sample Item
Learning Goal Orientation	Extent of students' adaptive motivational belief in science learning	It is important for me to learn the science content that is taught.
Task Value	Extent of the value the students place on the science tasks	What I learn is useful for me.
Self-Efficacy	Extent of the self-belief of students that they can achieve the desired outcomes	Even if the science work is hard, I can learn it.
Self-Regulation	Extent to which students engage in their learning and evaluate their progress	I don't give up even when the work is difficult.

Items are scored 1, 2, 3, 4 & 5, respectively, for the responses Strongly Disagree, Disagree, Not Sure, Agree and Strongly Agree

This table is based on Velayutham et al. (2011)

3.3.3 Future Intentions Scale

The Test of Science-Related Attitudes (TOSRA) was developed to measure seven distinct science-related attitudes of students (Fraser, 1981): 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. Section 2.3.1 describes the theoretical background and validation of the TOSRA. Scales from the TOSRA have been validated and used in numerous past studies involving the assessment of students' attitudes towards science (Aldridge et al., 1999; Aldridge, Fraser & Fisher, 2003; Fraser, Aldridge & Adolphe, 2010; Martin-Dunlop & Fraser, 2008; McRobbie & Fraser, 1993a; Wong & Fraser, 1995).

The TOSRA's 10-item Career Interest in Science scale was used as the basis for a scale developed for my study to assess student aspirations to study science further. This scale assesses whether or not students are interested in working in a scientific field in the future. If students wish to work in a scientific field, they are more likely to choose to study science subjects at Years 11 and 12. The wording of the items from the TOSRA scale was modified to include a broader range of careers that require students to have an assumed knowledge of senior-secondary science subjects. Negatively-worded items were reworded positively to avoid confusion and improve reliability (Schriesheim et al., 1991). For example, the item "I would dislike being a scientist after I leave school" was reworded to: "I would like to become a scientist when I leave school".

A total of six items, based on some of the items from the Career Interest in Science scale in the TOSRA, were included in the questionnaire. The six items are:

- "I would like to work in a science-related career after I leave school."
- "When I leave school, I would like to work in health, engineering, environmental science, medical research or science teaching."
- "A career that uses science would be interesting."
- "I would like to become a scientist when I leave school."
- "Working in a science laboratory, a hospital or an engineering office or site would be an interesting way to earn a living."
- "I would like to work with science when I leave school."

The Future Intentions scale was integrated into a single survey, with the SLEI preceding the Future Intentions scale and the SALES questionnaire following the Future Intentions scale (Appendix 1).

3.4 DATA COLLECTION

Data collection took place in two phases. The first phase was a pilot study, completed early in Term 3 (August), 2011. The questionnaire was trialled with one class of Year 9 students to determine the suitability of: the wording of the items; the wording of the five-point agreement scale; and the length of time taken to answer the survey. Ambiguity in any of the items was able to be identified through questions from the students during the trial. The pilot study is described further below in Section 3.4.1.

The second phase of the data collection for this study took place during late Term 3 and early Term 4 (September – October) 2011. Because secondary schools in South Australia require students to make their subject choices for the following year early in Term 3, the data-collection process was deliberately separated from the subject-selection schedule in the schools involved so that taking the survey wouldn't influence students' subject selections.

3.4.1 Pilot Testing of the Questionnaire

Because the wording of questionnaires is of paramount importance, pilot testing of surveys is crucial to their success (Cohen, Manion & Morrison, 2000). A pilot study has several functions, including: to check the clarity of the questionnaire items, instructions and layout; to eliminate ambiguities or difficulties in wording; to gain feedback on the type of question and its format; and to check the time taken to complete the questionnaire (Cohen et al., 2000).

A reference group of 20 Year 9 students was chosen from a science class from one school to see whether students experienced any difficulties with the survey, either in the administration of the instrument or with regard to the comprehensibility of items in the survey. The questionnaire was administered to the students and the total time needed was recorded. The total time included the time taken to explain the purpose of the study and outline the instructions to the students, together with the time taken for the slowest student to complete the survey. The survey was found to take a total of 25 minutes to administer to the slowest student, which easily fits into a single lesson period in any middle school.

During the field testing stage, as the researcher, I was concerned not to provide too much detail because the questionnaires would need to be self-explanatory and provide as few obstacles as possible for the administrators, teachers and students to be involved in the main study.

Upon completing the survey, the students were asked for any comments about the administration of the survey and the comprehensibility of items in the survey. The objective of the discussion was to elicit further information from the students' perspective about the survey so that any problems that were encountered could be quickly identified and rectified. There was no need for adjustment to the wording of the survey based upon feedback obtained during the trial. The students involved in the trial reported that the instructions were easy to follow and that the questions were clear.

3.4.2 Process of Administering the Questionnaire

Contact with each participating school was made four weeks before the administration of the questionnaire. Because students from Catholic schools were involved in the research, permission from the Catholic Education Office was needed before approaches could be made to principals of the various schools that had been chosen for the study.

Principals and teachers involved were very supportive of the research and were keen to be of assistance in facilitating the administration of the survey. A copy of the research proposal, participant information sheet (Appendix 2), the survey (Appendix 1) and a consent form (Appendix 2) were sent to each of the principals of the schools selected. It was clearly stated that student confidentiality would be respected and maintained, and that parental consent would be gained for any student participating in the study.

Each principal forwarded the information to the Head of Science, who became my primary contact within each school. Because the survey was able to be completed in a single lesson, no extra provision of time was needed for the classes selected for the research. Before any student completed the survey, parent and student consent were sought. The teacher of each science class informed the students about my research and invited them to participate. The students were assured that participation in the research was voluntary and that they were free to withdraw at any stage. A participant information sheet and a consent form were handed out to every student in each class involved. Consent was required from both the students and one of their parents or guardians. The survey was only administered to the students who returned a consent form signed by both the student and parent or guardian.

Approximately 40% of the students in Years 9 and 10 in the four schools were involved in the final sample. The survey was administered by the students' science teacher during a science lesson. I did not feel it necessary to undertake the administration of the survey personally because the framework of the study was clear to teachers and administrators and because the questionnaires were straightforward.

3.5 DATA ANALYSES

This section identifies which statistical analyses were undertaken with the data collected with the SLEI and the attitudes questionnaire. Section 3.5.1 discusses validation of the SLEI, SALES and the Future Intentions scales. Section 3.5.2 outlines the analyses conducted to investigate the statistical significance of differences based on the independent variables of sex and frequency of practical work for the five SLEI scales, the Future Intentions scale and the four scales from the SALES questionnaire. The analyses conducted to investigate associations between students' perceptions of their science laboratory environment and their attitudes towards science are described in Section 3.5.3.

3.5.1 Validation of SLEI, SALES and Future Intentions Scales

Statistical analyses were conducted to examine the internal structure of the 35 items of the SLEI for the sample of 431 Year 9 and 10 students. Principal axis factor analysis with varimax rotation and Kaiser normalisation was used to determine the factorial validity of the SLEI when used with middle-school students in metropolitan Adelaide. The criteria used for retaining any SLEI item were that it must have a factor loading of at least 0.40 for its *a priori* scale and a factor loading of less than 0.40 with each other scale. The individual student was used as the unit of analysis. Any items that did not meet the above criteria were removed.

For the revised 33-item SLEI, two additional measures of scale reliability and validity were generated. Internal consistency is the extent to which items in the same scale measure the same dimension. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency. An alpha coefficient of at least 0.70 is considered satisfactory and a value of 0.80 is considered good (Cohen et al., 2000). The mean correlation of a scale with the other four scales was used as a convenient index of discriminant validity, or independence, which is the degree of overlap of one scale with the other scales. A low discriminant validity value indicates that less overlap exists between a scale and the other scales.

Principal axis factor analysis with varimax rotation and Kaiser normalisation was also used to determine the factorial validity of the SALES questionnaire and the Future Intentions scale, when used with my sample of 431 middle-school students in metropolitan Adelaide. The SALES questionnaire and the Future Intentions scale were included in the same factor analysis and with the individual student used as the unit of analysis. For the Future Intentions and SALES scales, the Cronbach alpha reliability coefficient was used as an index of scale internal consistency, and the mean correlation of a scale with the other four scales was used as a convenient index of discriminant validity.

3.5.2 Sex and frequency of Practical Work as Determinants of Students' Perceptions of their Laboratory Environment and their Attitudes

To investigate the statistical significance of differences based on the independent variables of sex and frequency of practical work, a two-way MANOVA was conducted with the set of dependent variables being the five SLEI scales, the Future Intentions scale and the four scales from the SALES questionnaire. If the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, the univariate two-way ANOVA would be interpreted for each individual scale. If the interaction effect proved to be statistically nonsignificant for all scales, it not only would be meaningful to interpret the results independently for sex and frequency of laboratory work, but also my results concerning the effectiveness of an increased frequency of practical work could be applied equally well to male and female students.

The average item mean and the average item standard deviation for each classroom environment and attitude scale were determined for three different frequencies of practical work:

- on average once every three or more weeks (≥ 3wks);
- on average once every two weeks (2 wks);
- at least once a week (≤ 1wk).

In order to explore further the differences between each pair of different laboratory work frequencies, effect sizes were calculated as recommended by Thompson (2001) to portray the magnitude of differences in standard deviation units. Effect sizes provide a measure of the magnitude of the importance of differences in scale scores between practical work frequencies. The differences between practical work frequencies for each scale were calculated by dividing the difference in average item mean for each practical work frequency pair by the pooled standard deviation for those practical work frequencies. Also Tukey's HSD multiple comparison procedure was used to determine the statistical significance of differences between each pair of frequencies of practical work.

The average item mean and average item standard deviation for each classroom environment and attitude scale were determined separately for males and females. In order to estimate the magnitude of the differences between males and females, effect sizes again were calculated. The differences between males and females for each scale were calculated by dividing the difference in average item means for males and females by the pooled standard deviation for males and females.

3.5.3 Associations between Students' Perceptions of their Science Laboratory Environment and their Attitudes towards Science

Simple correlation and multiple regression analyses were used to explore associations between each attitude scale and the five laboratory environment scales. Simple correlation analysis is appropriate for examining the bivariate relationship between two specific variables. Multiple regression analyses provide information about the multivariate association between each attitude scale and the set of five environment scales. The multiple correlations describe the multivariate association between each attitude scale and the whole set of learning environment scales. Multiple regression analyses provide information about the SLEI scales that were most strongly and independently related to the Future Intentions and SALES scales. Using the standardised regression coefficients, I identified which environment scales contributed uniquely and significantly to the explanation of the variance in an attitude scale when all other SLEI scales were mutually controlled.

3.6 SUMMARY OF THE CHAPTER

This chapter described the sample involved in the study, the instruments used in the data-collection phase, the process used to ensure the effective administration of the instrument and the amount of time chosen for questionnaire administration. The data analyses conducted for each of the research questions were also outlined.

The study was undertaken in metropolitan Adelaide, South Australia with a sample of 431 students from four coeducational schools: two Independent schools and two Catholic schools. Year 9 and 10 students were selected for this study because subject selection for Year 11 is influenced by students' most recent experiences in Years 9 and 10. A pilot study was undertaken with one class of 20 Year 9 students to determine the suitability of the wording of the items and the five-point agreement scale, the length of time it took to answer the survey, and whether any ambiguities were experienced with the survey.

Scales from two questionnaires, the Science Laboratory Environment Inventory (SLEI) and the Student Adaptive Learning Engagement in Science (SALES) questionnaire, formed the basis of the survey used in this study. Also, a Future Intentions scale was developed to assess students' aspirations to study science at the senior secondary level.

If scales could be shown to be valid, then interpretation of quantitative data for other parts of this study could be based upon an instrument that had satisfied extensive statistical interrogation and exhibited coherence and congruence. Principal axis factor analysis with varimax rotation and Kaiser normalisation was used to determine the factorial validity of the SLEI, as well as the factorial validity of the Future Intentions and SALES scales. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency of each scale. The mean correlation of a scale with the other four scales was used as a convenient index of discriminant validity for the SLEI and for the Future Intentions and SALES scales.

The statistical significance of differences between practical work frequencies and between males and females was investigated using a two-way MANOVA with the set of dependent variables being the five SLEI scales, the Future Intentions scale and the four scales from the SALES questionnaire. Because the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, univariate two-way ANOVAs were interpreted for each individual scale. In addition, effect sizes were used to provide information about the magnitude of differences between males and females, and between the different frequencies of practical work, expressed in standard deviation units.

Associations between students' perceptions of the laboratory environment and students' attitudes towards science were examined using simple correlation and multiple regression analyses. Simple correlation analysis provided information about the bivariate association between each attitude and learning environment scale. Multiple regression analysis was used to investigate the multivariate association between the set of learning environment scales and each attitude scale.

The next chapter describes in detail the data analyses and findings of this study.

Chapter 4

DATA ANALYSES AND FINDINGS

4.1 INTRODUCTION

The purpose of this chapter is to describe the data analyses and findings for my study, which had three main purposes. The first was to modify and validate the SLEI and SALES questionnaire. The second purpose was to determine if student sex and the frequency of practical work are determinants of students' perceptions of their science laboratory environment (SLEI), their motivation towards science (SALES) and their intention to study science at the senior secondary level (based on the Career Interest in Science scale from the TOSRA). The third purpose was to investigate associations between students' perceptions of their laboratory learning environment and their attitudes towards science. The sample of 431 Year 9 and 10 science students was taken from four schools across metropolitan Adelaide, South Australia.

Analyses of the data collected using these instruments helped to answer the following research questions:

1. Are modified versions of the SLEI and the SALES questionnaire valid when used with middle-school students in Adelaide?
2. Are (i) the frequency of practical work and (ii) sex determinants of students':
    a. perceptions of the science laboratory environment;
    b. motivation towards science;
    c. aspirations to study science in Year 11 and 12?

3. Are there relationships between middle-school students' perceptions of their science laboratory environment and students':
    a. motivation towards science;
    b. aspirations to study science in Year 11 and 12?

The findings from analyses of survey data are reported in this chapter in the following sections: the validity and reliability of the SLEI (Science Laboratory Environment Inventory) and the SALES (Student Adaptive Learning Engagement in Science) questionnaire (Section 4.2); sex and the frequency of practical work as determinants of students' perceptions of the laboratory environment, their motivation in science lessons and their intention to study science at the senior secondary school level (Section 4.3); and relationships between students' perceptions of the laboratory learning environment, their motivation towards science and their intention to study science at the senior secondary school level (Section 4.4).

4.2 VALIDITY AND RELIABILITY OF SLEI AND ATTITUDE QUESTIONNAIRES

The two main questionnaires that formed the basis of the survey, outlined in Chapter 3, were the Science Laboratory Environment Inventory (SLEI) (Section 3.3.1) and the Student Adaptive Learning Engagement in Science (SALES) questionnaire (Section 3.3.2). As well, a Future Intentions scale (to measure the likelihood of students undertaking study of senior science subjects) was developed from the Career Interest in Science scale from the Test of Science-Related Attitudes (TOSRA) (Section 3.3.3).

The SLEI was created in response to the need to assess the learning environment specific to science laboratory classes, particularly in upper-secondary and higher-education contexts (Fraser et al., 1995). It measures the five dimensions of Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment. Each of these scales consists of 7 items, making 35 items in total. For further information about the SLEI, refer to Sections 2.2.3 and 3.3.1.

The SALES questionnaire was developed to assess students' motivation and self-regulation in science learning (Velayutham et al., 2011). It consists of four scales: Learning Goal Orientation, Task Value, Self-Efficacy and Self-Regulation. Each of the four scales of the SALES questionnaire has 8 items, making 32 items in total. More details about the SALES are provided in Sections 2.3.2 and 3.3.2. A Future Intentions scale, consisting of 6 items, was developed to assess student aspirations to study science at the senior secondary level. The Future Intentions scale was incorporated into the same questionnaire as the SALES for convenience in administration and data analysis only.

This section reports findings using the following organisation:

- Factor structure of the SLEI (4.2.1)
- Factor structure of the modified SALES questionnaire (4.2.2)
- Internal consistency reliability and discriminant validity of the SLEI (4.2.3)
- Internal consistency reliability and discriminant validity of the modified SALES questionnaire (4.2.4)

4.2.1 Factor Structure of the SLEI

Statistical analyses were conducted to examine the internal structure of the 35 items of the SLEI for the sample of 431 Year 9 and 10 students. Principal axis factor analysis with varimax rotation and Kaiser normalisation was used to determine the factorial validity of the SLEI when used with middle-school students in metropolitan Adelaide. Table 4.1 shows the factor loadings obtained for the SLEI (five scales) using the individual student as the unit of analysis, along with the percentage of variance and eigenvalues for each scale.

The criteria used for retaining any SLEI item were that it must have a factor loading of at least 0.40 for its *a priori* scale and a factor loading of less than 0.40 with each of the other four SLEI scales. The application of these criteria led to the retention of all items in their original scales, except SC7 and OE10 (see Table 4.1).

The percentage variance accounted for by different SLEI scales varied from 5.13% to 24.94% with a total of 52.78%. The value of the eigenvalue varies from 1.79 to 8.72 for different scales (see the bottom of Table 4.1). A commonly-used criterion to determine the number of factors to rotate is the eigenvalues-greater-than-one rule (Kaiser, 1960), which states that there are as many reliable factors as there are eigenvalues greater than one. All of the eigenvalues in Table 4.1 are satisfactory because they are all greater than one.

Table 4.1 provides strong support for the factorial validity of the SLEI when used in this study of middle-school students from metropolitan Adelaide. This study replicates research which has supported the factor structure of the actual version of the SLEI in several different Western and Asian countries (Fraser et al., 1995; Fraser & Lee, 2009; Fisher, Henderson & Fraser, 1997; Lightburn & Fraser, 2007; Wong & Fraser, 1995).

Table 4.1 Factor Analysis Results for Learning Environment Scales

Item	Factor Loadings				
	Student Cohesiveness	Open-Endedness	Integration	Rule Clarity	Material Environment
SC1	0.61				
SC2	0.58				
SC3	0.73				
SC4	0.69				
SC5	0.59				
SC6	0.51				
OE8		0.48			
OE9		0.56			
OE11		0.62			
OE12		0.64			
OE13		0.63			
OE14		0.59			
I15			0.66		
I16			0.65		
I17			0.63		
I18			0.63		
I19			0.69		
I20			0.56		
I21			0.69		
RC22				0.64	
RC23				0.65	
RC24				0.72	
RC25				0.67	
RC26				0.72	
RC27				0.49	
RC28				0.42	
ME29					0.66
ME30					0.48
ME32					0.68
ME32					0.60
ME33					0.63
ME34					0.68
ME35					0.65
% Variance	6.02	5.13	24.92	8.75	7.96
Eigenvalue	2.11	1.79	8.72	3.06	2.69

Principal axis factor analysis with varimax rotation and Kaiser normalisation.
Factor loadings smaller than 0.40 have been omitted.
Items SC7 and OE10 were omitted
N=431

4.2.2 Factor Structure of Modified SALES Questionnaire

Principal axis factor analysis with varimax rotation and Kaiser normalisation was also used to determine the factorial validity of my modified version of the SALES questionnaire that included the Future Intentions scale, when used with my sample of 431 middle-school students in metropolitan Adelaide. The SALES questionnaire and the Future Intentions scale were included in the same factor analysis. Table 4.2 shows the factor loadings for the SALES questionnaire (four scales, each with eight items) and the Future Intentions scale (six items), using the individual student as the unit of analysis, along with the percentage of variance and eigenvalue for each scale.

Every item had a factor loading of at least 0.40 for its own *a priori* scale and a factor loading of less than 0.40 for all other attitude scales. Therefore all items were retained in their original scales. The percentage variance varied from 4.96% to 42.18% for different attitude scales, with a total of 66.36% of the variance accounted for. The value of the eigenvalue varies from 1.88 to 16.03 for different attitude scales. As recommended by Kaiser (1960), the results indicate that each eigenvalue for each factor in Table 4.2 is satisfactory because it is greater than one.

Therefore Table 4.2 provides strong support for the factorial validity of the Future Intentions scale and the SALES questionnaire when used in this study of middle-school students from metropolitan Adelaide. These results replicate the findings of Velayutham, Aldridge and Fraser (2011) for their sample of 1360 students in Years 8, 9 and 10 across 78 classes. This analysis also suggests that the Future Intentions scale is independent of the four SALES scales.

Table 4.2 Factor Analysis Results for Attitude Scales

Item	Factor Loadings				
	Future Intention to Study Science	Learning Goal Orientation	Task Value	Self-Efficacy	Self-Regulation
FI36	0.83				
FI37	0.76				
FI38	0.73				
FI39	0.66				
FI40	0.69				
FI41	0.83				
LGO42		0.59			
LGO43		0.61			
LGO44		0.61			
LGO45		0.74			
LGO46		0.71			
LGO47		0.66			
LGO48		0.68			
LGO49		0.56			
TV50			0.58		
TV51			0.57		
TV52			0.77		
TV53			0.79		
TV54			0.71		
TV55			0.63		
TV56			0.59		
TV57			0.55		
SE58				0.64	
SE59				0.67	
SE60				0.67	
SE61				0.63	
SE62				0.60	
SE63				0.72	
SE64				0.68	
SE65				0.62	
SR66					0.71
SR67					0.76
SR68					0.72
SR69					0.69
SR70					0.42
SR71					0.66
SR72					0.66
SR73					0.63
% Variance	5.41	4.96	42.18	7.59	6.22
Eigenvalue	2.05	1.88	16.03	2.88	2.36

Principal axis factor analysis with varimax rotation and Kaiser normalisation.
Factor loadings smaller than 0.40 have been omitted.
N=431

4.2.3 Internal Consistency Reliability and Discriminant Validity of the SLEI

For the revised 33-item SLEI, two indices of scale reliability and validity were generated. Internal consistency is the extent to which items in the same scale measure the same dimension. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency. Generally, an alpha coefficient of at least 0.70 is considered satisfactory and a value of 0.80 is considered good (Cohen et al., 2000). Discriminant validity measures the independence of each dimension, or the degree of overlap of one scale with the other scales. A low discriminant validity value for a particular scale indicates that less overlap exists between that scale and the other scales. The mean correlation of a scale with the other four SLEI scales was used as a convenient index of discriminant validity in my study.

Table 4.3 shows that the Cronbach alpha reliability coefficients for the five SLEI scales, using the individual student as the unit of analysis, were high and ranged from 0.78 to 0.87. The discriminant validity, also shown in Table 4.3 and using the individual student as the unit of analysis, ranged from 0.27 to 0.39. These results suggest that raw scores on the SLEI measure distinct (but somewhat overlapping) aspects of classroom environment, but the factor analysis results reported in Section 4.2.1 attest to the independence of factor scores. The results in Table 4.3 replicate past studies that have supported the SLEI’s internal consistency reliability and discriminant validity (Fraser et al., 1993; Henderson et al., 2000).

Table 4.3 Mean, Standard Deviation, Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for SLEI

Scale	No of Items	Mean	SD	Alpha Reliability	Mean Correlation
Student Cohesiveness	6	3.86	0.57	0.81	0.27
Open-Endedness	6	2.73	0.72	0.78	0.28
Integration	7	3.88	0.63	0.87	0.36
Rule Clarity	7	4.01	0.57	0.83	0.33
Material Environment	7	3.68	0.71	0.86	0.39

N=431

4.2.4 Internal Consistency Reliability and Discriminant Validity of the Modified SALES Questionnaire

For the Future Intentions scale and the four SALES scales, the same two indices of scale reliability and validity were generated. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency, and the mean correlation of a scale with the other four scales was used as a convenient index of discriminant validity.

Table 4.4 shows that the Cronbach alpha reliability coefficients for the five attitude scales, using the individual student as the unit of analysis, were high and ranged from 0.91 to 0.93. The discriminant validity, shown in Table 4.4 using the individual student as the unit of analysis, ranged from 0.50 to 0.59. These results suggest that raw scores on the SALES measure distinct (but somewhat overlapping) aspects of student attitudes, but the factor analysis results in Table 4.2 support the independence of the factor scores. The results in Table 4.4 replicate the results of Velayutham et al. (2011).

Table 4.4 Mean, Standard Deviation, Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for Attitude Scales

Scale	No of Items	Mean	SD	Alpha Reliability	Mean Correlation
Future Intention To Study Science	6	2.74	1.09	0.93	0.50
Learning Goal Orientation	8	3.84	0.75	0.92	0.57
Task Value	8	3.32	0.82	0.92	0.59
Self-Efficacy	8	3.61	0.73	0.91	0.57
Self-Regulation	8	3.49	0.78	0.91	0.52

N=431

4.3 STUDENT SEX AND FREQUENCY OF PRACTICAL WORK AS DETERMINANTS OF LABORATORY ENVIRONMENT PERCEPTIONS AND ATTITUDES

My second research question involved sex and frequency of practical work as determinants of students' perceptions of their laboratory environment, their motivation towards science and their intentions to study science. For this study 'practical work' was defined as a method for learning the processes and skills involved in the development of scientific literacy (Bradley, 2005) and included teacher demonstrations, closed laboratory exercises, practical design tasks, open-ended student-choice investigations and field work. These differences were investigated using the sample of 431 students in Years 9 and 10 from four schools across metropolitan Adelaide.

To investigate the statistical significance of differences based on the independent variables of sex and frequency of practical work, a two-way MANOVA was conducted with the set of dependent variables being the five SLEI scales, the Future Intentions scale and the four scales from the SALES questionnaire. Because the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, the univariate two-way ANOVA was interpreted for each individual scale.

Table 4.5 shows the *F* ratio obtained for each dependent variable for sex, the frequency of practical work, and the interaction of sex with the frequency of practical work. Because the interaction effect was statistically nonsignificant for all scales, it was meaningful to interpret the results independently for sex and frequency of laboratory work; as well, the absence of interactions effects suggests that any findings about the frequency of practical work can be applied equally well to male and female students. Table 4.5 shows that statistically significant differences ($p<0.05$) emerged for student sex for four scales (Integration, Rule Clarity, Future Intentions and Self-Efficacy) and for frequency of practical work for five scales (Open-Endedness, Integration, Material Environment, Task Value and Self-Regulation).

The results are discussed below in two sections. The frequency of practical work as a determinant of students' perceptions of their laboratory environment, their motivation towards science and their intentions to study science is discussed in Section 4.3.1. Student sex as a determinant of students' perceptions of their laboratory environment, their motivation towards science and their intentions to study science is discussed in Section 4.3.2.

Table 4.5 Two-Way ANOVA for Sex and Frequency of Laboratory Work for SLEI and Attitude Scales

	Scale	*F*		
		Sex	Frequency of Lab Work	Sex x Frequency of Lab Work
Learning Environment	Student Cohesiveness	1.40	0.45	0.03
	Open-Endedness	0.07	7.58**	1.19
	Integration	3.94*	6.87**	0.86
	Rule Clarity	3.67*	1.59	0.31
	Material Environment	3.17	4.04*	1.25
Attitudes	Future Intentions	4.59*	0.77	0.99
	Learning Goal Orientation	0.18	2.28	0.28
	Task Value	1.71	8.21**	0.15
	Self-Efficacy	8.47**	0.54	0.06
	Self-Regulation	0.00	4.13*	0.55

Sample Size = Females 221, Males 210
Frequency of Lab Work: ≥3 wks = 121, 2 wks = 204, ≤1 wk = 106
**p*<0.05, ***p*<0.01

4.3.1 Frequency of Practical Work as a Determinant of Students' Perceptions of their Laboratory Environment, Motivation towards Science and Intentions to Study Science

Table 4.6 reports the average item mean and the average item standard deviation for each classroom environment and attitude scale for three different frequencies of practical work. The following descriptors were used to refer to different frequencies of undertaking practical work:

- "≥3 wks" refers to student perceptions that practical work was undertaken on average once every three or more weeks;

- "2 wks" refers to student perceptions that practical work was undertaken on average once every two weeks;
- "≤1 wk" designates that students perceived that practical work was undertaken on average once a week or more frequently.

The ANOVA results from Table 4.5 are repeated in Table 4.6 to show the statistical significance of differences between the different frequencies of practical work for each scale.

Tables 4.5 and 4.6 show that statistically significant differences were found for frequency of practical work for the environment scales of: Open-Endedness, Integration and Material Environment and for the attitude scales of Task Value and Self-Regulation. Generally the scale means in Table 4.6 suggest that more frequent practical work was linked with higher scores for perceived classroom Open-Endedness, Integration and Material Environment and more positive attitudes for Task Value and Self-Regulation.

However, the means in Table 4.6 also suggest that, for the scales of Open-Endedness, Integration and Material Environment, the differences between the practical work frequencies of once every three or more weeks and once every week or more are larger than the differences for the other two comparisons (once every three or more weeks and once every two weeks, and once every two weeks and once a week or more). For the scales of Task Value and Self-Regulation, Table 4.6 shows larger differences between the practical work frequencies of once every three or more weeks and once every two weeks than for the other two practical work frequency comparisons (once every three or more weeks with once a week or more, and once every two weeks with once a week or more). This is explained further below.

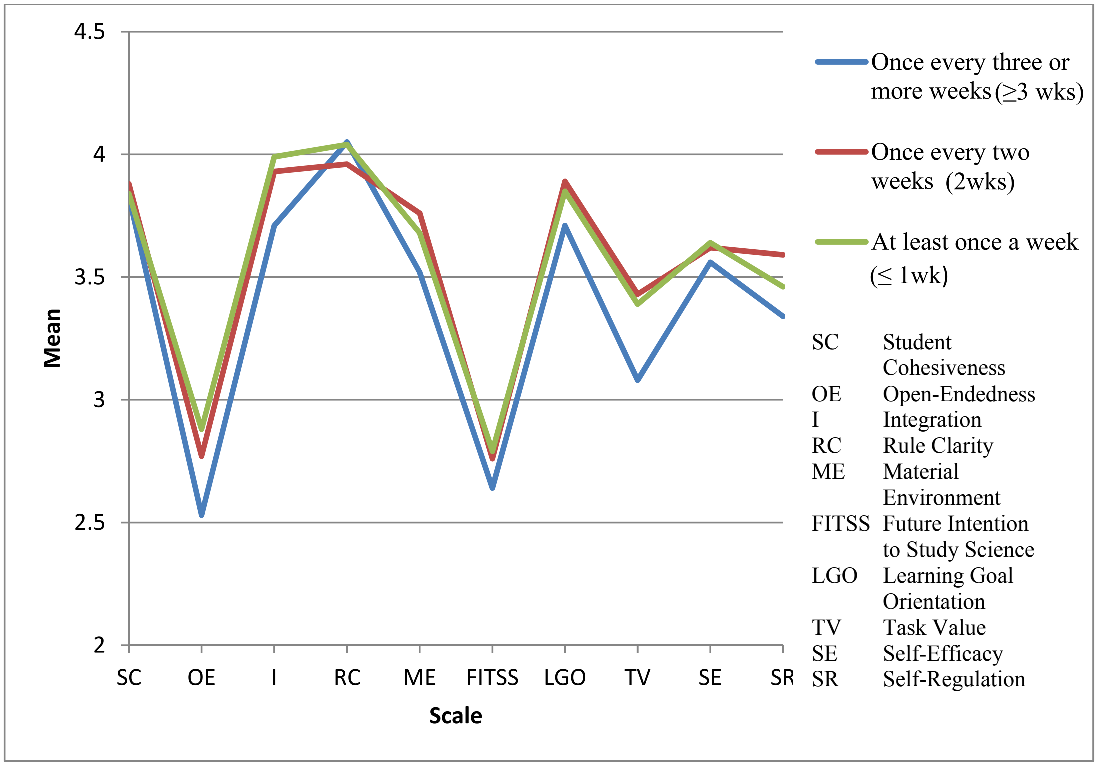
Table 4.6 Mean, Standard Deviation and ANOVA Results for Differences between Three Frequencies of Laboratory Work for Learning Environment and Attitude Scales

	Scale	Mean			SD			*F*
		≥ 3 wks	2 wks	≤ 1 wk	≥ 3 wks	2 wks	≤ 1 wk	
Learning Environment	Student Cohesiveness	3.83	3.88	3.84	0.54	0.57	0.59	0.45
	Open-Endedness	2.53	2.77	2.88	0.65	0.76	0.64	7.58**
	Integration	3.71	3.93	3.99	0.69	0.58	0.61	6.87**
	Rule Clarity	4.05	3.96	4.04	0.56	0.58	0.53	1.59
	Material Environment	3.52	3.76	3.68	0.71	0.73	0.66	4.04*
Attitudes	Future Intentions	2.64	2.76	2.79	1.08	1.07	1.12	0.77
	Learning Goal Orientation	3.71	3.89	3.85	0.77	0.73	0.76	2.28
	Task Value	3.08	3.43	3.39	0.84	0.78	0.82	8.21**
	Self-Efficacy	3.56	3.62	3.64	0.81	0.70	0.67	0.54
	Self-Regulation	3.34	3.59	3.46	0.87	0.73	0.73	4.13*

*$p<0.05$, **$p<0.01$ N = 121 (≥3 wks), 204 (2 wks), 106 (≤ 1 wk)
≥ 3 wks: practical work frequency of on average once every three or more weeks
2 wks: practical work frequency of on average once every two weeks
≤ 1 wk: practical work frequency of on average once a week or more frequently

Figure 4.1 depicts in a graphical form the mean values of each frequency of practical work for student perceptions of the laboratory learning environment and attitudes to science. This graph demonstrates that the frequency of practical work is a determinant of more favourable learning environment and attitude scores on some scales. Generally, the more frequently that students engaged in practical work, the more positive were the scores on these scales.

Figure 4.1 Differences between Three Frequencies of Laboratory Work for Learning Environment and Attitude Scales



In order to explore further the differences between each pair of different laboratory work frequencies for each scale, effect sizes were calculated as recommended by Thompson (2001) to portray the magnitude of differences, whereas Tukey's HSD multiple comparison procedure was used to determine the statistical significance of differences. Table 4.7 shows the magnitudes and statistical significance of differences between pairs of laboratory work frequencies (≥3 wks vs. 2 wks; 2 wks vs. ≤1 wk.; ≥3 wks vs. ≤1 wk). For simplicity, Table 4.7 is restricted to the cases in

Table 4.6 for which there were statistically significant overall differences based on frequency of practical work.

Table 4.7 Effect Size and Tukey's HSD Multiple Comparison for Statistical Significance of Difference Between each Pair of Frequencies of Practical Work for Learning Environment and Attitude Scales for which Significant Overall Differences were Found

Scale	Effect Size & Tukey HSD		
	≥3 wks vs. 2 wks	2 wks vs. ≤1 wk	≥3 wks vs. ≤1 wk
Open-Endedness	0.33**	0.15*	0.54**
Integration	0.34**	0.10*	0.42**
Material Environment	0.33**	-0.11	0.23**
Task Value	0.43**	-0.04	0.37**
Self-Regulation	0.31**	-0.18*	0.14*

*$p<0.05$, **$p<0.01$
N = 121 (≥3 wks), 204 (2 wks), 106 (≤1 wk)
≥ 3 wks: practical work frequency of on average once every three or more weeks
2 wks: practical work frequency of on average once every two weeks
≤ 1 wk: practical work frequency of on average once a week or more frequently

Effect sizes provide a measure of the magnitude or the importance of differences in scale scores between practical work frequencies. The differences between practical work frequencies for each scale were calculated by dividing the difference in average item mean for each practical work frequency pair by the pooled standard deviation for those practical work frequencies. Thompson (2001) states that effect size interpretation should not be as rigid as interpretation of other statistics, such as alpha coefficients.

The first column of results in Table 4.7 provides a comparison of students experiencing practical work with a frequency of once every 3 or more weeks (≥3 wks) with students experiencing practical work with a frequency of approximately once every 2 weeks (2 wks) for the five scales of Open-Endedness, Integration, Material Environment, Task Value and Self-Regulation for which significant results were reported in Table 4.6. These results suggest that a change in frequency of practical work from once every 3 or more weeks to a frequency of approximately once every 2 weeks was associated with statistically significant ($p<0.01$) differences ranging from 0.31 to 0.43 standard deviations for these five scales. These effect sizes could be considered moderate.

In contrast, the second column of results in Table 4.7 shows that increasing the frequency of practical work from approximately once every 2 weeks (2 wks) to at least once every week (≤1 wk) was associated with only very small changes of between 0.04 and 0.18 standard deviations for the five different scales. These changes were statistically significantly positive for Open-Endedness and Integration, were statistically non-significant for Material Environment and Task Value, and were statistically significantly negative for Self-Regulation. These results suggest ‘diminishing returns’ for increasing the frequency of practical work from about once every two weeks to at least once a week. Specifically, small gains were found for Open-Endedness and Integration, but a small decrease was found for Self-Regulation. The small decrease for Self-Regulation suggests that, as the frequency of practical work was increased, students perceived that they were less able to concentrate in class, complete set tasks on time and continue working even if the work was hard or there were better things to do.

The third column of results in Table 4.7 shows that increasing the frequency of practical work from once every 3 or more weeks to at least once a week was associated with small to medium changes ranging between 0.14 and 0.54 standard deviations. Increasing the frequency of practical work had the largest effect for

Open-Endedness (0.54 standard deviations) and Integration (0.42 standard deviations).

The results from Table 4.7 suggest that the most beneficial frequency of practical work in terms of Material Environment, Task Value and Self-Regulation was about once every two weeks, but the most beneficial frequency of practical work for Open-Endedness and Integration was at least once a week overall. A practical work frequency of once every three or more weeks was less beneficial than practical work frequencies of once every two weeks or at least once a week. Furthermore, the absence of any statistically significant frequency–by–sex interactions suggests that the above findings apply equally well to male and female students.

4.3.2 Sex as a Determinant of Students' Perceptions of their Laboratory Environment, Motivation towards Science and Intentions to Study Science

Tables 4.5 and 4.8 show that statistically significant differences between the sexes were found for the environment scales of Integration and Rule Clarity and for the attitude scales of Future Intentions and Self-Efficacy. Table 4.8 reports the average item mean and average item standard deviation for each classroom environment and attitude scale separately for males and females. In order to estimate the magnitude of the differences between males and females, effect sizes were calculated as recommended by Thompson (2001). Effect sizes provide a measure of the magnitude of the importance of differences in scale scores between males and females. The differences between males and females for each scale were calculated by dividing the difference in average item mean for males and females by the pooled standard deviation for males and females.

The effect sizes in Table 4.8 show the magnitudes of the differences between males and females expressed in standard deviations. Table 4.8 also repeats the ANOVA results from Table 4.5 to show the statistical significance of differences between males and females for each scale.

The results presented in Table 4.8 show that statistically significant differences were present between males and females for the learning environment scales of Integration and Rule Clarity, as well as for the attitude scales of Future Intentions and Self-Efficacy. The effect sizes for the four scales for which sex differences were statistically significant ranged from 0.18 to 0.28 of a standard deviation, which are relatively small differences according to Cohen (1988).

Interestingly, the direction of sex differences for the environment scales was different from the direction of sex differences for the attitude scales. Table 4.8 shows that females were more positive than males about their laboratory learning environment, but males were more positive than females about their future career intentions in science and their self-efficacy.

Figure 4.2 depicts in a graphical form the mean values of each laboratory learning environment and attitude to science scale separately for males and females. This graph demonstrates that, relative to males, females generally had more positive perceptions of their learning environment, but less positive attitudes for career interest in science and self-efficacy.

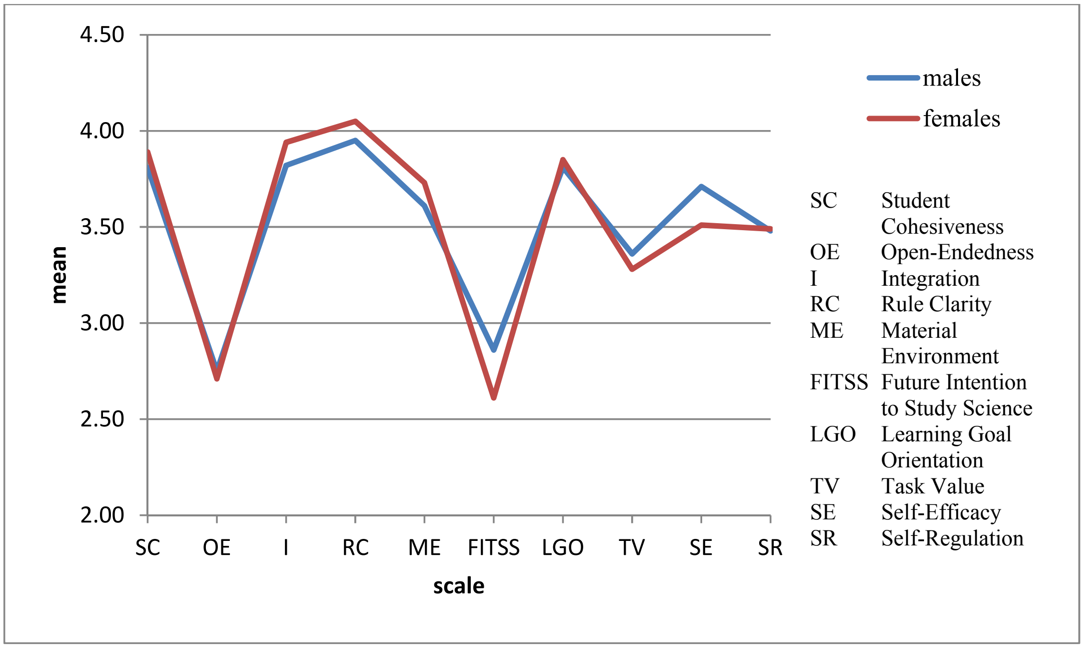
Table 4.8 Sex Differences for Learning Environment and Attitude Scales

	Scale	Mean		SD		Difference	
		Male	Female	Male	Female	*F*	Effect Size
Learning Environment	Student Cohesiveness	3.81	3.89	0.62	0.52	1.40	-0.14
	Open-Endedness	2.75	2.71	0.75	0.67	0.07	0.06
	Integration	3.82	3.94	0.66	0.59	3.94*	-0.19
	Rule Clarity	3.95	4.05	0.60	0.53	3.67*	-0.18
	Material Environment	3.61	3.73	0.73	0.69	3.17	-0.17
Attitudes	Future Intentions	2.86	2.61	1.03	1.13	4.59*	0.23
	Learning Goal Orientation	3.81	3.85	0.71	0.79	0.18	-0.05
	Task Value	3.36	3.28	0.81	0.82	1.71	0.10
	Self-Efficacy	3.71	3.51	0.71	0.73	8.47**	0.28
	Self-Regulation	3.48	3.49	0.78	0.77	0.00	-0.01

*$p<0.05$, **$p<0.01$
N = Males 210, Females 221

In the absence of insights from qualitative research, it would be highly speculative to guess at explanations for these differences. The results of my study replicate many past classroom environment studies that have revealed that, generally, females have more favourable perceptions of the learning environment than their male counterparts (Fraser, 2002, 2007). Past research has also shown that males reported more favourable attitudes than females for enjoyment of science, instrumental motivation, future orientation to study or work in science, science self-efficacy and science self-concept (Thomson & DeBortoli, 2008).

Figure 4.2 Sex Differences for Each Learning Environment and Attitude Scale



4.4 RELATIONSHIPS BETWEEN THE LABORATORY LEARNING ENVIRONMENT, STUDENT MOTIVATION TOWARDS SCIENCE AND STUDENT ATTITUDES

Associations between students' perceptions of the laboratory environment (as assessed by the actual form of the SLEI), their motivation towards science (as assessed by the SALES questionnaire) and their intentions to study science further (as assessed by a scale developed from the Career Interest in Science scale from the TOSRA) are reported in Table 4.9 These associations were investigated using the sample of 431 Year 9 and 10 students from four schools across metropolitan Adelaide. The statistics reported in Table 4.9 are the simple correlations, standardised regression coefficients and multiple correlations between each attitude scale and the five laboratory environment scales.

The simple correlation analysis (*r*) is appropriate for examining the bivariate relationship between two specific variables. The multiple regression analysis provides information about the multivariate association between an attitude scale and the set of five environment scales. Using the standardised regression coefficients (β), we can identify which environment scales contribute uniquely and significantly to the explanation of the variance in an attitude scale when all other SLEI scales are mutually controlled.

Table 4.9 shows that, with the individual student as the unit of analysis, all of the environment scales were statistically significantly correlated ($p<0.01$) with every attitude scale, with only one the exception (namely, Future Intentions and Student Cohesiveness).

The multiple correlations (*R*) reported at the bottom of Table 4.9 for the set of five SLEI scales was statistically significant ($p<0.01$) for each of the five attitude scales.

To identify which classroom environment scales contributed most to the variance in a specific attitude scale, the standardised regression weights (β) were examined.

Table 4.9 Simple Correlation and Multiple Regression Analyses for Associations between Learning Environment and Attitude Scales

Scale	Attitude-Environment Association									
	Future Intentions		Goal Orientation		Task Value		Self-Efficacy		Self-Regulation	
	R	β	*r*	β	*r*	B	*r*	β	*r*	β
Student Cohesiveness	0.07	0.03	0.23**	0.10*	0.21**	0.03	0.16**	0.07	0.16**	0.07
Open-Endedness	0.34**	0.27**	0.22**	0.03	0.44**	0.28**	0.23**	0.11*	0.23**	0.09*
Integration	0.26**	0.13*	0.44**	0.29**	0.43**	0.21**	0.33**	0.21**	0.31**	0.14**
Rule Clarity	0.19**	0.10	0.36**	0.16**	0.29**	0.06	0.31**	0.21**	0.29**	0.13*
Material Environment	0.19**	0.01	0.34**	0.09	0.43**	0.19**	0.20**	0.04	0.31**	0.12*
Multiple Correlation *R*		0.38**		0.51**		0.59**		0.41**		0.39**

$*p<0.05, **p<0.01$
$N=431$

Table 4.9 shows that:

- Open-Endedness and Integration were statistically significant independent predictors of student Future Intentions to study science.
- Student Cohesiveness, Integration and Rule Clarity were statistically significant independent predictors of Goal Orientation.
- Open-Endedness, Integration and Material Environment were statistically significant predictors of Task Value.
- Open-Endedness, Integration and Rule Clarity were statistically significant predictors of Self-Efficacy.
- Open-Endedness, Integration, Rule Clarity and Material Environment were statistically significant predictors of Self-Regulation.

It is noteworthy that every statistically significant simple correlation and regression coefficient in Table 4.9 is positive, suggesting that a positive relationship existed between a more favourable laboratory learning environment and students' attitudes. This replicates considerable prior research with the SLEI (Brownson, 2005; Fraser et al., 1995; Fraser & Lee, 2009; Henderson et al., 2000; Lightburn & Fraser, 2007; McRobbie & Fraser, 1993a; Wong & Fraser, 1996).

Some particular associations in Table 4.9 between students' perceptions of their laboratory environments and their attitudes towards science are noteworthy. Integration was significantly and independently associated with every attitude scale. Also, Open-Endedness was significantly and independently associated with all attitude scales except Goal Orientation. Fraser and Lee (2009) also found that integration between practical and theory classes was the strongest predictor of several attitude criteria.

The result that Open-Endedness was a strong, positive and independent predictor of all scales except Goal Orientation contradicts the findings of Henderson et al. (2000) who, in their study of 489 senior biology students in eight schools in Tasmania, found that students had more negative science-related attitudes when laboratory work was more open-ended. Fraser et al. (1995) also found that senior students had negative science-related attitudes when laboratory work was open-ended. This difference in results could be explained by the need for senior students in Fraser et al.'s (1995) study to have a clear outcome for the tasks that they undertake because of the importance of gaining the highest possible tertiary-entrance score at the end of Year 12. In contrast, because my study involved a middle-school sample, students had more positive science-related attitudes when laboratory work was open-ended. It is noteworthy that my study was the first investigation of associations between SLEI scales and attitudes to include a measure of students' future intentions to study science. The tentative findings from my study were that Open-Endedness was a significant, positive and independent predictor of Future Intentions.

4.5 CONCLUDING REMARKS

This chapter has reported findings for three key research questions. Section 4.2 reported the validity and reliability of modified versions of the SLEI and the SALES questionnaires, together with a Future Intentions scale, when used with a sample of 431 middle-school science students from four coeducational schools (two

Independent and two Catholic) in Adelaide, South Australia. Section 4.3 reported results for sex and frequency of practical work as determinants of students' perceptions of the laboratory learning environment, their motivation in science lessons and their intention to study science at the senior secondary school level. Section 4.4 reported associations between students' perceptions of the laboratory learning environment and their motivation towards science and their intention to study science at the senior secondary school level.

The structure of the SLEI was examined using principal axis factor analysis with varimax rotation and Kaiser normalisation. A similar factor analysis was used to examine the structure of the attitude scales (namely, four SALES scales and the Future Intentions scale). All items of the SLEI except Item 7 in Student Cohesiveness and Item 10 in Open-Endedness had factor loadings of at least 0.40 on their own scale and less than 0.40 on all other scales, resulting in the acceptance of a version of the SLEI comprising 33 items in 5 scales. The total percentage variance accounted for was 52.78%. All items of the SALES questionnaire and the Future Intentions scale had factor loadings of at least 0.40 on their own scale and less than 0.40 on all other scales, and therefore were retained. The total variance accounted for was 66.36%

The Cronbach alpha reliability coefficient was used as an index of scale internal consistency, and the mean correlation of a scale with the other four scales was used as a convenient index of discriminant validity. All scales of the SLEI and the SALES questionnaire exhibited sound internal consistency reliability. The separate scales from both questionnaires were found to measure distinct, but somewhat overlapping, aspects of the classroom environment and student attitudes.

These findings answer the first research question: the modified version of the SLEI and the modified version of the SALES that includes a Future Intentions scale were reliable and valid when used with middle-school science students in Adelaide.

The second research question involved (i) the frequency of practical work and (ii) sex as determinants of students' perceptions of the science laboratory environment, motivation towards science and aspirations to study science in Year 11 and 12. To investigate the statistical significance of differences based on the independent variables of sex and frequency of practical work, a two-way MANOVA was conducted with the set of dependent variables being the five SLEI scales, the Future Intentions scale and the four scales from the SALES questionnaire. Because the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, the univariate two-way ANOVA was interpreted for each individual scale. The interaction effect between sex and frequency of practical work was statistically nonsignificant for all scales. Overall statistically significant differences were found for frequency of practical work for the environment scales of Open-Endedness, Integration and Material Environment and for the attitude scales of Task Value and Self-Regulation.

In order to explore further the differences between each pair of different frequencies in laboratory work, effect sizes were calculated as recommended by Thompson (2001) to portray the magnitude of differences, and Tukey's HSD multiple comparison procedure was used to determine the statistical significance of differences. These analyses were restricted to the five scales (Open-Endedness, Integration, Material Environment, Task Value and Self-Regulation) for which MANOVA had revealed significant differences overall.

A change in frequency of practical work from once every 3 or more weeks to a frequency of approximately once every 2 weeks was associated with modest and statistically significant ($p<0.01$) increases in scores ranging from 0.31 to 0.43 standard deviations for each of these five scales (Open-Endedness, Integration, Material Environment, Task Value and Self-Regulation).

Increasing the frequency of practical work from approximately once every 2 weeks to at least once every week was associated with only small changes of between 0.04 and 0.18 standard deviations for the five different scales. These changes were statistically significant and positive for Open-Endedness and Integration, statistically non-significant for Material Environment and Task Value, and statistically significant and negative for Self-Regulation.

Increasing the frequency of practical work from once every 3 or more weeks to at least once a week was associated with small to medium changes of between 0.14 and 0.54 standard deviations for different scales. Increasing the frequency of practical work had the largest effect for Open-Endedness (0.54 standard deviations) and Integration (0.42 standard deviations).

The results suggest that the most beneficial frequency of practical work in terms of Material Environment, Task Value and Self-Regulation was about once every two weeks, but the most beneficial frequency of practical work for Open-Endedness and Integration was at least once a week. A practical work frequency of once every three or more weeks was less beneficial than the practical work frequencies of once every two weeks or at least once a week. Furthermore, because there were no statistically significant frequency–by–sex interactions, these findings apply equally well to male and female students.

Statistically significant but relatively small differences between males and females were found for the learning environment scales of Integration (effect size 0.19 standard deviations) and Rule Clarity (0.18), with females being more positive about their laboratory learning environment than males, and for the attitude scales of Future Intentions (effect size 0.23 standard deviations) and Self-Efficacy (0.28), with males expressing more positive attitudes.

Section 4.4 answered the third research question involving associations between students' perceptions of the learning environment, students' attitudes and students' future intentions. All of the environment scales were statistically significantly correlated with every attitude scale, with only exception (namely, Student Cohesiveness with Future Intentions). Standardised regression weights indicated that: Integration was statistically and independently associated with all attitude scales and the Future Intentions scale; Open-Endedness was statistically and independently associated with all attitude scales (except Goal Orientation) and was also statistically and independently associated with the Future Intentions Scale; Rule Clarity was statistically and independently associated with Goal Orientation, Self-Efficacy and Self-Regulation; Material Environment was statistically and independently associated with Task Value and Self-Regulation; and Student Cohesiveness was statistically and independently associated with Goal Orientation.

Every statistically significant simple correlation and regression coefficient was positive, suggesting a positive relationship between a more favourable laboratory learning environment and students' attitudes. This replicates considerable prior research (Fraser & Lee, 2009; Lightburn & Fraser, 2007; McRobbie & Fraser, 1993a). In particular, emphasis on classroom environment scales such as Integration and Open-Endedness was closely associated with positive student attitudes and student future intentions. These findings are important because these dimensions of the laboratory environment could provide the basis for greater student involvement in the study of science subjects at the senior-secondary level.

Chapter 5

CONCLUSION

5.1 INTRODUCTION

This chapter provides a summary of the material presented in the preceding chapters with the aim of answering the research questions posed in Chapter 1. The major findings of my study are drawn together (Section 5.2), the significance of the study is outlined (Section 5.3), limitations of the study are discussed (Section 5.4), directions for further research are suggested (Section 5.5) and concluding remarks are made (Section 5.6).

Chapter 1 provided a background for my study and delineated my research questions. Chapter 2 reviewed relevant literature related to past research on learning environments, attitudes, sex differences in science education and practical work. In particular, literature on the development and use of the SLEI and the SALES questionnaire was reviewed in depth. Chapter 3 outlined the methodology and included a description of the sample, the development of the questionnaires used in my study, the process of data collection and the data analyses conducted. A detailed reporting of the data analyses and findings was presented in Chapter 4 including: the validity and reliability of the SLEI and the SALES questionnaire; student sex and the frequency of practical work as determinants of students' perceptions of the laboratory environment, their motivation in science lessons and their intention to study science at the senior secondary school level; and relationships between students' perceptions of the laboratory learning environment and their motivation towards science and their intention to study science at the senior secondary school level.

Although numerous past studies have examined associations between student perceptions of the learning environment in science classes and student outcomes, relatively few studies in the field of learning environments have been conducted in middle-school science laboratory classes worldwide, and the SLEI has not previously been validated and used with middle-school students in Adelaide, South Australia.

Much research has involved the use of classroom environment instruments in exploring relationships between the classroom environment and student attitudes towards science (Fraser, 2012). The SALES is a new instrument that, apart from its validation study with 1360 middle-school students (Velayutham et al., 2011), has not been used in other published research. Also, I developed a Future Intentions scale for my study to assess student aspirations to study science at the senior secondary level.

Involvement in practical work is advocated in reviews of contemporary science education as one of the solutions to increasing student engagement in science and enrolment in science courses, but little research evidence supports this widespread belief. One of the aims of my study was to address this gap in the research by investigating frequency of practical work as a determinant of middle-school students' perceptions of their laboratory learning environments, their attitudes and their future intentions to study science at the senior secondary level.

Much past classroom environment research (e.g. Quek et al., 2005; Thompson & DeBertoli, 2008) has examined sex differences in perceptions of the learning environment, attitudes towards science and career aspirations. My study built on this research by investigating sex differences in students' perceptions of their laboratory learning environments, their attitudes towards science and their future intentions to study science at the senior-secondary level.

5.2 MAJOR FINDINGS OF THIS STUDY

My study posed three research questions. Each is restated below and addressed in turn.

Research Question One

Are modified versions of the SLEI and the SALES questionnaire valid when used with middle-school students in Adelaide?

The validity and reliability of modified versions of the SLEI and SALES questionnaire were investigated and reported in Sections 4.2.1 – 4.2.4.

Principal axis factor analysis with varimax rotation and Kaiser normalisation was conducted to examine the internal structure of the 35 items of the modified SLEI for the sample of 431 Year 9 and 10 students. The criteria used for retaining any SLEI item were that it must have a factor loading of at least 0.40 for its *a priori* scale and a factor loading of less than 0.40 with each other scale. The application of these criteria led to the retention of all items, except Student Cohesiveness Item 7 and

Open-Endedness Item 10. The percentage variance accounted for by different SLEI scales varied from 5.13% (for Open-Endedness) to 24.94% (for Integration), with a total variance of 52.78%. My results provided strong support for the factorial validity of the SLEI when used with my sample of middle-school students from metropolitan Adelaide.

The factorial validity of the modified SALES questionnaire (32 items) and Future Intentions scale (6 items) was also determined using principal axis factor analysis with varimax rotation and Kaiser normalisation. Every item was retained because it had a factor loading of at least 0.40 for its own *a priori* scale and a factor loading of less than 0.40 for all other scales. The percentage variance varied from 4.96% (Learning Goal Orientation) to 42.18% (Task Value), with a total of 66.36% of the variance accounted for. My results provided strong support for the factorial structure of the modified SALES questionnaire.

For the revised 33-item SLEI, two further indices of scale reliability and validity were generated. Cronbach alpha reliability coefficients were high, ranging from 0.78 to 0.87, and supported the internal consistency of these scales. The discriminant validity (using the mean correlation of a scale with the other four scales as a convenient index) ranged from 0.27 to 0.39, which suggests that raw scores on the modified SLEI measure distinct (but somewhat overlapping) aspects of classroom environment. But the factor analysis results attested to the independence of factor scores.

For the 6-item Future Intentions scale and the 32-item SALES questionnaire, the Cronbach alpha reliability coefficients for the five attitude scales, using the individual student as the unit of analysis, were high and ranged from 0.91 to 0.93. Scale discriminant validity ranged from 0.50 to 0.59, which suggests that raw scores on the SALES measure distinct (but somewhat overlapping) aspects of student attitudes, but the factor analysis results support the independence of the factor scores.

My results replicate past validity and reliability studies for the SLEI and the SALES questionnaire. The factor structure of the actual version of the SLEI was supported in studies in several different countries, and satisfactory Cronbach alpha reliability and discriminant validities for the SLEI were reported (Fisher, Henderson & Fraser, 1997; Fraser et al., 1995; Fraser & Lee, 2009; Lightburn & Fraser, 2007; Wong & Fraser, 1995). Velayutham et al. (2011), for a sample of 1360 students in Years 8, 9 and 10 across 78 classes, reported results similar to mine for the factorial validity and reliability of the SALES.

Research Question Two

Are (i) the frequency of practical work and (ii) sex determinants of students':

c. perceptions of the science laboratory environment;
d. motivation towards science;
e. aspirations to study science in Year 11 and 12?

To investigate the statistical significance of differences based on the independent variables of sex and frequency of practical work, a two-way MANOVA was conducted with the set of dependent variables being the five SLEI scales, the Future

Intentions scale and the four scales from the SALES questionnaire. Because the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, the univariate two-way ANOVA was interpreted for each individual scale. Because the interaction effect was statistically nonsignificant for all scales, it was meaningful to interpret the results independently for sex and frequency of laboratory work (Sections 4.3.1 – 4.3.2).

Generally scale means suggested that more frequent practical work was linked with higher scores for perceived classroom Open-Endedness, Integration and Material Environment and more positive attitudes for Task Value and Self-Regulation. Differences between each pair of practical work frequencies (once every three or more weeks compared to once every two weeks; once every two weeks compared to once a week or more; and once every three or more weeks compared to once a week or more) were determined for the five scales of Open-Endedness, Integration, Material Environment, Task Value and Self-Regulation by calculating effect sizes. Effect sizes provided a measure of the magnitude or the importance of differences in scale scores between practical work frequencies. Effect sizes were calculated as recommended by Thompson (2001) to portray the magnitude of differences expressed in standard deviation units, whereas Tukey's HSD multiple comparison procedure was used to determine the statistical significance of differences between pairs of practical work frequencies.

The results in Table 4.7 suggest that a change in frequency of practical work from once every 3 or more weeks to a frequency of approximately once every 2 weeks was associated with statistically significant ($p<0.01$) differences ranging from 0.31

(Self-Regulation) to 0.43 (Task Value) standard deviations for the five scales. Increasing the frequency of practical work from approximately once every 2 weeks to at least once every week was associated with only small differences of between 0.04 and 0.18 standard deviations for the five different scales.

The results from Section 4.3.1 suggest that the most beneficial frequency of practical work in terms of Material Environment, Task Value and Self-Regulation was about once every two weeks, but the most beneficial frequency of practical work for Open-Endedness and Integration was at least once a week overall. A practical work frequency of once every three or more weeks was less beneficial than the practical work frequencies of once every two weeks and at least once a week. Because there were no statistically significant frequency–by–sex interactions, these findings apply equally well to male and female students.

The Future Intentions scale was designed to assess the aspirations of students to study science at the senior-secondary school level. No statistically significant difference was found between frequencies of practical work for the Future Intentions scale.

The results presented in Section 4.3.2 (Table 4.8) show that statistically significant differences were present between males and females for the learning environment scales of Integration and Rule Clarity, as well as for the attitude scales of Future Intentions and Self-Efficacy. The effect sizes for the four scales for which sex differences were statistically significant were relatively small in magnitude (ranging from 0.18 to 0.28 standard deviations).

The direction of sex differences for the environment scales was different from the direction of sex differences for the attitude scales. The results in Section 4.3.2 show that females were more positive than males about their laboratory learning environment, but males were more positive about their future career intentions in science and in their self-efficacy than females.

Research Question Three

Are there relationships between middle-school students' perceptions of their science laboratory environment and students':

a. motivation towards science;
b. aspirations to study science in Year 11 and 12?

In order to address my third research question, the statistical analyses involved simple correlations, standardised regression coefficients and multiple correlations between each attitude scale and the five laboratory environment scales (see Table 4.9).

With the individual student as the unit of analysis, each of the environment scales was statistically significantly correlated with each attitude scale, with one exception (Future Intentions with Student Cohesiveness). The multiple correlation (R) for the set of five SLEI scales was statistically significant for each of the four attitude scales and the Future Intentions scale. To identify which classroom environment scales contributed most to the variance in an attitude scale, the standardised regression weights (β) were examined. The results showed that:

- Open-Endedness and Integration were statistically significant independent predictors of student Future Intentions to study science.
- Student Cohesiveness, Integration and Rule Clarity were statistically significant independent predictors of Goal Orientation.
- Open-Endedness, Integration and Material Environment were statistically significant predictors of Task Value.
- Open-Endedness, Integration and Rule Clarity were statistically significant predictors of Self-Efficacy.
- Open-Endedness, Integration, Rule Clarity and Material Environment were statistically significant predictors of Self-Regulation.

Further examination of the standardised regression weights showed that Integration was a statistically significant independent predictor of all five attitude scales and Open-Endedness was a statistically significant independent predictor four of the five attitude scales (the exception being Goal Orientation).

Furthermore, every statistically significant simple correlation and regression coefficient was positive, suggesting a positive relationship between a more favourable laboratory learning environment and students' attitudes. This replicates considerable prior research in a variety of countries (Fraser et al., 1995; Fraser & Lee, 2009; Lightburn & Fraser, 2007; McRobbie & Fraser, 1993a; Wong & Fraser, 1996).

5.3 SIGNIFICANCE AND IMPLICATIONS OF THIS STUDY

Relatively few studies in the field of learning environments have been conducted in middle-school science laboratory classes. The SLEI has not previously been validated with middle-school students in Adelaide, South Australia. My study addressed this gap in the research by validating modified versions of the SLEI and SALES questionnaire for use with middle-school students in Adelaide. These instruments could be beneficial for use by middle-school science teachers who want to assess their students' perceptions of their laboratory learning environments and their students' attitudes and motivations towards learning science in order to provide the most positive learning environment and attitude outcomes for students. These validated questionnaires could also be used by teachers for evaluating the effectiveness of instructional strategies and materials designed to increase students' motivation to study science as they progress through school.

My study is unique in its focus on the relationship between the frequency of practical work and students' perceptions of their laboratory environment, their attitudes towards learning science and their aspirations. Although practical work is identified in several literature reviews as one of the solutions for increasing student engagement in science (Lyons & Quinn, 2010), surprisingly little research has been conducted in this area. Therefore, my study contributed to the fields of learning environment and attitudes research.

My study revealed that more frequent practical work was linked with higher scores for perceived classroom Open-Endedness, Integration and Material Environment and more positive attitudes for Task Value and Self-Regulation. In particular, the most beneficial frequency of practical work in terms of Material Environment, Task Value and Self-Regulation was about once every two weeks, but the most beneficial frequency of practical work for Open-Endedness and Integration was at least once a week overall. A practical work frequency of once every three or more weeks was less beneficial than practical work frequencies of once every two weeks or at least once a week.

These findings have practical implications for middle-school science teachers who wish to improve their students' perceptions of their laboratory learning environments and attitudes towards learning science by increasing the frequency of practical work in their science teaching programmes. Students who undertook more frequent practical work perceived aspects of their laboratory learning environments more positively than students who undertook less frequent practical work. Students also placed a higher value on learning science and were more inclined to stay on-task and complete set activities than students who experienced less frequent practical work.

Very few prior studies have investigated relationships between middle-school students' perceptions of their science laboratory learning environment and their attitudes towards studying science. The use of the SLEI together with the SALES questionnaire is unique to my study. Middle-school science teachers can use the information from my study, that each of the environment scales was statistically significantly correlated with each attitude scale, with the exception of Future Intentions with Student Cohesiveness, to maximise the level of student engagement in learning science in their school settings. Students who perceived the laboratory learning environment more positively were more positive in their attitudes and engagement towards learning science. Teachers could use this information to change their teaching practices so that the laboratory learning environment is perceived as positively as possible by students.

5.4 LIMITATIONS OF THIS STUDY

Because the selected sample for this study was limited to co-educational middle-school students from four schools in Adelaide, South Australia, findings should not be generalised to all students in Years 9 and 10. A concerted effort was made to include typical schools from both the Independent and Catholic Education sectors so that different school sectors were included in the sample, but schools from the State Department of Education were not involved in this study. It is important, therefore, to confine findings to the types of schools involved and not to extrapolate findings to others. The schools in my sample were from different geographical and socio-economic regions, but not all regions were represented. Extrapolation of the findings should not be made to different regions in Adelaide.

The number of students included in my study (431) was typical of many past classroom environment studies. Because larger representative samples lead to greater validity of the inferences that can be drawn (Creswell, 2008), a larger sample in my study would have produced even more dependable findings.

Nevertheless, the results of my study replicate many past classroom environment studies. My results are consistent with past studies of sex differences in that they revealed that, generally, females have more favourable perceptions of the learning environment than their male counterparts (Fraser, 2002, 2007). Past research has shown that males recorded more favourable attitudes than females for enjoyment of science, instrumental motivation, future orientation to study or work in science, science self-efficacy and science self-concept (Thomson & DeBortoli, 2008). My results confirmed that males had more favourable attitudes than females in terms of future orientation to study or work in science and science self-efficacy. My investigation of associations between the laboratory learning environment and middle-school science students' attitudes showed that every statistically significant simple correlation and regression coefficient was positive, suggesting a positive relationship between a more favourable laboratory learning environment and students' attitudes. This replicates considerable prior research (Fraser & Lee, 2009; Lightburn & Fraser, 2007; McRobbie & Fraser, 1993a).

The research methods for my study were limited in that a wholly-quantitative design was used. Qualitative data can provide additional insights into students' perceptions (Tobin & Fraser, 1998), but qualitative information was not collected as part of my study except for a pilot study involving 20 Year 9 students conducted to determine the suitability of the wording of the items, the wording of the five-point agreement scale and the length of time it took to answer the survey. The study was quantitative in design because this design was highly suitable for investigating sex and frequency of practical work as determinants of students' attitudes and aspirations towards learning science. Better external validity can be achieved in quantitative research studies compared to qualitative research studies (Lowhorn, 2007). In addition, qualitative data were not collected because care was taken to ensure that disruption to the students' usual school programme was minimised. Quantitative data collection was the best way to minimise adverse impacts on students' class time. Nevertheless, combining quantitative and qualitative research methods in future research is recommended. In the absence of insights from qualitative research, it would be highly speculative to guess at explanations for the differences and associations found in my study.

My study focussed on sex and the frequency of practical work as determinants of students' perceptions of their laboratory environment, their attitudes towards learning science and their aspirations. A possible limitation of my study is that achievement was not also included as a student outcome. That is, sex and the frequency of practical work could also have been investigated as determinants of students' achievement in science. Associations between the laboratory environment and students' achievement levels could also have been included in my study.

A possible limitation of my study is that different types of practical work (such as teacher demonstrations, practical workbook exercises, open-ended investigations and student-choice investigations) were not identified. The questionnaire could have included an item that asked students about the proportion of practical work time that they spent on each type of practical activity. Types of practical work could have been investigated as a determinant of students' attitudes and future intentions.

5.5 SUGGESTIONS FOR FURTHER RESEARCH

Lyons and Quinn (2010) recommended that further research be undertaken to determine the influence of students' attitudes to science on their enrolment intentions and, in particular, to clarify at what point students' attitudes are most salient for their future enrolment decisions. My study investigated sex and the frequency of practical work as determinants of students' perceptions of their laboratory learning environments and their attitudes to science, but not the influence of students' attitudes to science on their enrolment intentions in the senior years. Further analyses of my data could be conducted to yield some answers to the question "what is the influence of middle-school students' attitudes to science on their aspirations to study science at the senior-secondary level?"

My sample included analyses of the responses from students in Years 9 and 10 as a whole. Further analyses of my data could be conducted to examine whether year-level differences exist for perceptions of the laboratory learning environment and students' attitudes towards science between students in Years 9 and 10. A longitudinal study could be designed and conducted to investigate whether changes in students' attitudes and aspirations occur over time.

My study produced some interesting findings for the three frequencies of practical work investigated. Further studies could be conducted to determine the optimum frequency of practical work for the most positive results for a variety of student outcomes. In particular, the effect of the frequency of practical work on student achievement levels could be studied in future research.

The quality of the practical work undertaken by the students was not assessed in my study as my focus was only on its frequency. Further research could investigate differences between different frequencies of practical work for different types of practical work (e.g. teacher demonstrations, closed investigations, open investigations and free-choice investigations) in terms of students' perceptions of their laboratory environments, attitudes and aspirations.

The quantitative nature of my study restricted my opportunity to provide explanations for differences between the sexes and frequencies of practical work. Further research involving qualitative methods could enhance the findings of my study, provide some insight into reasons for the existence of these differences, and allow triangulation of findings from using qualitative and quantitative methods.

5.6 FINAL COMMENTS

This study has validated the modified SLEI and SALES questionnaire for use with middle-school science students in Adelaide. It has also examined sex and frequency of practical work as determinants of students' perceptions of the laboratory environment, their motivation in science lessons and their intention to study science at the senior secondary school level. Associations between students' perceptions of their laboratory learning environments and their attitudes towards studying science also were identified in this study.

The questionnaires used in this study allow researchers and teachers to assess middle-school science students' perceptions of the science laboratory learning environment and attitudes towards science in an economical and practical manner. The results reported in this thesis have implications for teachers of science who are interested in the development of positive attitudes and science-related aspirations among their students.

Teachers could use information from associations identified in my study to focus their teaching practices in ways that ensure that the laboratory learning environment is perceived as positively as possible by their students, in order to improve their students' attitudes and aspirations towards studying science. The results from my study suggest that one way in which teachers can provide a more positive laboratory learning environment and improve students' attitudes towards studying science is likely to be to include more frequent practical work as part of their science teaching programmes.

The results of my study also highlight that more-frequent practical work is not a direct determinant of middle-school science students' future intentions to follow a science-related career. In order to increase the uptake of students in the senior-secondary science classes, the results of my study suggest that it is not sufficient for teachers simply to increase the frequency of practical work in their middle-school science classes. Rather, the development of a positive laboratory learning environment is fundamental to improving students' attitudes and aspirations.

It is hoped that the findings of my study, together with suggestions for future research into middle-school science laboratory environments, will encourage further research and understanding of determinants of positive middle-school student attitudes towards learning science, so that middle-school students are inspired to choose to continue to learn science in their senior-secondary schooling years.

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Appendix 1

OPINIONS ABOUT THIS CLASS SURVEY

In this questionnaire, Items 1 – 35 are based on the Science Laboratory Environment Inventory (SLEI, Fraser et al., 1992), Items 36 – 41 are based on the Career Interest in Science scale from the Test Of Science-Related Attitudes (TOSRA, Fraser, 1981) and Items 42 – 73 are based on the Students' Adaptive Learning Engagement in Science questionnaire (SALES, Velayutham, Aldridge & Fraser, 2011). These questionnaire items were used in my study and are included in this thesis with the authors' permission.

Opinions About This Class

Gender (please circle one)**:** Male Female

Year Level (please circle one): 9 10

Frequency of Practical Work in Science Lessons

Directions for students

This question is asking you about the frequency of practical work undertaken in science lessons. Circle the number that gives the best estimate of the frequency of practical work in your science class. Only circle **one** of the numbers.

FREQUENCY OF PRACTICAL WORK IN SCIENCE LESSONS			
	On average, once every three or more weeks	**On average, once every two weeks**	**On average, at least once a week**
In science lessons, practical work is completed:	1	2	3

Directions for students

This questionnaire contains statements about:

1. practices which could take place in this laboratory class
2. your future intentions to work in a science-related career and
3. your opinions about science lessons

There are no right or wrong answers. Your opinion is what is wanted.

For each statement draw around

1 if you **Strongly Disagree** with the statement
2 if you **Disagree** with the statement
3 if you are **Not Sure** about the statement
4 if you **Agree** with the statement
5 if you **Strongly Agree** with the statement

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another. Some statements in this questionnaire are similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example.

Suppose that you were given the statement: "I choose my partners for laboratory experiments."
You would need to decide the extent to which you agree with the statement that you are able to choose your partners
For example, if you selected *Strongly Agree*, you would circle the number 5.

SCIENCE LABORATORY ENVIRONMENT		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Student Cohesiveness						
1	I get on well with students in this laboratory class.	1	2	3	4	5
2	I have the opportunity to get to know other students in this laboratory class.	1	2	3	4	5
3	Members of this laboratory class help me.	1	2	3	4	5
4	I get to know students in this laboratory class well.	1	2	3	4	5
5	I am able to depend on other students for help during laboratory classes.	1	2	3	4	5
6	It does not take me long to get to know everybody by his/her first name in this laboratory class.	1	2	3	4	5
7	I work cooperatively in laboratory sessions.	1	2	3	4	5
Open-Endedness						
8	There is opportunity for me to pursue my own science interests in this laboratory class.	1	2	3	4	5
9	In this laboratory class, I am required to design my own experiments to solve a given problem.	1	2	3	4	5
10	In my laboratory sessions, other students collect different data than I do for the same problem.	1	2	3	4	5
11	I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1	2	3	4	5
12	In my laboratory sessions, I do different experiments from some of the other students.	1	2	3	4	5
13	In my laboratory sessions, the teacher allows me to decide the best way to carry out the experiments.	1	2	3	4	5
14	I decide the best way to proceed during laboratory experiments.	1	2	3	4	5
Integration						
15	What I do in my theory science class lessons is related to my laboratory work.	1	2	3	4	5
16	The laboratory work is related to the topics that I am studying.	1	2	3	4	5
17	My regular science class work is integrated with laboratory activities.	1	2	3	4	5
18	I use the theory from my regular science class sessions during laboratory activities.	1	2	3	4	5
19	The topics that I cover are similar in regular science class work and in laboratory sessions.	1	2	3	4	5
20	What I do in laboratory sessions helps me to understand the theory covered in regular science classes.	1	2	3	4	5
21	My laboratory work and regular science class work are related.	1	2	3	4	5

Rule Clarity		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
22	My laboratory class has clear rules to guide my activities.	1	2	3	4	5
23	My laboratory class is formal with rules for me to follow.	1	2	3	4	5
24	I am required to follow certain rules in the laboratory.	1	2	3	4	5
25	There is a recognised way for me to do things safely in this laboratory.	1	2	3	4	5
26	There are fixed rules for me to follow in laboratory sessions.	1	2	3	4	5
27	The teacher outlines safety precautions to me before my laboratory sessions.	1	2	3	4	5
28	My laboratory class is run under clearer rules than my other classes.	1	2	3	4	5
Material Environment						
29	I find that the laboratory has enough space when I am doing experiments.	1	2	3	4	5
30	The equipment and materials that I need for laboratory activities are readily available.	1	2	3	4	5
31	I am proud of the appearance of the laboratory.	1	2	3	4	5
32	I find that the laboratory equipment is in good working order.	1	2	3	4	5
33	I find that the laboratory is comfortable to work in.	1	2	3	4	5
34	The laboratory is an attractive place for me to work in.	1	2	3	4	5
35	My laboratory has enough room for individual or group work.	1	2	3	4	5
Future Intention to Study Science						
36	I would like to work in a science-related career after I leave school.	1	2	3	4	5
37	When I leave school, I would like to work in health, engineering, environmental science, medical research or science teaching.	1	2	3	4	5
38	A career that uses science would be interesting.	1	2	3	4	5
39	I would like to become a scientist when I leave school.	1	2	3	4	5
40	Working in a science laboratory, a hospital or an engineering office or site would be an interesting way to earn a living.	1	2	3	4	5
41	I would like to work with science when I leave school.	1	2	3	4	5

LEARNING GOAL ORIENTATION		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	In this science class….					
42	One of my goals is to learn as much as I can.	1	2	3	4	5
43	One of my goals is to learn new science content.	1	2	3	4	5
44	One of my goals is to master new science skills.	1	2	3	4	5
45	It is important that I understand my work.	1	2	3	4	5
46	It is important for me to learn the science content that is taught.	1	2	3	4	5
47	It is important for me to improve my science skills.	1	2	3	4	5
48	It is important that I understand what is being taught.	1	2	3	4	5
49	Understanding science ideas is important to me.	1	2	3	4	5
TASK VALUE						
	In this science class….					
50	What I learn can be used in my daily life.	1	2	3	4	5
51	What I learn is interesting.	1	2	3	4	5
52	What I learn is useful for me.	1	2	3	4	5
53	What I learn is helpful to me.	1	2	3	4	5
54	What I learn is relevant to me.	1	2	3	4	5
55	What I learn is of practical value.	1	2	3	4	5
56	What I learn satisfies my curiosity.	1	2	3	4	5
57	What I learn encourages me to think.	1	2	3	4	5
SELF-EFFICACY						
	In this science class….					
58	I can master the skills that are taught.	1	2	3	4	5
59	I can figure out how to do difficult work.	1	2	3	4	5
60	Even if the science work is hard, I can learn it.	1	2	3	4	5
61	I can complete difficult work if I try.	1	2	3	4	5
62	I will receive good grades.	1	2	3	4	5
63	I can learn the work that we do.	1	2	3	4	5
64	I can understand the content taught.	1	2	3	4	5
65	I am good at this subject.	1	2	3	4	5

SELF-REGULAION		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
	In this science class….					
66	Even when tasks are uninteresting, I keep working.	1	2	3	4	5
67	I work hard even if I do not like what I am doing.	1	2	3	4	5
68	I continue working even if there are better things to do.	1	2	3	4	5
69	I concentrate so that I won't miss important points.	1	2	3	4	5
70	I finish my work and assignments on time.	1	2	3	4	5
71	I don't give up even when the work is difficult .	1	2	3	4	5
72	I concentrate in class.	1	2	3	4	5
73	I keep working until I finish what I am supposed to do.	1	2	3	4	5

Appendix 2

PARTICIPANT’S INFORMATION SHEET

AND CONSENT FORM

Curtin University
Science and Mathematics Education Centre

Participant's Information Sheet

My name is Joanne Rogers. I am preparing to undertake a piece of research for my PhD in Science Education at Curtin University.

Purpose of Research

I am investigating whether the laboratory classroom environment, the amount of practical work undertaken and the gender of students are determinants of middle-school science students' attitudes and aspirations to study science at the senior secondary and tertiary levels.

Your Role

I am interested in finding out if there are any relationships between the amount of practical work undertaken, your perceptions of your laboratory learning environment, your attitudes towards science and your aspirations to study science further.

You would be required to complete a questionnaire about your perceptions of your laboratory environment, your attitudes towards science and your aspirations to study science further.

It is anticipated that the questionnaire will take no more than twenty-five minutes of your time.

Consent to Participate

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. Whether you choose to participate in the study or not, you will not be penalised, and your marks will not be affected in any way.

Both you and your parents need to sign the consent form. When you have returned the signed consent form, I will assume that you have agreed to participate and allow me to use your data.

Confidentiality

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

Further Information

This research has been approved by the Curtin University Human Research Ethics Committee (approval number **HR 92/2011**). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. 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, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

If you would like further information about the study, please feel free to contact me on 8272 0444 or by email on jrogers@concordia.sa.edu.au. Alternatively, you can contact my supervisors:

Professor Barry Fraser on 89266 7896 or email B.Fraser@curtin.edu.au
Associate Professor Jill Aldridge on 89266 3592 or email J.Aldridge@curtin.edu.au

Your involvement would be greatly appreciated.

Curtin University
Science and Mathematics Education Centre

Laboratory classroom environment, amount of practical work and gender as determinants of middle-school science students' attitudes and aspirations

CONSENT FORM

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

Participant's Name:____

Participant's Signature:____________________________________

Date: ______________________________

Parent/Guardian Name:____

Parent/Guardian Signature:____________________________________

Date: ______________________________