Chapter 2

Literature and Research Review

This chapter contains a review of the literature and research relevant to the two major components of this study. The first area of research concerns the expanded and updated validation of the measures of the SLEI. Relevant literature includes a review of learning environment research, the design of the measures and overall instrument, as well as past studies on the validation of the SLEI. The second area of interest concerns the influence of academic level and experience on student's perceptions of learning environments. Relevant literature in this area includes an examination of academic achievement with student perceptions as well as a discussion of influences in science classrooms in the United States today.

Background on prior validation of the SLEI

Learning Environment Research

Research question 1 focuses on the dimensional structure of the SLEI measures. The various dimensional models focused upon in the article presented in Chapter 4 are derived from the literature on learning environments on which the SLEI item development was based. The measures of the SLEI are built upon the construct of the science classroom laboratory learning environment. This construct was developed based upon learning environment research completed by Moos (1987) and Walberg (1981) on the theory of psychosocial construction through human interaction (Dorman, 2002). The dimensions of human environments include relationships, personal development and system maintenance as well as change (Moos, 1987). Relationship dimensions are those relating to the nature and intensity of personal relationships. Personal development dimensions refer to the path through which knowledge development progresses. System maintenance and system change dimensions refer the orderliness, clarity, control and responsiveness to change in the environment (Moos, 1987). Table 1 illustrates the elements of Moos' taxonomy.

Table 1

Moos' General dimensions of psychosocial construction

Moos Category	Description
Relationship Dimension	Extent to which students know, help and are supportive of one another.
Personal Dimension	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation and Extent to which the laboratory activities are integrated with non-laboratory and theory classes.
Systems Maintenance and Systems Change Dimension	Extent to which behavior in the laboratory is guided by formal rules. and Extent to which the laboratory equipment and materials are adequate.

(Fraser, McRobbie, & Giddings, 1993)

Following the research of Moos and earlier classroom environment research, five dimensions of human environments as factors of the science laboratory were identified (Fraser, 1998b; Fraser, McRobbie, & Giddings, 1993). These dimensions included student cohesiveness, open-endedness, integration, rule clarity and material environment. Student cohesiveness describes how well students know each other, work well together and support one another. Open-endedness describes the nature of the laboratory activities in the classroom. Integration represents how well lab activities are related to material in the curriculum and the science theory being taught. Rule clarity refers to the extent of the formal rule structure and how it is followed within the classroom. Material environment describes the classroom and lab materials (Fraser, McRobbie, & Giddings, 1993). Table 2 illustrates how the elements of Moos' taxonomy align with the scales of the SLEI instrument.

Table 2

Alignment of Moos' General dimensions with the SLEI

Moos Category	SLEI Scale Name	Description
Relationship Dimension	Student Cohesiveness	Extent to which students know, help and are supportive of one another.
Personal Dimension	Open-endedness	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.
	Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.
Systems Maintenance and Systems Change Dimension	Rule Clarity	Extent to which behavior in the laboratory is guided by formal rules.
	Material Environment	Extent to which the laboratory equipment and materials are adequate.

(Fraser, McRobbie, & Giddings, 1993)

Research question 1 focuses on the dimensional structure of the measures of the SLEI. The review of extant theory and literature has identified three theoretical models. The first model, supported by the work of Moos, is a three dimensional structure that examines the human environments including relationships, personal development and system maintenance and change (Moos, 1987) (Figure 1).

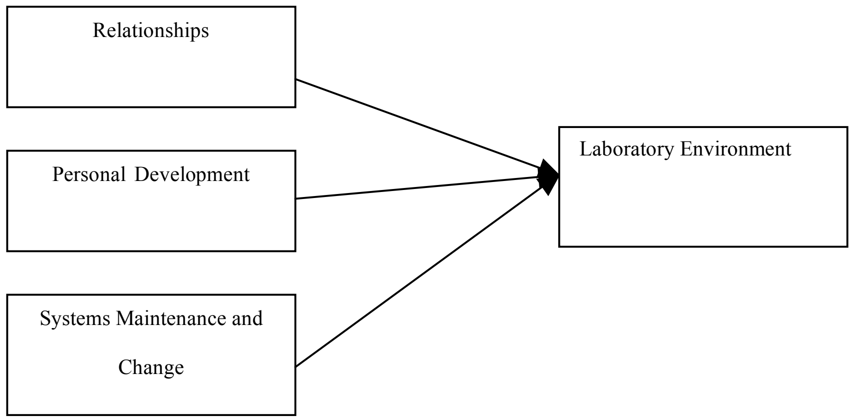

Figure 1 Three Dimensional Model

The second model, used by Fraser, is a five dimensional model. These dimensions include student cohesiveness, open-endedness, integration, rule clarity and material environment (Figure 2).

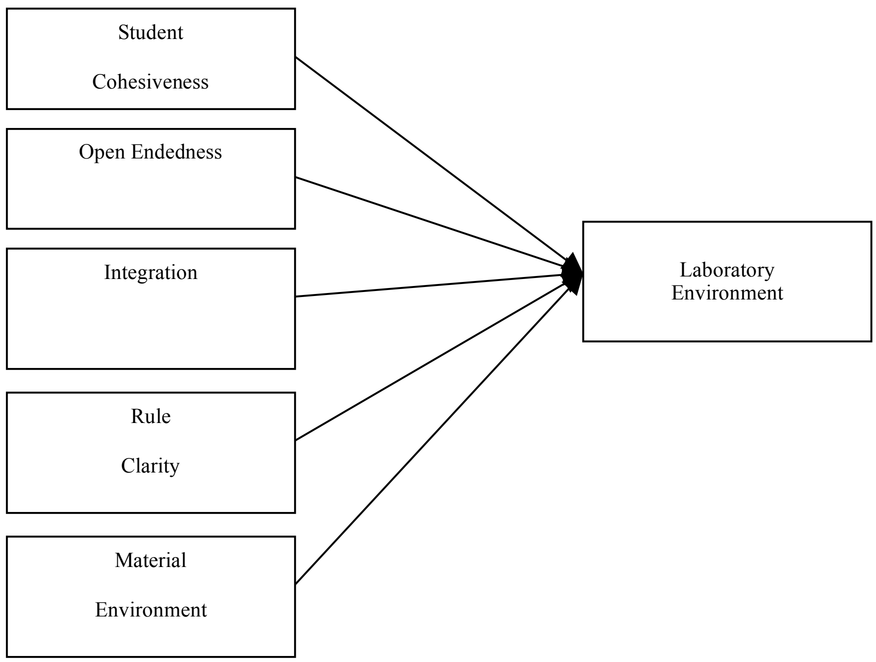

Figure 2. Five dimensional model

The final model examines the construct of the science laboratory environment as a unified dimension. Conceptually, the five elements of the learning environment (Fraser, Giddings, & McRobbie, 1992; Fraser, McRobbie, & Giddings, 1993; Moos, 1987) were considered sub-factors in a single construct.

Instrument Design

The primary purpose of the research presented in Chapter 4 is to update the validation evidence for the SLEI. In anticipation of that, the instrument development process and the existing validation evidence are summarized here. The SLEI measures 5 aspects of the science laboratory learning environment: (a) student cohesiveness, (b) open-endedness, (c) integration, (d) rule clarity, and (e) material environment. There are two forms of the instrument. The "actual" form was designed to measure student perceptions of the experienced learning environment. Student perceptions of the favored learning environment are assessed through the "preferred" form (Fraser, 1998a, 1998b, 2002, 2007; Fraser, Giddings, & McRobbie, 1992; Fraser, McRobbie, & Giddings, 1993). Each form contains seven statements relating to each of the five aspects of the environment for a total of 35 items. The statements describe lab activities, rules, equipment and student to student and student to teacher interactions. Students respond by indicating how often these activities take place on a five-point scale ranging from "almost never" to "very often." Thirteen of the items are reverse-scored.

The SLEI measures were designed to assess the construct of the learning environment in high school science laboratories. Student Cohesiveness describes how well students know each other, work well together and support one another. Open-endedness describes the nature of the laboratory activities in the classroom. Integration represents how well lab activities are related to material within the curriculum and science theory being taught. Rule Clarity refers to the extent of the formal rule structure and how it is followed in the classroom. Material environment describes the classroom and lab materials (Fraser, McRobbie, & Giddings, 1993).

Classroom environment research as supported by the measures of the SLEI can contribute to understanding student perspectives of their laboratory classroom. Additionally, the measures can help researchers learn more about the impact of the laboratory upon student learning. Research has revealed a positive correlation between student perspectives of learning environments and academic achievement (Fraser, McRobbie, & Giddings, 1993; Haertel, Walberg, & Haertel, 1981). Further research has established relationships between inquiry skills and positive science related attitudes (Fraser & Fischer, 1982). Learning environment instruments can also be considered as a tool for curriculum evaluation, to discern differences in student perspectives (Fraser, 1981).

The scales of the SLEI were intended to describe the perceptions of high school or "secondary school" students in science laboratory classes. The five factors measure different aspects of the classroom learning environment (Fraser, McRobbie, & Giddings, 1993; Moos, 1987). These factors are described in detail within this literature review.

The measures of the SLEI were developed and validated in 1993. Fraser, McRobbie and Giddings (1993) examined several areas to comprehensively develop these measures. These areas included an examination of the extant literature on laboratory teaching, classroom environment research, consistency with classroom environment dimensions on existing environments (Moos, 1987), relevance to teacher and students and efficiency of the instrument (Fraser, McRobbie, & Giddings, 1993).

The measures identified through the original validation study were modeled from a five, six and seven factor design. Item analysis was completed to assess internal consistency. In addition, analyses were completed by individual score and composite mean score by class. Through the original field study and validation, the instrument was reduced from seven possible scales to five scales, each with seven items. Principal component analysis was also completed. Each item had a factor loading of greater than .30 on the associated measure and less than .30 on the other 4 measures.

Research question 2 addresses the rating scale structure of the SLEI. Prior work published on the SLEI did not include an examination of the behavior of the rating scale and whether the 5-point scale was appropriate given the response structure. The instructions for the instrument describe the rating scale in detail on each page of the instrument. Responses are recorded from 1 to 5 (1= almost never, 2= seldom, 3= sometimes, 4= often, 5= very often). There were thirteen negatively worded items. The original validation evidence did not consider the appropriateness of this rating scale structure.

Research question 3 concerns an examination of the technical quality of the items. The SLEI contains 35 items and there are seven statements for each of the five dimensions. They appear sequentially in order of the dimensions, and the pattern is repeated throughout (item 1 = student cohesiveness, item 2 = open-endedness, item 3 = integration, item 4= rule clarity, item 5 = material environment, etc.).

Negatively worded items have been often used and discussed in survey design as a way to modify respondents' behaviors. With negatively worded items, respondents theoretically respond the opposite way than they do for positively worded items. This can reduce instances of response sets, where the participant responds in a similar way for all of the items on an instrument (Barnette, 2000; Bergstrom, 1998; Marsh, 1996; Schriesheim & Hill, 1981; Yamaguchi, 1997).

However, responses to negative items do not necessarily represent polar opposite responses from positive items. Research has shown that negative items tend to cluster as if they constituted a unique dimension unto themselves (Schriesheim, Eisenbach, & Hill, 1991). Because of this pattern of negative item responses behaving differently than expected, reduced internal consistency may result (Chamberlain & Cummings, 1984; Marsh, 1996; Schriesheim, Eisenbach, & Hill, 1991). The use of polar opposite questions and item phrasing significantly reduces internal consistency and reliability according to the research of Schriesheim et al (1991).

Several researchers have recommended that the practice of using negative items to control response sets should be eliminated (Chamberlain & Cummings, 1984; Schriesheim, Eisenbach, & Hill, 1991; Schriesheim & Hill, 1981; Yamaguchi, 1997). Three alternative approaches, as outlined by Marsh (1996) include removing negatively worded items completely, balancing the number of negatively worded items with positively worded items or including the negative items for reduction of response bias; and not including responses to those items in the analyses. Confirmatory factor analysis was recommended as one way of discerning whether a unilateral positive set of items or a mixture of positive and negative would be better (Marsh, 1996). Caution should be exercised when considering redesign of items, as the removal of too much variability, even if it is associated with negative items, could also reduce the reliability of the measures (Alliger & Williams, 1992). Hence, in the evaluation of research questions 1 and 3, we focus on the functioning of the SLEI items that are negatively worded.

Research question 4 focuses on the reliability of the subscale measures. Different aspects of validity were examined for the measures of the instrument: internal consistency, discriminant validity, and the ability to differentiate between classrooms for the total sample. Research question 4 is designed to facilitate examination of the technical quality of the items for the measures of this instrument.

In past studies, the measures of the SLEI instrument were examined across six nations to evaluate its reliability (Fraser, Giddings, & McRobbie, 1992; Fraser, McRobbie, & Giddings, 1993). The initial validation included a total of 3,727 students in six different countries. The *Actual* and *Preferred* forms were examined in each of the countries. The data were collected and analyzed both on the individual and class mean responses to each of the five dimensions. The sample size was largest for Australia (1875) and smaller for the other countries: USA (885), Israel (359), Canada (282), Nigeria (218) and England (108). The surveys were translated to the language of the country were they were administered. No information was provided on the determining factors for the selection of the countries in the sample or the sampling procedure for selection of respondents to the survey.

The Cronbach's alpha reliability ranged from .49 in Nigeria on the individual open-endedness dimension, to .96 in the USA on the class-mean integration dimension. The open-endedness dimension has been highlighted throughout the examination of the reliability and validity as a possible area for further research and investigation.

Internal consistency was examined through the use of Cronbach's Alpha. This statistic was calculated for each scale, for both forms of the instrument and for individual scores as well as class mean scores. The convergent validity for the SLEI was examined by dimension in both forms, for individual and class mean responses (Fraser, Giddings, & McRobbie, 1992; Fraser, McRobbie, & Giddings, 1993).

Additional analysis of variance was used to distinguish it's proportion accounted for by class grouping. Students within each class had similar perceptions of the classroom environment, but differentiation between classrooms was possible and measurable. Class membership was used as the main effect and the individual was the unit of analysis. The η^2 for each of the dimensions ranged from .19 to .23 ($p< .001$). Table 3, below, provides the details of these analysis.

Table 3.

Internal Consistency (Cronbach Alpha Coefficient), Discriminant Validity (mean correlation with other scales), and Ability to Differentiate between classrooms for Total Sample

Scale	Unit of Analysis	Alpha Reliability Actual	Alpha Reliability Preferred	Mean Correlation with Other Scales Actual	Mean Correlation with Other Scales Preferred	ANOVA Results η^2 Actual*
Student Cohesiveness						
	Individual	0.77	0.72	0.34	0.39	0.21
	Class Mean	0.92	0.89	0.39	0.42	
Open-endedness						
	Individual	0.70	0.60	0.07	0.13	0.19
	Class Mean	0.81	0.72	0.11	0.16	
Integration						
	Individual	0.83	0.81	0.37	0.39	0.23
	Class Mean	0.95	0.92	0.41	0.32	
Rule Clarity						
	Individual	0.75	0.70	0.33	0.35	0.21
	Class Mean	0.92	0.85	0.38	0.39	
Material Environment						
	Individual	0.75	0.72	0.37	0.41	0.21
	Class Mean	0.88	0.89	0.42	0.45	

*$p < 0.001$

(The η^2 statistic [which is the ration of "between" to "total" sum of squares] represents the proportion of variance explained by class membership)

(Fraser, McRobbie, & Giddings, 1993) page 11

Research question 5a examines the extent of group differences across the measures based on gender or ethnicity. Existing research has not utilized the SLEI to examine the existence of these differences. In a study that employed two related measures of perception of learning environments among students in the Pacific islands, the Questionnaire on Teacher Interaction and the College and University Classroom Environment Inventory, researchers found minimal evidence of differences in perception of teacher student interactions based on ethnicity for this population (Coll, Taylor, & Fisher, 2002). On the other hand, prior research has suggested that gender differences may influence student perceptions of the learning environment. In one study, researchers compared Australian male and female responses to the Learning Process

Questionnaire and determined that females were more positive about their learning environments, although the observed effect sizes were small (Dart et al., 1999). In the Coll, Taylor, and Fisher (2002) study, Pacific island university females also reported more positive perceptions of the learning environment than did males. Research conducted with students from Singapore using the SLEI revealed statistically significant differences for gender in the dimensions of student cohesiveness, rule clarity, and material environment. The researchers found that gifted males and females perceive open-endedness similarly but that non-gifted females provided more positive depictions of classroom open-endedness than did males. Non-gifted males students were, on the other hand, more positive about the material environment than were the non-gifted female students (Lang, Wong, & Fraser, 2005).

Research questions 5b and 5c examine group differences based on biology experience, as well as academic course levels (regular and honors). The authors also reviewed the predictive validity of the measures of this instrument on academic performance, although direct information on student achievement was not collected. Students completed a short survey on their attitudes toward science. Correlation analyses were completed regarding the student attitudes. The dimensions of the SLEI as a whole were positively correlated with positive attitudes toward science. Using class mean as sample selection, a simple correlation between the *Integration Dimension* and student attitudes toward the classroom was greater than 0.60. This finding reflects the presence of positive student attitudes in classes perceived as higher in integration(Fraser, McRobbie, & Giddings, 1993; Giddings & Fraser, 1990).

Once the initial validation work had been completed, Fraser, McRobbie and Giddings (1993) examined the internal consistency and discriminant validity for cross validation purposes with a new sample (Fraser, 1998a). The new sample consisted of nearly 1600 chemistry students and 92 high school classes in and around Brisbane, Australia. The same validity and reliability analyses were completed for the new sample. This analysis provided the same strong evidence regarding the internal validity of each dimension and the external reliability across classrooms. Table 4 illustrates these findings.

Table 4

Internal Consistency (Cronbach Alpha Reliability) and Discriminant Validity (Mean Correlation with Other Scales) for Actual and Preferred Versions for a Cross-Validation Sample for Class Mean as Unit of Analysis

	Alpha Reliability		Mean Correlation with Other Scales	
Scale	Actual	Preferred	Actual	Preferred
Student Cohesiveness	0.80	0.82	0.31	0.31
Open-endedness	0.80	0.70	0.25	0.15
Integration	0.91	0.92	0.44	0.36
Rule Clarity	0.76	0.80	0.43	0.35
Material Environment	0.74	0.85	0.34	0.40

*p < 0.001

(Fraser, McRobbie, & Giddings, 1993) page 15

Influence of academic level and experience on student perceptions

Work in the study of classroom environments has provided evidence of the relationship between student achievement and the science laboratory classroom. This evidence directly relates to research question 5c, which examines group differences based on academic achievement levels. Research conducted by Henderson, Fisher and Fraser (2000) supported a positive correlation between students' preferred learning environments and positive academic achievement (Henderson, Fisher, & Fraser, 2000). The authors found that teachers' strong leadership behaviors, student self-responsibility and integration of practical as well as theoretical research in biology led to higher academic achievement (Henderson, Fisher, & Fraser, 2000). Dorman and Adams (2004) completed a study that provided evidence correlating students' perceptions of the science classroom and academic efficacy. A mixed methods study completed by Roth (1997) provided further evidence supporting the relationship between classroom environment and academic achievement. Additional research validates the concept that new approaches to teaching and learning support positive change in classroom learning environments (J.M. Aldridge, Dorman, & Fraser, 2004; Jill M. Aldridge, Laugksch, Seopa, & Fraser, 2006; Fraser, Giddings, & McRobbie, 1992; Haertel, Walberg, & Haertel, 1981).

An understanding of the influences in current lab environments is necessary to fully explore research questions 5b and 5c. Causal relationships have been identified between instructional approaches, including those identified as constructivist or inquiry-based, and tighter alignment between students' perceptions of their actual and preferred laboratory learning environments (Hofstein, Nahum, & Shore, 2001; Kim, Fisher, & Fraser, 1999).

Inquiry based learning and hands-on lab work by high school students has taken place in sweeping curriculum reform across the United States in the past two decades. *America's Lab Report* suggests that all lab experiences should give participants the opportunity to enhance expertise in their subject matter (Singer, Hilton, & Schweingruber, 2005). Students experience authentic research from the early design of their research question, determination of the experiment design and the analyses and summarization of their findings. The National Science Standards define inquiry as a central component in the science laboratory.

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known;

> planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations(Hofstein & Lunetta, 2003, p. 30).

The science laboratory is a critical component of student understanding and meta-cognition of scientific concepts along with the development of scientific skills (Hofstein & Lunetta, 2003). Student participants should also begin to learn to develop scientific reasoning process skills through modeling of behaviors present in authentic inquiry. The ability to make a scientific argument includes the ability to write comprehensively, think critically and respond comprehensively to feedback and findings. Laboratory work should help students understand the complexity of the work they are doing. Often, the learning occurs not in the end result, but in the process of the experiment construction and implementation. Students should also develop practical skills through their lab experiences; whether these are safety norms or how to handle equipment (Hofstein & Lunetta, 2003).

A comprehensive understanding of the "nature of science" is also necessary. This means that students comprehend that science is a human endeavor based upon empirical evidence used to understand the material world, and that these understandings change over time. All of this supports that student lab experiences should foster new and advanced interest in participation and learning in the sciences (Fraser, McRobbie, & Giddings, 1993).

> "Laboratory experiences may be the only way to advance the goal of helping students understand the complexity and ambiguity of empirical work." (Singer, Hilton, & Schweingruber, 2005, pp. 77-78).

Fletcher Brown completed an assessment of learning environments and student attitudes toward science in an inquiry based science course designed for pre-service elementary education teachers. The results indicate that students worked well with one another in small groups while working on laboratory based activities and other class problem solving activities (Brown, 2000). Earlier research examined the effect of innovative teaching strategies on student outcomes. This research revealed a strong relationship between inquiry learning and increased student performance with effects sizes ranging from .25 to .39 as measured by η^2 (eta squared is the ratio of the sum of squares for the effect divided by the total sum of squares) (Bredderman, 1984; Fraser & Fischer, 1982; Shymansky, Jr., & Alport, 1983; Weinstein, Boulanger, & Walberg, 1982; Wise & J.R.Okey, 1983).

Research Direction

Research Question 1 (Dimensionality) asks what dimensional structure best depicts student attitudes toward science lab environments. In this chapter, several relevant theory-based models were presented. Hence, this question is addressed via confirmatory factor analyses conducted within a structural equation modeling framework. Multiple fit indices are used to evaluate the fit of the three models. The development of the original SLEI measures was based upon a five dimensional model and it is expected that the resulting analysis would reflect a similar structure.

Research Question 2 (Rating scale structure) asks which measurement model and rating scale configuration best depicts the rating scale structure of these data. The original SLEI validation efforts did not address the appropriateness of the rating scale configuration. Individuals are expected to respond to items according the theory behind the construction of the measures. Person fit, item difficulty hierarchy and rating scale function are some of the ways that substantive validity can be analyzed (Wolfe & Smith, 2007b). Empirical evidence for rating scale optimization is assessed through detailed guidelines as identified by Linacre (2002).

Research Question 3 (Item Quality) considers the technical quality of the items in the instrument. Two indicators of the technical quality of the items are used to explore this question. The item score-theta correlation (AKA, point-measure correlation) is examined, and items are flagged if the value of this index is less than .30. Next, the standardized weighted mean square fit indices are considered, and items are flagged if the value of this index was greater than 2.00. Flagged items will be examined for potential problems. However, based on earlier validation work (Fraser, McRobbie & Giddings, 1993) it was expected that there would be few items flagged as problems.

Research Question 4 (Reliability) considers the reliability of the subscale measures. Analyses relating to this question will focus on the reliability of separation index of theta for each dimension modeled in the MRCMLM. This index depicts the estimated proportion of observed variance that is true variance, and is interpreted in a manner comparable to coefficient alpha. Based on earlier research on the measures of the SLEI, it was hypothesized that the reliability scores would be stronger for this multidimensional study.

Research Question 5 (Group Differences) explored differences in reported measures between groups. These groups included an examination of gender and ethnicity; experience level differences; and regular and honors student differences across the measures. We addressed this question through several different analyses by determining whether the different groups exhibited different means on the five subscales of the SLEI. It was hypothesized that based on our sample, there might be meaningful differences between genders (Lang, Wong & Fraser, 2005), but no meaningful differences amongst different ethnic/ racial groups. It also was hypothesized that there would be differences amongst honors and regular course offerings, as well as amongst grade levels

The methodology for these research questions is discussed in detail in chapter 3. The detail of the analyses and a full discussion of results can be found in Chapter 4 (question 1-5a) and Chapter 5 (questions 5b and c).