Science and Mathematics Education Centre

Students' Learning Outcomes and Perceptions of the Learning Environments in Physical Chemistry Laboratory Classes in Thailand

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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 publish by any other person except where due acknowledgement has been made.

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ABSTRACT

The purposes of this study were to analyse the learning environment, teacher-student interactions and educational outcomes in physical chemistry laboratory classrooms in Thailand. In addition, the validation of the Chemistry Laboratory Environment Inventory (CLEI), the Questionnaire on Teacher Interaction (QTI) and Attitude Scale was examined. The sample was composed of 100 physical chemistry students in four Rajabhat Universities who responded to both Actual and Preferred Forms of the CLEI and QTI. Also, interviews and written stories were used with twelve students. Students' learning outcomes were investigated using a cognitive test, a practical test and the Attitude Scale. Before the questionnaires were used with the 100 students sample, the reliability and validity of the CLEI, QTI and Attitude Scale were confirmed with 198 tertiary science students in seven Rajabhat Universities. In addition, the results of students' interviews and written stories supported the validity of both the CLEI and QTI, and students improved their achievement outcomes. The study found that there were differences between the students' preferred learning environments and what they perceived to be actually present. Associations were also found between students' perceptions of the classroom environment and student outcomes.

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CHAPTER 1

INTRODUCTION AND OVERVIEW

1.1 ORIGIN OF THIS THESIS

The aim of this thesis is to analyze the learning environment in university classrooms in terms of social relations and educational outcomes. Why was I interested in this work? The reasons are as follows. First, I have taught chemistry for many years. When students' cognitive achievement scores were measured on the end-of-year examination, their scores year after year were not as high as I wished in my mind. Second, sometimes I found that if students respected and liked the teacher who was interested in them, they would get higher scores in their examinations. Finally, I also found that if students liked their classroom environments, for example their friends and the teaching methods used, they would get higher scores in their examinations. I have reflected on my class learning environments in terms of the social relations between my students and myself for many years, as I am a tertiary teacher. All of these factors could lead to more positive attitudes that students showed to the teacher and this would enhance their educational outcomes. Therefore, I asked myself, "How could I improve this situation?" I concluded that students should be provided with a learning environment which promoted positive student attitudes and interest in the subject. This would help students to achieve good educational outcomes.

Much research has stated that generally, students spend a great deal of time at school. For example, graduates have spent nearly 20,000 hours in educational institutions by the time they complete their university courses (Fraser, 2001). Therefore, what happens to students at school and universities, and students' reactions to instructors are surely important factors to students and worthy of further study. As well, student perceptions of their educational experiences are important, and especially important is what goes on in school and university classrooms. It is difficult for science and mathematics teachers to include classroom environment measures among their methods of evaluation because they concentrate almost exclusively on the assessment of academic achievement, and pay little attention to factors which might be related to their students' performance. Although everybody would accept the worth of student achievements, these alone cannot give a complete picture of the educational process.

Physical chemistry laboratory teaching is a unique feature of education in science, but one can question whether the high cost of maintaining and staffing laboratories is really justified (Hofstein & Lunetta, 1982) and whether or not many aims of the physical chemistry laboratory teaching could be followed more effectively (Pickering, 1980). Because research has not been comprehensive, we simply do not know enough about the effects of physical chemistry laboratory teaching on student learning and attitudes. While it is a unique feature of science education and a major source of learning, serious questions arise regarding the effectiveness of the learning which takes place when students engage in physical chemistry laboratory investigations (Hodson, 1990; Lazarowitz & Tamir, 1994).

Moreover, in the context of chemistry, past classroom research has more often focused on students' understanding of chemical knowledge (Krajcik, 1991; Osborne & Cosgrove, 1983; Stavy, 1988) rather than on the effects of the learning environment on learning. Recently, however, one statement revealed that the notion of knowledge is constructed through a process of social negotiation and consensus (Linn & Burbules, 1993). Therefore, Riah and Fraser (1997) concluded that students needed not only to interact with the curriculum materials but also needed to interact with significant others, that is, classroom peers and teachers. They also noted that these interactions, which provided opportunities for students to participate freely in class discussions, to plan their own investigations and to work cooperatively with others, can provide insightful learning. This suggested that classroom environment is an important factor for learning.

This research study involved students from four Rajabhat Universities situated in Thailand, namely, Rajabhat Kamphaeng Phet University, Rajabhat Maha Sarakham University, Rajabhat Phanakhon University and Rajabhat Phitsanulok University and combined quantitative and qualitative methods within the same study, providing a more complete picture of the learning environment. As Tobin, Kahle, and Fraser (1990) have indicated, qualitative and quantitative methods, when used in the same learning environment study, can provide a more in-depth understanding of learning environments.

The current research study is concerned with issues about the physical chemistry laboratory instruction and student perception of physical chemistry laboratory learning environments. The rationale for this research is that an investigation of university classroom learning environments in terms of social relations and educational outcomes will provide an opportunity to encourage science teachers to assess the environment of physical chemistry laboratory classes at the university level, and so improve the quality of their teaching and professional life.

1.2 BACKGROUND TO THIS STUDY

Thailand is situated in southeastern Asia, and borders the Andaman Sea, the gulf of Thailand, and the southeast of Burma. The country has a total area of 514,000 square kilometers. The population of Thailand is around 64,265,276, of which 95% are Buddhists, 3.8% are Muslims, 0.5% are Christians, 0.1% are Hindus and 0.6% are other (The Government Public Relations Department, n.d.).

In the 1970s and 1980s, Thailand succeeded in providing all children with access to good quality primary education. However, the expansion of opportunities at lower and upper secondary levels, and in post-secondary education, proceeded more slowly because of a restriction of educational progress and budget (The World Bank Group, 1999).

In the early 1990s, less than 40% of people in the Thai workforce had completed secondary school, and about 80% had completed primary schooling. In the meantime, the serious issues of curriculum relevance and quality also received increasing attention. The actions of the Schools Council of Education and Training contributed to curriculum revision and many instructors were contacted in regard to improving the curriculum. At the tertiary level, science and engineering programs were weak, and graduates were not employed in renowned workplaces. A productivity gap emerged between Thailand and other newly industrialized nations, which led to a decline in Thailand's export share of labor-intensive goods. Generations of Thai students also found it difficult to adapt to rapidly changed occupations and jobs because those students completed their education by rote learning methods in narrow vocation courses of secondary school (The World Bank Group, 1999; Boonklurb, 1999).

Subsequently, the government began to address issues of access and quality in secondary and higher education. More people had a greater opportunity to enrol in school and university, with the budget supported by the World Bank. Therefore, programs to improve the quality of science, mathematics and foreign language instruction in teacher education colleges and secondary schools were started (The World Bank Group, 1999).

Thailand's long-term challenges are then to continue the expansion of the secondary and higher education system and improvements in the quality of education available. Critical to meeting this challenge will be an expanded role for the private sector in employment training, and the direct provision of education (The World Bank Group, 1999).

On the whole, the education system in Thailand is almost centralised. Students in Thailand undergo examinations that determine their selection and promotion. The education system is largely content driven, with an emphasis on students passing their examinations (MSU Cross-University collaboration helps build environmental education in Thailand, 1996).

Although education in Thailand continues to advance, these advances are not enough to offer sufficient progress for the country. For some time in Thailand, the Schools Council of the Education and Training has been concerned with issues about physical chemistry laboratory instruction and student perceptions of physical chemistry laboratory learning environments (The World Bank Group, 1999; Boonklurb, 1999).

Many researchers have said that the learning environment in the classroom is important in enhancing student learning. Wallin (2003) said that effective teaching might be summarized as having three dimensions: the classroom itself, the teaching style, and the learning environment. Wallin continued to say that the learning environment can lead to effective classroom learning within a supportive atmosphere, where students work in both small and large groups, in individualized learning activities, as well as in cooperative learning environments. It means that students are given ample time and opportunity to master skills, and students assume a high degree of responsibility for their learning through participation, by becoming involved in setting their own learning goals, and helping to monitor their own progress.

I questioned whether there was a relationship between student cognitive achievement, attitude to a subject and the learning environments in classrooms in Thailand. As Rickards (1998) indicated, there was a relationship between student cognitive achievement, attitude to a subject and the learning environment in classrooms in Australia. I accepted Rickards' observation and also asked myself that if such research was undertaken in Thailand, this may help teachers provide a more positive learning environment. The nature of teacher-student interactions and learning environments can contribute to the effective classroom learnings, for as Chumnankij, (1998) said, both the psychological environment and the physical environment can enhance the learning in classrooms.

Even though the field of classroom learning environment provides ideas and techniques that could be very valuable in assisting teachers to become more reflective and to improve their practice, little progress has been made in incorporating learning environment ideas into physical chemistry laboratory classes (Fraser, 1989). Also, despite the current availability of convenient questionnaires to measure classroom environment, little has been reported on attempts to improve the learning environment of university classes in Thailand. Again, even though the study of learning environment has been undertaken in other countries for a long time, it is a new subject in Thailand, and especially the learning environment of a physical chemistry laboratory class at university level. Thus, the focus of this study is to determine relationships between student perceptions of learning environments and their outcomes.

1.3 THEORETICAL FRAMEWORK

The questionnaires which have been used in studies of learning environments, are related to the theoretical framework for human environments described by many researchers. First of all, this study will outline the historical background of learning environments. Henderson, Fisher, and Fraser (1995) wrote that foundations for classroom environment research had been laid more than 50 years ago, when the work of Lewin and Murray had assumed particular significance. Lewin (1931) described human behaviour as being affected by the person and the environment. Then Murray (1938) described the concept of the personal needs of an individual (goals and drives) and the environmental press (stimulus, treatment and process variables). The work of Lewin and Murray led to the development of various measures of personality although environmental measures hardly were considered in early studies.

Waldrip and Fisher (2000) pointed out that early research on human environments was carried out by Moos (1979). Moos found that the diverse characteristics of learning environments consisted of three general categories. This finding emerged from Moos' work in a variety of environments including hospital wards, school classrooms, prisons, military companies, university residences and work milieus. Those three dimensions are: Relationship dimensions, which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other; Personal Development dimensions, which assess personal growth and self-enhancement; and System Maintenance and System Change dimensions, which involve the extent to which the environment is orderly, clear in expectations, maintains control, and is responsive to change. Moreover, in the past 25 years, Moos' work has influenced the development and use of questionnaires to assess the qualities of the classroom-learning environment from the perspective of the student (Fraser, 1986, 1994; Fraser & Walberg, 1991). Examples of classroom environment questionnaires include: the *Science Laboratory Environment Inventory* (SLEI)

(McRobbie & Fraser, 1993a); the *College and University Classroom Environment Inventory* (CUCEI) (Fraser, Treagust, & Dennis, 1986); and the *Constructivist Learning Environment Survey* (CLES) (Taylor, Fraser, & Fisher, 1997).

Learning environment research has become firmly established, especially in the field of science education (Fraser, 1986, 1994: Fraser & Walberg, 1991). Furthermore, a questionnaire specifically suited to assessing the environment of science laboratory classes at the senior high school or higher education levels was developed because of the critical importance and uniqueness of the laboratory setting in science education (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995; Fraser, McRobbie, & Giddings, 1993). The Science Laboratory Environment Inventory (SLEI) has five scales (each with seven items) and the five response alternatives are Almost Never, Seldom, Sometimes, Often and Very Often. The SLEI was field tested and validated simultaneously with many samples in six different countries (Fraser & McRobbie, 1995; Fisher, Henderson, & Fraser, 1997; Wong & Fraser, 1995).

Many instructors and researchers are not aware of how to effectively evaluate innovations, new curricula and new teaching methods. Because classroom environment questionnaires can provide meaningful information about classrooms and are an important basis to guide improvements, an economical, easily-administered, hand-scorable learning environment research questionnaire is provided as part of this study. It is desirable for science teachers to make use of the SLEI to monitor students' views of their laboratory classes, investigate the impact that different laboratory environments have on student outcomes, and provide a basis for guiding systematic attempts to improve these learning environments.

In particular, for science teachers, the proposed method for improving the environment of science laboratory classes can be especially useful as a basis for them. Fraser, Giddings, and McRobbie (1992) consistently noted that in order to stimulate fruitful discussion and guide improvement attempts as a part of school-based professional development initiatives, the SLEI is easily administered and scored, providing an excellent foundation for attempts to improve the laboratory environments.

During the early 1980s much more attention was focused on research on interpersonal teacher behaviour than was the case in the 1950s and 60s (Wubbels & Levy, 1993). This research, which originated in The Netherlands, focuses on the nature and quality of interpersonal relationships between teacher and students (Créton, Hermans, & Wubbels, 1990; Wubbels, Brekelmans, & Hooymayers, 1991; Wubbels & Levy, 1993). The *Questionnaire on Teacher Interaction* (QTI), which draws upon a theoretical model of proximity (cooperation-opposition) and influence (dominance-submission), was developed to assess student perceptions of eight behaviour aspects. Each item of the QTI has a five-point response scale ranging from Never to Always.

This study used both the 35-item SLEI and the 48-item QTI to assess student perceptions of their learning environments.

Although learning environments have been a focus for education research, as noted above, learning environment research should be used to address contemporary educational issues. Examples of such learning environment approaches include: associations between student outcomes and environment; differences between student and teacher perceptions of actual and preferred environment; do students achieve better in their preferred environment?; teachers' attempts to improve classroom environments; and combining quantitative and qualitative methods (Fraser, 1998b).

In the past about three decades or so, researchers (Fraser, 1991, 1994, 1998a; Fraser & Walberg, 1991) have noted that the development and use of questionnaires focused on examining the qualities of the classroom environment from students' perspectives. In the meanwhile, associations between learning environment variables and student outcomes also has provided a particular focus for the use of learning environment questionnaires. Haertel, Walberg, and Haertel (1981) used a meta-analysis for examining 823 classes in eight subject areas and representing the perceptions of 17,805 students in four nations. This study found that student achievement was enhanced in classes in which students felt greater cohesiveness, satisfaction, and goal direction and less disorganization and friction. Since then other literature reviews have found there to be associations between classroom environment variables and students outcomes (Fraser, 1994).

Until 20 years ago or so, the study of science students' outcomes focused primarily on educational objectives in the cognitive domain. However, much attention (Weinburgh, 1995) has been recently paid to outcomes in the affective domain, and the study of student attitudes has formed part of this research. For example, Shulman and Tamir (1972) suggested that affective outcomes of education are as important as cognitive outcomes, and acknowledgement of the importance of affective outcomes was reflected in their increasing emphasis in curricula (Gardner & Gauld, 1990; Hough & Piper, 1982; Mathews, 1974). Fraser, Giddings, and McRobbie (1995) found that associations existed between classroom environment perceptions of students and their attitudes towards science laboratories.

Despite the successes in using learning environment for students' learning outcomes in the research, several studies have also mentioned the variance involved in this research. Walberg (1981, 1984), who devised a theory of educational productivity, noted that there were nine factors which contribute to the variance in students' cognitive and affective outcomes. The nine factors are student ability, maturity, motivation, the quality of and quantity of instruction, the environment at home, the classroom environment, the peer group outside the classroom and the time involved in viewing video/television media. This model (Walberg, Fraser, & Welch, 1986), which was successfully tested as part of a national study showed that student achievement and attitudes were influenced jointly by these nine factors rather than by one dominant factor. The results from these studies also showed that classroom and school environment factors were particularly important influences on student outcomes. These findings were consistent with the theoretical model of Getzels and Thelen (1960), which describes the school class as a social system. This model states that the group behaviour of humans could be predicted from personality needs, role expectations, and classroom environment.

This study is aimed to investigate students' attitudinal outcomes in the physical chemistry laboratory. This study is consistent with the past classroom research investigating associations between student outcomes and the science classroom environment using the SLEI (McRobbie & Fraser, 1993a). Past research has found that students' attitudinal scores were higher in classrooms in which students perceived a greater presence of student cohesiveness, integration between theory and practice, clear rules and a better material environment (Fraser, Giddings, & McRobbie, 1992). McRobbie and Fraser (1993a) used the SLEI to investigate associations between student outcomes and the learning environment in the science laboratory and found that the Integration scale of the SLEI showed the strongest positive association with both students' cognitive and attitudinal outcomes. It would be expected that the higher students' attitudinal outcomes were the better the students' cognitive outcomes (Neville, n.d.).

1.4 AIMS AND OBJECTIVES

The present study was conducted with tertiary students during regular class time and examined classroom environment and teacher-student interaction. The study is interesting in that it examines a combination of the SLEI, the QTI, attitudinal outcomes, cognitive outcomes and practical outcomes with students studying a physical chemistry laboratory subject. This study also aims to extend previous research of classroom environment by examining students' learning outcomes and perceptions of their physical chemistry laboratory class by combining quantitative and qualitative methods within the same study in tertiary science classrooms in Thailand. Such a study has never before been carried out in Thailand.

To achieve these aims, the following objectives were proposed. The objectives of this study were to:

1. provide further validation information about the SLEI and the QTI questionnaires in terms of reliability for use in the physical chemistry laboratory classrooms in Thailand.

2. investigate students' perceptions of their physical chemistry laboratory classes and their teacher-student interactions.

3. investigate differences between the students' perception of their actual and preferred learning environments, and students' perception of their actual and ideal teacher interactions.

4. investigate attitudes students have towards their physical chemistry laboratory classes.

5. investigate associations between the students' perceptions of their learning environments in the physical chemistry laboratory, and attitudinal, cognitive and practical outcomes, and of their laboratory teacher's interpersonal behaviour.

6. confirm whether students' perceptions of their actual physical chemistry learning environment can be changed towards their preferred learning environment.

7. confirm the construct validity of the SLEI and the QTI by using qualitative data.

1.5 SIGNIFICANCE OF THE STUDY

Previous studies of classroom environment have indicated that interpersonal teacher behaviour is an important aspect of the learning environment and that it is related strongly to student outcomes (Fisher, Rickards, & Fraser, 1996). Accordingly, if the QTI can be validated for use in Thailand, science teachers can make use of it to monitor students' views of their classes and to achieve greater congruence between actual and ideal of teacher-student interactions in classrooms. For example, a science teacher can adjust understanding behaviour while he/she is interacting with students when he/she knows the student scores on the Understanding scale of the Actual Form of the QTI are lower than the Ideal Form. Science teachers could show more understanding behaviour in the classroom by listening more to the opinions of students. Teachers might also like to consider strategies or design activities in a classroom that could enhance their understanding behaviour. In addition, the QTI could be used in Thailand to assess changes that result from the introduction of new curricula or teaching methods, and in checking whether the science teacher's interpersonal behaviour is seen differently by students of different genders, ability or ethnic backgrounds outcomes (Fisher, Rickards, & Fraser, 1996). Similarly to the QTI, when the validated SLEI can be used to monitor students' views of their laboratory classes, investigations on the impact that different laboratory environments have on student outcomes, and provide a basis for guiding systematic attempts to improve student learning outcome (Fraser, Giddings, & McRobbie, 1992).

This study provides reliability and validity data on the SLEI and the QTI and researchers will be able to use these questionnaires with confidence in physical chemistry laboratories and classrooms in Thailand at the tertiary level.

As well, findings from the interviews and written stories presented in this thesis lead to more insights on classroom environments in Thailand and expand our knowledge of learning environment generally.

1.6 LIMITATIONS OF THE STUDY

One of the limitations of this study is that the sample was comprised of only 198 science students from seven Rajabhat Universities because of time, budget and resource limitations. Students from secondary and primary schools were not involved in this study because of the focus on physical chemistry laboratory classrooms for tertiary science students.

When the questionnaires were returned, the initial estimates were made of how many of the students in the sample should be interviewed and asked, bearing in mind the time, budget and resource limitations. Even though only some students' comments provided valuable insights and information about the study, those comments were expected to be representative of the population of tertiary chemistry students.

1.7 OVERVIEW OF THE METHODOLOGY

In recent years, it has been shown that combining quantitative and qualitative methods within the same study in research on classroom learning environments can lead to a more in-depth understanding of learning (Fraser & Tobin, 1991; Tobin, Kahle, & Fraser, 1990). Data from questionnaires can be used not only to provide an economic view of learning environments, but also as a starting point from which qualitative data can be collected using such methods as classroom observation, written accounts, and interviews with students. Thus it was decided that this study should not only include quantitative methods of data collection, but also include interviews and written accounts.

There were three particular reasons for including qualitative methods of data collection besides its use in confirming the construct validity of the SLEI and the QTI. First, the researcher was able to explain differences and similarities between the learning environments in each university; second, in order to ascertain reasons why students reported different perceptions of the learning environment in classrooms gained from the use of Actual and Preferred Forms of the SLEI, and the Actual and Ideal Forms of the QTI questionnaires; and third in order to modify the questionnaires by asking students to comment on any difficulties which they experienced in interpreting or understanding the items in the questionnaires and whether there were any additional items or issues that should have been included in the questionnaire in relation to improving the learning environment in classrooms. Therefore, this study involved the use of widely-applicable questionnaires, and involved interviews and written stories which have provided rich insights into classroom life (Rutter, Maughan, Mortimore, Ouston, & Smith, 1979; Stake & Easley, 1978).

A number of students from nine Rajabhat University classes were involved in the quantitative aspects of the study in order to provide dependable validation data. In the quantitative data collecting, the 35-item version of the SLEI (Fraser, Giddings, & McRobbie, 1992) and the 48-item version of the QTI (Wubbels, 1993) were used to collect data on students' perception of their laboratory environments, and of their teachers' interpersonal behaviour respectively, in nine Rajabhat University classes in Thailand.

Students' attitudes to science were measured by using an Attitude Scale derived from the *Test Of Science Related Attitudes* (TOSRA) (Fraser, 1978, 1981c). The test on student cognitive achievement, which was based on the physical chemistry laboratory content, was constructed by the researcher in order to investigate students' cognitive achievement. This test was trialled in order to test its validity and reliability. Also one practical performance test was constructed in order to investigate students' practical outcomes. This test was based on the *Practical Test Assessment Inventory* (PTAI) (Tamir, Nussinovitz, & Friedler, 1980, 1982). To validate this test, it was given to five academics for comment, and then trialled with students. It was then modified to improve its validity.

Data analysis was completed using both manual and computerised methods. Quantitative data were examined using Microsoft Excel Version 98 (Microsoft Corporation, 1998) and SPSS Version 10 (Norusis, 1998).

The stories and their subsequent commentaries, and interviews provided means by which the researcher was able to explain differences and similarities between the learning environments in each Rajabhat University, and supported the validity of two questionnaires.

A previous study of science classroom environments has been conducted using both the SLEI and the QTI questionnaires (Henderson, Fisher, & Fraser, 1995). However, such a study has never been conducted in Thailand.

1.8 OVERVIEW OF THIS THESIS

This thesis consists of seven chapters and 23 appendices.

The first chapter summarises the purpose of this study, outlines the objectives, describes the significance of the study, reports the limitations of this study, provides a brief overview of the methodology, provides an overview of the thesis and also includes a summary section.

Chapter 2 reviews some of the literature describing learning environment research, the Science Laboratory Environment Inventory and research which involved the Science Laboratory Environment Inventory, interpersonal behaviour research and the Questionnaire on Teacher Interaction. As well, there are some explanatory statements within each topic.

Chapter 3 describes the methodology used in this study. Included are the research questions derived to achieve the objectives, historical background of questionnaires used in the study, data collection, the sample and the measures used to analyse qualitative and quantitative data.

Chapter 4 describes the validation of the SLEI and QTI and provides data on the two versions of each questionnaire that were used in this study.

Chapter 5 describes data from the other measures used in this study. These included the Attitude Scale, and the cognitive and practical achievement measures.

Chapter 6 presents the qualitative student data which were collected, and its use in confirming the validation of the SLEI and QTI. From this qualitative data, a comprehensive view of classroom environments and teacher behaviours was obtained.

Finally, Chapter 7 reports the results related to the research questions proposed. Associations between students' perceptions of the classroom-learning environment, and their attitudinal and achievement outcomes are also described. Moreover, the relationships between the qualitative and quantitative findings are discussed. This chapter also discusses the conclusions of this study and its implication for teachers and other educators. Furthermore, suggestion for further research is based on the findings of this study, are outlined.

There are references, 23 appendices consisting of a full set of the questionnaires used in this study, samples of cognitive and performance tests, a copy of the report materials provided to students participating in this study, and letters of consent are also included.

1.9 CHAPTER SUMMARY

The first section has outlined the origin of this thesis. The following four sections described the background, framework, objectives and significance. The limitations of this research, which were introduced here, will be again discussed in the final chapter of this thesis. The first chapter has also provided an overview of the methodologies used in this study and an overview of the contents of each chapter contained in this thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION AND OVERVIEW

The primary aim of this study was to investigate students' perceptions of the environment of their physical chemistry laboratory classes in Thailand. The study involved data collection on student outcomes for cognitive and practical performance achievement, and attitudes to physical chemistry laboratory class. The first objective of this chapter is to build a conceptual framework for this study by reviewing the literature, which involves studies on learning environments. As well, a historical background of learning environment questionnaires up to the development of the SLEI and QTI, is included in this review. The second objective is to review completed research in the area of learning environments, which reports students' perceptions of their learning environments and students' learning outcomes using the SLEI and QTI. In addition, associations between the classroom environment and student outcomes with the incorporation of the SLEI and QTI are reported in the second objective review. At the end of this chapter, a summary of recent literature in these areas is presented. In Chapter Three, there is a review of literature supporting the validation of the SLEI and QTI.

2.2 CONCEPTUAL FRAMEWORK FOR RESEARCH ON LEARNING ENVIRONMENTS

Learning environment describes the shared perceptions of students and sometimes of their teachers. This has two advantages in describing the class through the eyes of actual participants and obtaining data, which an external observer could miss or consider unimportant. Accordingly, the learning environment has been studied with a view to identifying those characteristics of learning environments that are associated with enhanced student outcomes.

This section describes studies of researchers whose work was significant in the development of a conceptual framework on learning environments, such as the studies of Walberg and Moos, Lewin and his colleagues, and Murray's concept of the human environment.

Considerable interest within the educational research field has been focused on the nature of the classroom learning environment (Fraser, 1998b; Fraser, & Walberg, 1991; Moos, 1979; Walberg, 1979). Studies of the classroom environment by international researchers involved the conceptualization, assessment and investigation of perceptions of aspects of the classroom environment and this continued to be a growing field of study. For example classroom environment research has recently focused on constructivist classroom environment (Taylor, Dawson, & Fraser, 1995), computer-assisted instruction classroom (Teh & Fraser, 1994a) and teacher interpersonal behaviour in the classroom (Wubbels, Créton, Levy, & Hooymayers, 1993; Kent & Fisher, 1997).

The work on educational environment was established in the 1930s and built upon the ideas of Lewin, Murray and their followers, such as Pace and Stern. First of all, Lewin's seminal work on field theory recognised that both the environment and its interaction with individual personality characteristics were potent determinants of human behaviour (Lewin, 1936). This theory was expressed in the Lewinian formula:

$$B = f(P, E)$$

This formula provided the impetus for new research strategies in which human behaviour (B) was described as a function of the person (P) and the environment (E).

Murray (1938) was the first to follow Lewin's approach by proposing a needs-press model, which allowed the analogous representation of person and environment in common terms. Murray defined personal needs as motivational personality characteristics representing tendencies to move in the direction of certain goals.

Environmental press was defined as providing an external situational counterpart, which supported or frustrated the expression of internalized personality needs.

After that, a needs-press theory was popularised and elucidated for describing student outcomes (e.g., Pace & Stern, 1958; Stern, 1970). Murray's needs-press theory led to the development of various personality measurements, and Murray (1938) introduced the term alpha press to describe the environment as assessed by a detached observer, and the term beta press to describe the environment as perceived by inhabitants of the environment.

Stern, Stein, and Bloom (1956) who distinguished between an idiosyncratic view and a shared view of the environment extended Murray's distinction between the alpha press and the beta press. The idiosyncratic view is defined as each person's view of the environment (private beta press), and the shared view describes that which members of a group hold about the environment (consensual beta press). The private and consensual beta press could differ from each other, and both could differ from a detached view as assessed by a trained non-participant observer. Therefore, in designing classroom environment studies, researchers must decide whether their data is to be obtained from individual students (private beta press) or obtained from the average of environment scores of all students within the same class (consensual beta press).

Brophy and Good (1986) further indicated that using students' and teachers' perceptions to study the educational environments, as said above, contrasted with an external observer's direct observation and systematic coding of classroom communication and events.

Rickards (1998) suggested that although Murray's needs-press model has been utilized and extended to report on high inference measurement in educational learning environment (Pace & Stern, 1958), outside observers rely on observations that are based on external experiences of the learning environment.

2.3 THE DEVELOPMENT OF LEARNING ENVIRONMENT QUESTIONNAIRES

There have been many classroom environment questionnaires developed, and the scales of these questionnaires have been incorporated to measure certain aspects of the environment in which the utility of incorporated scales depends on the hypothesis of researcher and the field of study. This section describes both historically important and contemporary questionnaires that have been used to assess the quality and nature of classroom learning environments over the past three decades. The classification of each scale of each questionnaire is in accordance with Moos' (1974) scheme for classifying human environments, as discussed in Chapter One. The three basic dimension types of Moos are Relationship Dimension, Personal Development Dimension and System Maintenance and System Change Dimension. The Relationship Dimension is defined as the nature and intensity of personal relationships within the environment and assessment the extent to which people are involved in the environment and support and help each other. The Personal Development Dimension assesses personal growth and self-enhancement. The System Maintenance and System Change Dimension involve the extent to which the environment is orderly, clear in expectations, maintains control, and is responsive to change.

Educational environment fields may be divided into two kinds, namely the classroom-level environment and the school-level environment. As such, Fraser and Rentoul (1982a) indicated that it was useful to distinguish classroom or the classroom-level environment from school or the school-level environment. The school-level environment involves the psychosocial aspects of whole school climate. School climate research provides various theories, instrumentation and methodology built on earlier work on organisational climate in business contexts. Two questionnaires widely used in the school environment research, namely, Halpin and Croft's (1963) *Organizational Climate Description Questionnaire* (OCDQ) and Stern's (1970) *College Characteristics Index* (CCI), heavily relied on previous work in business organisations. Despite their simultaneous development and logical relations, the classroom-level and school-level environment fields have remained different. For this study, I chose to investigate the classroom-level environment.

The classroom environment questionnaires which are relevant to the study and are briefly discussed here are as follows:

- *Learning Environment Inventory* (LEI)
- *My Class Inventory* (MCI)
- *College and University Classroom Environment Inventory* (CUCEI)
- *Classroom Environment Scale* (CES)
- *Individualised Classroom Environment Questionnaire* (ICEQ)
- *Constructivist Learning Environment Survey* (CLES)
- *Geography Classroom Environment Inventory* (GCEI)
- *Computer Classroom Environment Inventory* (CCEI)
- *What Is Happening In This Classroom* (WIHIC)
- *Cultural Learning Environment Questionnaire* (CLEQ)
- *Distance and Open Learning Environment Survey* (DOLES)
- *Socio-Cultural Environment Scale* (SCES)

2.3.1 The Learning Environment Inventory (LEI)

The Learning Environment Inventory (LEI) measures student perceptions of 15 environment dimensions with secondary school classrooms (Fraser, Anderson, & Walberg, 1982). The LEI was also widely used to study associations between school classes, classroom expectations and classroom environment, which affected student-learning outcomes (Walberg, 1969a, 1969b). In the late 1960s, initial development and validation of the first version of the LEI began in conjunction with the evaluation of Harvard Project Physics (Fraser, Anderson, & Walberg, 1982; Walberg & Anderson, 1968).

The final version of the LEI contains a total of 105 statements (or seven per scale) in describing typical school classes. Items are scored on a four point Likert scale (Likert, 1932), with some items being reversed. Although the scales of 15 dimensions of the LEI makes it a good indicator questionnaire and it is relevant to social psychological theory (Fraser & Walberg, 1991), it is difficult to interpret, and it is considered to be too long for students at lower grade levels, especially for whom English is not their first language (Majeed, Fraser, & Aldridge, 2001).

2.3.2 The My Class Inventory (MCI)

The My Class Inventory (MCI) is a simplified form of the LEI for use with 8-12 year old children (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg, 1982; Fraser & O'Brien, 1985). It also has been found to be very useful with students in junior high school, especially those with limited reading skills in English (Majeed, Fraser, & Aldridge, 2001), and those who might have difficulty reading with other questionnaires (Fraser, 1995). The MCI differs from the LEI in four important ways. First, the MCI contains only five of the LEI's original 15 scales, in order to reduce fatigue among younger children. Second, item wording of the MCI has been simplified to enhance readability. Third, the LEI's four-point response format has been reduced to a two-point (Yes-No) response format. Fourth, the students answer on the questionnaire itself instead of on a separate response sheet, to avoid errors in transferring the responses from one place to another.

The final form of the MCI contains 38 items altogether. Goh, Young, and Fraser (1995) have successfully used a three-point response format (Seldom, Sometimes and Most of the Time) with a modified version of the MCI including a Task Orientation scale.

2.3.3 The College and University Classroom Environment Inventory (CUCEI)

The College and University Classroom Environment Inventory (CUCEI) was developed for use in small classes (5 to 30 students) typically encountered at the post-secondary level, which are sometimes referred to as a 'seminar'. This questionnaire was developed because few studies had centred on higher education classrooms (Fraser & Treagust, 1986; Fraser, Treagust, & Dennis, 1986).

The final form of the CUCEI contains seven seven-item scales. Each item has four responses, and a score direction is reversed for approximately half of the items. Recently, the CUCEI has been successfully used in hospital-based education in Australia. The CUCEI has been adapted to form new questionnaires that are specific for particular studies, for example *the Secondary Colleges Classroom Environment Inventory* (SCCEI) (Rickards, 1998).

2.3.4 The Classroom Environment Scale (CES)

The Classroom Environment Scale (CES) is a questionnaire used frequently in the current research, and was developed by Rudolf Moos at Stanford University (Fisher & Fraser, 1983a; Moos, 1979; Moos & Trickett, 1987). The CES grew out of a comprehensive program in research involving the perceptual measurements of a variety of human environments including psychiatric hospitals, prisons, university residences, school classrooms, correctional institutions and work milieus. The development of the CES enabled examination of the psychosocial environment of school classrooms from the aspect of participant interaction, including behaviour exhibited by teacher, teacher-student interaction and student-student interaction (Rickards, 1998).

The final published version of the CES contains nine scales with 10 items of a True-False response format in each scale, and about half of the items are reverse-scored. Published materials associated with the CES include a test manual, a questionnaire, an answer sheet and a transparent hand-scoring key.

2.3.5 The Individualised Classroom Environment Questionnaire (ICEQ)

The Individualised Classroom Environment Questionnaire (ICEQ) was developed in response to literature and academic conferences associated with inquiry approach learning. It assesses dimensions, which distinguish individualised classrooms from other learning environments. The initial development of the ICEQ was guided in three important ways: a review of the literature on individualised open and inquiry-based education; extensive interviewing of teachers and secondary school students; and reactions to draft versions was sought from selected researchers, teachers and junior high school students (Rentoul & Fraser, 1979). Furthermore, the ICEQ has been applied in association with the LEI and CES in studies which focus on general aspects of classroom environment (Fraser & Fisher, 1982a).

The latest published version of the ICEQ contains 50 items. Each item is responded to on a five point Likert-type response scale, and the scoring direction is reversed for some items. The published version has a progressive copyright arrangement which gives permission to purchasers to make an unlimited number of questionnaires and response sheet copies (Fraser, 1990).

2.3.6 The Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) was developed with a psychological view of learning that focuses on students as co-constructors of their own knowledge and as a response to a need to assess such innovative classroom environments (Taylor & Fraser, 1991; Taylor, Dawson, & Fraser, 1995b; Taylor, Fraser, & Fisher, 1997). It was originally developed to measure students' perceptions of the extent to which constructivist approaches are present in classrooms (Aldridge, Fraser, Taylor, & Chen, 2000). A new version of the CLES was developed by Taylor (1996) to include a theoretical framework from the aspect of critical constructivism. As well, it was developed to assist researchers and teachers to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and reshape their teaching practices (Taylor, Dawson, & Fraser 1995; Taylor, Fraser, & Fisher, 1997).

Because the CLES contained conceptual strength and a psychometric structure, it was rigorously tested using quantitative and qualitative methods, which led to the omission of negative and conceptually-complex items. Moreover, items of the same scale of the CLES were grouped together under a simple scale name to provide a contextual cue for respondents (Taylor, Dawson, & Fraser, 1995a, 1995b; Taylor, Fraser, & White, 1994).

The CLES has 30 items including six items reversed, and a five-point frequency response scale. Recently, the CLES was revised by Johnson and McClure (2002) leading to a shortened form of the questionnaire where the five original scales were retained, but the number of items in each scale was reduced from six to four and the negatively-worded items were eliminated. This 20-item questionnaire is named the CLES 2.

2.3.7 The Geography Classroom Environment Inventory (GCEI)

The Geography Classroom Environment Inventory (GCEI) has four scales intending to investigate computer aided learning classroom environments. The GCEI was validated by 348 responses from investigating inequities in computer aided learning in Singapore (Teh & Fraser, 1994b). Later, it was applied in distance education geography classes at undergraduate levels. Teh (1999) considered internal consistency and discriminant validity of 92 responses for asynchronous distance education students in Singapore, and it was found that research of learning environments was significant in this case because of the rare combination between geography education research and distance education research in Singapore and elsewhere. The four scales of the GCEI are: Gender Equity; Investigation; Innovation and Resource Adequacy.

2.3.8 The Computer Classroom Environment Inventory (CCEI)

The Computer Classroom Environment Inventory (CCEI) assesses students' perceptions of learning environments, which involve both an inquiry learning approach and a computerized database use (Maor & Fraser, 1993, 1996). This questionnaire measures students' and teachers' perceptions on five scales with 30 items in total. Some of the items, which are responded to on a five point Likert-type scale, are reversed. The development of the CCEI was based on the dimensions outlined by Moos, the existing literature on inquiry learning, quick and efficient completion and hand score, and salience to teachers and students in the target audience. Use was made of the CCEI to investigate students' inquiry skills during a computerised database program (Fraser, 1997).

2.3.9 The Cultural Learning Environment Questionnaire (CLEQ)

The Cultural Learning Environment Questionnaire (CLEQ) was specifically developed for the study of cultural sensitivity in education settings. The CLEQ's development was guided by six criteria: consistency with the important learning style dimensions identified by Grashna (1972); coverage of Moos' general dimensions, with scales for the CLEQ chosen to include at least one scale from each of Moos' three dimensions; consistency with previous learning environment research, and all relevant scales contained in relevant existing questionnaires designed for assessing the learning environment were examined for guidance in identifying suitable scales; consistency with the important cultural dimensions in the unique environment of multicultural organisations identified by Hofstede (1984); interviews with teachers and students were used to ensure that the CLEQ's scales and individual items were salient; and the CLEQ was designed to have a relatively small number of reliable scales, each containing a small number of items. The final result was a CLEQ containing eight scales with five items in each scale, giving an economical total of 40 items. These 40 items not only drew on scales from previous research, but also included novel scales, which elicit information about the influence of culture on the learning environment (Waldrip & Fisher, 2000).

2.3.10 The What Is Happening In this Classroom (WIHIC)

The What Is Happening In this Classroom (WIHIC) questionnaire was developed by Fraser, Fisher, and McRobbie (1996) to combine modified versions of the most salient scales from a wide range of existing questionnaires with additional scales that accommodated contemporary educational concerns (e.g., equity and co-operation) to assess classroom learning environment in a parsimonious way. The original 90-item nine-scale version was refined using both statistical data from 355 junior high school science students and extensive interviewing including views of students' classroom environments in general, the wording and salience of the individual item and their questionnaire responses (Fraser, Fisher, & McRobbie, 1996). The final form of the WIHIC contains seven scales with eight items in each scale. Fraser and Chionh (2000) successfully used this version with 2,310 high school students in Singapore. Pickett and Fraser (2002) also used the WIHIC in elementary schools to provide insight into the effects of a mentoring program for beginning teachers in the USA.

2.3.11 The Distance and Open Learning Environment Survey (DOLES)

In 1995, the Distance and Open Learning Environment Survey (DOLES) was developed, a pioneering questionnaire combining learning environment research and distance education research focusing on technology and interaction (Jegede, Fraser,

& Fisher, 1995). The DOLES was developed in 1995 in order to focus exclusively on distance education among university students (Fraser, 1998b; Jegede, Fraser, & Fisher, 1998). Use was made of the DOLES in focusing on World Wide Web-delivered subjects with a distinct Australasian focus, and considering participants' perspectives of in primary distance education science classes originating from Queensland and Western Australian universities (Jegede, Fraser, & Fisher, 1998). The final version of the DOLES has 52 items providing five core scales and two optional scales. The core scales are: 1) Student Cohesiveness, 2) Teacher Support, 3) Personal Involvement and Flexibility, 4) Task Orientation and Material Environment, and 5) Home Environment. Optional scales are: 1) Student-Centred Environment, and 2) Technology Resources.

2.3.12 The Socio-Cultural Environment Scale (SCES)

The Socio-Cultural Environment Scale (SCES) measures the socio-cultural factors, which affect the teaching and learning of science and was developed by Jegede and Okebukola (1993) for measuring those elements of the socio-cultural environment which affect significantly pupils' learning within science classrooms. Jegede and Okebukola (1993) expected that further research might be recommended to establish the validity of the SCES or to the SCES with the ultimate objective being to get the best measure of the socio-cultural environment in science classes. Science teachers need to be aware of these socio-cultural elements in order to develop intervention strategies for reducing the anxiety of students. The SCES has five scales with six items in each scale. The items are scored on a three point Likert type response scale.

2.4 ACTUAL AND PREFERRED FORMS

Although classroom environment questionnaires have been used to investigate perceptions of 'actual' or experienced classroom environment, some classroom environment questionnaires also have been used to investigate perceptions of 'preferred' or ideal classroom environment; such as the Science Laboratory Environment Inventory (SLEI), the Questionnaire on Teacher Interaction (QTI) and the CUCEI, for example. The Preferred Form is concerned with ideal goals and value orientations in classrooms, and measures the perceptions of the classroom environments ideally liked or preferred. Item wording in the Actual and Preferred Forms is slightly different, and instructions are used to detail whether respondents are rating what the environment is actually like or what they would prefer it to be. For example, an item in the Actual Form such as 'I get on well with students in this laboratory class' is changed in the Preferred Form to 'I would get on well with students in this laboratory class (Fraser, 1982a).

In such a way, the Preferred Form is used to explore whether outcomes (for example, cognitive achievements and attitudes) are better in the classes in which there is a greater similarity between the actual and preferred learning environment perceived by the students. Therefore, the researcher can measure the degree to which students perceive their actual classroom environments to be congruent with these ideal environments, and how environments can be changed to correspond more closely to preferred environments. There were past studies that supported this statement. One such study involving perception of classroom environment by Majeed, Fraser, and Aldridge (2001) noted that actual-preferred congruence (or person-environment fit) predicted student achievement in the affective and cognitive outcomes. The more congruent actual and preferred classroom environments are within the classes, the more likely the enhancement of student outcomes.

Past use of the SLEI by Wong (1994) indicated that preferred perceptions were generally more favourable than actual perceptions by students. Moreover, the results of learning environment research conducted by Fisher and Fraser (1983b), Hofstein and Lazarowitz (1986), Kim, Fisher, and Fraser (1999), Moos (1974), and Wubbels, Brekelmans, and Hooymayers (1991) consistently suggested that the students preferred a more positive classroom environment than the classroom environment they perceive to be present.

2.5 SHORT AND LONG FORMS OF THE CES, ICEQ AND MCI

There are three questionnaires described in Section 2.3 that have a short form: the ICEQ, the MCI and the CES (Fraser, 1982b; Fraser & Fisher, 1983a). Fraser (1998a) consistently noted that there were some researchers and teachers who would prefer the questionnaires to take less time in administering and scoring. Even though long forms of classroom environment questionnaires have been successfully utilized in assessing students' perception of their classroom environments, these still take time, and are expensive to use. Therefore, the short forms of the CES, ICEQ and MCI were developed for responding to the needs of researchers and teachers. The development of short forms of existing questionnaires was based on the three main criteria. First, the total number of items in each questionnaire was reduced to about 25 to provide greater economy in testing and scoring time. Second, the short form was designed for easy hand scoring. Third, the short form was developed to have adequate reliability for students' perceptions within a class to enable class means to be used. The short forms of the CES, ICEQ and MCI consist of 24, 25 and 25 items, respectively (Fraser, 1982b; Fraser & Fisher, 1983a). Despite the quick administration, easy and low expense associated with use of the short forms, studies have confirmed the adequate reliability at a class level of these questionnaires (Fraser & Deer, 1983).

2.6 SUMMARY OF LEARNING ENVIRONMENT QUESTIONNAIRES

The development of the various learning environment questionnaires over the last 30 years has enabled the field of learning environment research to undergo considerable progress because each of the questionnaires examines a specific aspect of learning environment. For example, recent classroom environment research has focused on areas as varied as science laboratory classroom environments (Fraser, Giddings, & McRobbie, 1993), the interpersonal relationships between teachers and students (Wubbels, Créton, & Hoomayers, 1992; Wubbels & Levy, 1993), constructivist classroom environments (Taylor, Dawson, & Fraser, 1995a), cultural factors of the classroom environments (Waldrip & Fisher, 1996a, b), computer-based environments (Levine & Donitsa-Schmidt, 1995; Maor & Fraser, 1993; Teh & Fraser, 1994a) and the conceptualisation, assessment and investigation of perceptions of psychosocial aspects of the classroom environment (Fraser, 1994; Fraser & Walberg, 1991).

Although in many studies, the learning environment questionnaires are independently used, some questionnaires are incorporated into other questionnaires for specific work. For example, Idiris and Fraser (1997) incorporated the CLES and the ICEQ into a suitable questionnaire to study the learning environment of agricultural science classes in Nigeria. This new questionnaire consists of four scales, namely, Negotiation, Autonomy, Student Centreness, and Investigation and Differentiation. A questionnaire to cater for the reading ability of middle school students was developed by Sinclair and Fraser (1997), using scales from the MCI and the WIHIC. Four scales in this questionnaire are, namely, Cooperation, Teacher Empathy/Equity, Task Orientation, and Involvement.

It can be said that at present there are many learning environment questionnaires available for the study of classrooms learning environments. It is clear that all the learning environment questionnaires are selected for specific research, and perhaps for describing associations between the students' perceptions of their learning environments and their learning outcomes.

The following table of learning environment questionnaires was adapted from Fraser (1998b) and Rickards (1998) to provide a summary outlining in the major features and scales of these questionnaires, and a classification of scales according to Moos' dimensions. The SLEI and QTI are described later because they have been selected for this study and therefore are discussed in more detail.

Table 2.1
Overview of Scales of Twelve Classroom Environment Questionnaires

			Scales Classified According to Moos' Scheme		
Questionnaire Maintenance Dimension	Level	Items Per Scale	Relationship Dimensions	Personal Development Dimensions	System and Change
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness, Friction, Apathy Favouritism, Cliqueness, Satisfaction	Speed, Difficulty Competitiveness	Diversity, Formality, Material Environment, Goal, Direction, Disorganisation, Democracy
My Class Inventory (MCI)	Elementary	6-9	Cohesiveness Friction,, Satisfaction	Difficulty, Competitiveness	
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalisation, Involvement, Cohesiveness, Satisfaction,	Task Orientation	Innovation, Individualisation,

Table 2.1 continued

Classroom Environment Scale (CES)	Secondary	10	Involvement, Affiliation, Teacher Support	Task Orientation, Competition	Order & Organisation, Rule, Clarity, Teacher Control, Innovation
Individualized Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation, Participation	Independence, Investigation	Differentiation
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance, Scientific Uncertainity	Critical Voice, Shared Control	Student Negotiation
Geography Classroom Environment Inventory (GCEI)	Secondary	4	Gender Equity	Investigation, Resource Adequacy	Innovation
Computer Classroom Environment Inventory (CCEI)	Secondary	5	Satisfaction	Investigation, Open Endedness	Material Environment Organisation
Cultural Learning Environment Questionnaire (CLEQ)	Secondary	8-10	Gender Equity, Collaboration, Risk Involvement	Competition Congruence	Teacher Authority, Modelling, Communication
What Is Happening In this Classroom (WIHIC)	Secondary	8	Student Cohesiveness, Teacher Support, Involvement	Investigation, Task Orientation, Cooperation	Equity
Distance and Open Learning Environment Scale (DOLES)	Tertiary	4-12	Student Cohesiveness, Teacher Support, Personal Involvement& Flexibility	Task Orientation & Material Environment, Technology Resources	Student Center Environment, Home Environment
Socio-Cultural Environment Scale (SCES)	Secondary Elementary	6	African World View	Social Expectation	Authoritarianism Goal Structure, Sacredness of Science

(Source: developed from Fraser, 1998b; Rickards, 1998)

2.7 THE SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI)

Not only is the learning environment of general science important in classroom learning, but the learning environment of the laboratory setting is important too. The activity or laboratory work, which occurs in the science laboratory classroom, is an integral part of most science disciplines, but is different from the activity of the normal classroom. Accordingly, Fraser, Giddings, and McRobbie (1992) indicated that expectations of the different learning environments was found when practical activities in the science laboratory classroom were compared with those of the typical science classroom. The Science Laboratory Environment Inventory (SLEI) was specifically developed to assess the environment of science laboratory classes at secondary or higher education levels. Therefore, it was decided to use the SLEI in this study and this section discusses the development and applications of the SLEI.

The researchers asked questions like, "What effect does the laboratory activities have upon student learning?" "Should other outcomes be investigated by a science laboratory learning environment questionnaire?" The SLEI was constructed to elicit student perceptions of their science laboratory learning environment to answer such questions (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995).

2.7.1 The Development of the Science Laboratory Environment Inventory

The initial development of the SLEI was guided by five criteria as follows (Waldrip, 1994, p. 81).

i. Consistency with the literature on teaching and learning in science laboratory classes.
ii. Consistency with already existing learning environment questionnaires designer designed for non-laboratory settings.
iii. Coverage of Moos' general categories. For example, the extent of interpersonal support and help between participants in the laboratory would belong in the Relationship Dimension, where rules of structure and response to change would belong in System Maintenance and System Change Dimension of Moos.
iv. Salience to teachers and students. The development of this aspect of the SLEI was aided by interviewing science teachers and students at senior high schools and asking them to comment on draft versions of items. This attempt was made to ensure that the SLEI' dimensions and individual items were considered salient by teachers and students.
v. Economy. The SLEI was designed to have a relatively small number of items in a small number of scales for achieving economy and the saving of time in responding and scoring the questionnaire.

The initial version of the SLEI contained eight scales: Teacher Supportiveness, Involvement, Student Cohesiveness, Open-Endedness, Integration, Organisation, Rule Clarity and Material Environment. Each scale contained nine items. This version of the SLEI was tried out in six countries, namely, Australia, Canada, England, Israel, Nigeria and the USA with 4,643 students in 225 laboratory classes. The reliability of each scale was found to vary from 0.56 to 0.81 (Waldrip, 1994). The first version of the SLEI was developed in a Class Form, which assessed the individual student's perception of the class as a whole (Lightburn, 2002).

The SLEI was then refined to contain seven scales with 52 items, the refining being based on item analysis (Waldrip, 1994). Administration of the 52-item SLEI was again used with students in six countries (Australia, Canada, England, Israel, Nigeria and the USA), and it was found that it had satisfactory reliability for use in any of the six countries in either the actual or preferred version (Waldrip, 1994).

Factor and item analyses of data were then used to refine the 52-item version of the SLEI. Finally, a 34-item version of the SLEI was developed from the 52-item version, and an extra item included in the 34-item version to produce the 35-item version. The 35-item version of the SLEI spreads over five scales, and the five alternative responses for each item are Almost Never, Seldom, Sometimes, Often and Very Often (Waldrip, 1994).

The meaning of each of the five scales, which are classified according to Moos' scheme is shown in Table 2.2. Table 2.2 contains a scale description and sample item for each scale. The reliability of the scales in this 35-item version ranged from 0.62 to 0.82 (Waldrip, 1994).

Learning involves negotiation and consistent building with other learners, and also involves the personal cognitive process that an individual learner uses to make sense of world experiences (Tobin, 1993 & Von Glasersfeld, 1989). The SLEI was further developed to include a Personal Form, which assesses a student's perception of an individual's role within the class. As such, Fraser, Giddings, and McRobbie (1995) constructed the Personal Form of SLEI, which asked students for their personal perceptions of the laboratory environment. The example items in Table 2.2 are from the Personal Form. The Personal Form of the SLEI exists in both actual and preferred versions. Although the item wording in the Actual and Preferred Forms are almost identical, directions for answering the two forms clearly suggest to students whether they are rating what their class is actually like or what they would prefer their class to be like. For example, changing "there is..." to "there would be..." is clearly a change of focus from what actually happens in the classroom to what the student would prefer to happen in an ideal environment. Appendix A and B contain the Actual Form and the Preferred Form of the SLEI used in this study.

Table 2.2
Descriptive Information and Sample Item for Each Scale of the SLEI

Scale name	Moos category	Description	Sample item
Student Cohesiveness	R	Extent to which students know, help and are supportive of one another.	I get along well student in this laboratory class. (+)
Open-Endedness	P	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation .	In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments. (-)
Integration	P	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	I use the theory from my regular science class sessions during laboratory activities. (+)
Rule Clarity	S	Extent to which behaviour in the laboratory is guided by formal rules.	There is a recognised way for me to do things safely in this laboratory. (+)
Material Environment	S	Extent to which the laboratory equipment and materials are adequate.	I find that the laboratory is crowded when I am doing experiments. (-)

R: Relationship dimension; P: Personal Development dimension, S: System Maintenance and System Change dimension.
Items designated (+) are scored 1,2,3,4 and 5 respectively for the responses Almost Never, Seldom, Sometimes, Often and Very Often. Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3.
(Source: adapted from Giddings & Fraser, 1989).

2.7.2 Review of Past Studies Using the SLEI

As noted above, the development of SLEI was aimed at assessing the science laboratory classroom environment at secondary or tertiary education levels. Science laboratory research is not sufficiently advanced to enable determination of the effects of laboratory instruction on students' learning and attitudes (DeCarlo & Rubba, 1991; Wong, Young, & Fraser, 1997), but much research has included the SLEI in learning environment investigation, and has found associations between students' cognitive and affective outcomes; some of these studies are detailed below.

Fraser, Giddings, and McRobbie (1992) used the SLEI for examining associations between students' perceptions of the laboratory learning environments and students' attitudes to laboratory work with a large-scale study at the tertiary level. All the scales of the SLEI were positively correlated with more favourable student attitudes to laboratory work, particularly the Student Cohesiveness and Integration scales. On the other hand, the Open-Endedness scale was related negatively to attitudes for some student groups.

Giddings and Waldrip (1996) found that the scales of Student Cohesiveness and Open-Endedness were more favourably perceived in Australian and USA science laboratories than with Asian and South Pacific teachers and students. Their study suggested that science teachers were largely unconvinced as to the value of open-ended practical activities in science laboratory classrooms because the Open-Endedness was similarly perceived in science laboratories with the least favourable scores.

McRobbie and Fraser (1993a) used the SLEI in an investigation with 1,594 senior high school chemistry students. Students' perceptions of classroom psychosocial environments predicted appreciable amounts of variance in students' outcome occurred even when students' ability was controlled. As well, the Integration scale showed the strongest positive association with both students' cognitive and attitudinal outcomes.

Wong and Fraser (1994) used the SLEI with 1,592 high school chemistry students in 56 classes in Singapore. They found that all scales of SLEI were positively related to students' attitudinal outcomes except the Open-Endedness. It was also found that generally females had more favourable perceptions of their learning environments than did males on all scales except Open-Endedness, which was perceived more favourably by the males. Finally, the preferred perceptions were generally more favourable than the actual perceptions, and only the preferred perceptions were different in the students in each stream.

Waldrip (1994) studied the effect of specific teaching practices on academic success with a sample of 3,182 students in Papua New Guinea secondary schools. The objective of his research was to determine whether an educational productivity model associated with learning applied to current teaching practices in Papua New Guinea secondary science laboratory classrooms. The results of this study indicated that most of the students perceived the Open-Endedness scale with the lowest score, and boys' attitudes to science were more favourable than those of girls. As well, science academic achievement, science practical achievement, and attitudes were related to quality and quantity of instruction, the science laboratory learning environment and gender. Waldrip' results were similar to those in other countries. For example, male students did significantly better than female students on external science achievement examinations, and the female students received better grades on a practical science process test. Therefore, in current teaching involving science learning environments, instructors should consider their teaching methods and environments in classrooms.

McRobbie and Fraser (1993b) used the Actual Form of the SLEI with 4,596 students in 240 classes in four countries for developing a typology of science laboratory learning environments. More than 90% of those classes could be assigned to one of eight distinct typologies, and students' attitudinal outcomes were found to vary according to the typology of the class.

Harrison, Fisher, and Henderson (1997) extended this research to investigate student perceptions of cognitive and practical tasks with a sample including 387 biology, chemistry and physic students in 20 classes in Tasmania and Australia by using the

SLEI. Quantitative and qualitative methods were combined in their study for measuring effectiveness of the laboratory-based science courses. They found that the students perceived physics to be more open-ended than either biology or chemistry; rule clarity was greatest in the chemistry; and the biology less integrated than either the physics or the chemistry. As well, Laboratory Structure, Task Analysis Inventory and Laboratory Task Analysis were seen to be more open-ended when physics was investigated, and students' learning outcomes were associated with their classroom environment perceptions.

Hofstein, Cohen, and Lazarowitz (1996) successfully used the SLEI to identify the differences between student perceptions in chemistry and biology laboratory environments. They found that the scales of Integration and Open-Endedness showed significant differences between chemistry and biology laboratory environments. Their finding suggested that students' perceptions of their learning laboratory environment in different subjects can be determined by the SLEI. After that, Hofstein and Even (2000) used the SLEI in a study of assessment outcomes of inquiry-based laboratory experiments in high school chemistry in Israel. The chemistry, which was taught, learned, and assessed improved teachers' professional development. Due to the fact that inquiry-type experiments were developed and implemented to chemistry classes.

Pohl (1999) investigated a field-based environmental setting in a water quality-monitoring program with 580 students drawn from water quality and non-water quality-monitoring schools in Australia. Again, there was a direct association between the quantitative results and qualitative information in relation to the learning dimension scales of the SLEI.

Lee and Fraser (2001a, b) investigated Korean high school students' perceptions of their laboratory classrooms using the SLEI. The study involved 439 high school students from three different streams, in which 145 of those were from a humanities stream, 195 were from a science-oriented stream and 99 were from a science-independent stream. The perceptions of the students from the three streams were compared, and it was found that the students from the science-independent stream perceived their classroom environments more favourably than did the students in the other streams, and answering patterns in the SLEI of the Korean high school students were similar to those from other countries.

The study of Swain, Monk, and Johnson (1999) reported that Korean science teachers had a positive attitude to science, and that science practical work was emphasized in fact and illustration. Swain, Monk, and Johnson (1999) also found that the Korean science teachers understood motivation to laboratory tasks about what students already learn in theory lessons, and the learning environment perceptions among the students from the science-independent stream were positive.

The SLEI has also been used to investigate differences between students in their perceptions of the actual classroom environment and the environment that they preferred. Fraser and Fisher (1983a, 1983b) reported that many studies used the Actual and Preferred Forms of environment questionnaires together to examine whether students achieve better when the actual classroom environment and that preferred by students were similar. They suggested that actual-preferred congruence could be important in predicting student achievement of affective and cognitive aims. Therefore, changing the actual classroom environment in ways to make it more congruent with that preferred by the class was likely to enhance student outcomes. In line with this research, differences between the actual and preferred classroom environments, as assessed by the SLEI and QTI, were determined in this study.

As can be seen in these previous research studies, the SLEI has the potential to improve teaching and learning in science laboratory classes (Hofstein & Lunetta, 1982; Lehman, 1989). In addition, recent research on laboratory classroom environments in Australia has consistently indicated that dimensions of the SLEI are positively related to students' attitudinal and cognitive outcomes (McRobbie & Fraser, 1993a; Fisher, Fraser, & Rickards, 1997) although Fraser (1998a) noted that associations with both cognitive and affective learning outcomes and the SLEI scales does not seem to have been investigated at the tertiary level.

2.8 CONCEPTUAL FRAMEWORK FOR INTERPERSONAL BEHAVIOUR

This section discusses the development and theoretical background of the Questionnaire on Teacher Interaction used for the assessment of teacher-student interpersonal behaviour.

In the past two decades, some research studies have involved cognitive-behavioural psychology on the impact of an emotionally supportive environment on cognitive processing, where researchers have tested the proposition that supporting environments produce improved affective and cognitive outcomes (Neville, n.d.). Neville (n.d.) also noted recent research on the impact on different classroom learning environments of a teacher's friendliness, and support of students' learning. Interpersonal teacher behaviour affects student outcomes, for example strict, leadership and friendly behaviours of the teachers are positively associated with student cognitive outcomes (Wubbels, 1993). Consequently, besides the use of the SLEI in assessing laboratory classroom environments in this study, the QTI was incorporated for assessing interpersonal behaviours between teacher and students.

2.8.1 The System Theory of Communication Model

The system theory of communication model was used by Wubbels, Créton, and Holvast (1988) to investigate teacher behaviour in classrooms from a systems perspective. The systems perspective which the Dutch researchers investigated was called "the interactional aspect of teacher behaviour" (Rickards, 1998, p. 40). This was approached using a theory on communication developed by Watzlawick, Beavin, and Jackson (1967) to describe teacher behaviour within a classroom setting (Goh & Fraser, 2000). Communication in this theory is seen as a circular process, that is "changes in one aspect affect changes in another" (Goh & Fraser, 2000, p. 219). This assumes that the behaviours of participants influence each other. Therefore, the behaviour of the teacher is influenced by the behaviour of the students and this in turn influences student behaviour. That is, the circular communication processes include the behaviour and the determining behaviour because the behaviour of the teacher determines, and is determined by the students' behaviour (Rickards, Fisher, & Fraser, 1996; Goh & Fraser, 2000).

In order to explain more clearly the nature of teacher interaction within a conceptual framework, Wubbels, Créton, and Hooymayers (1985) developed a model to map interpersonal teacher behaviour which was based on the work of Leary (1957). This model has been used in the development of the Questionnaire on Teacher Interaction (QTI) (Rickards, Fisher, & Fraser, 1996) which is used to gather students' and teachers' perceptions of interpersonal teacher behaviour (Wubbels, Brekelmans, & Hooymayers, 1991; Wubbels & Levy, 1993).

2.8.2 Leary's Model for Interpersonal Behaviour

Originally, Leary and his coworkers suggested a 16 dimension model with two levels of behaviour (Leary, 1957). The dimensions of level one behaviour were classified in interpersonal gestures or reflexes. The dimensions of level two behaviours were classified in terms of interpersonal attributes or traits. These dimensions are shown in Figures 2.1 and 2.2 respectively.

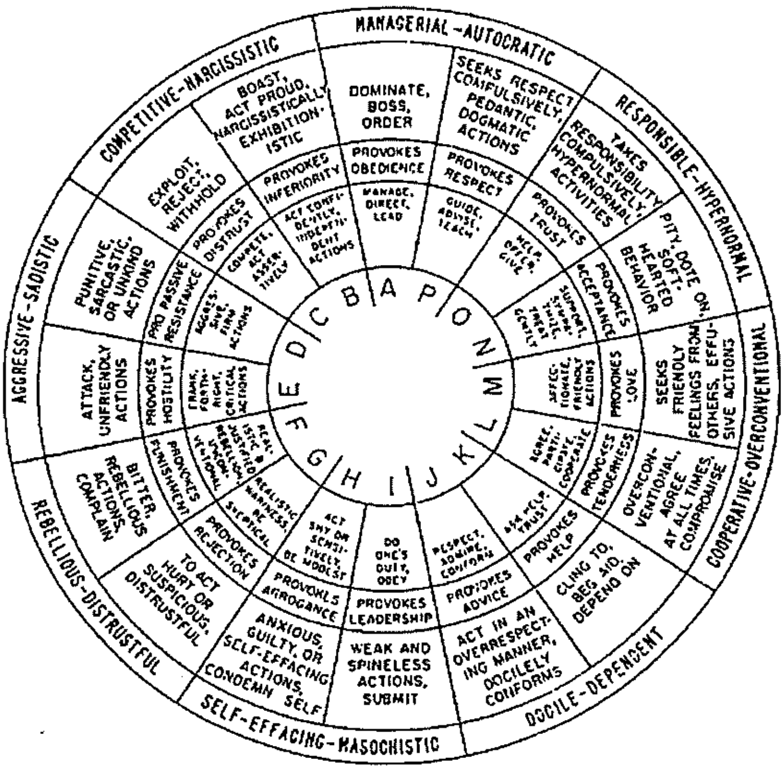


Figure 2.1. Classification of interpersonal behaviour into sixteen mechanisms or reflexes.
(Source: Leary, 1957, p. 65)

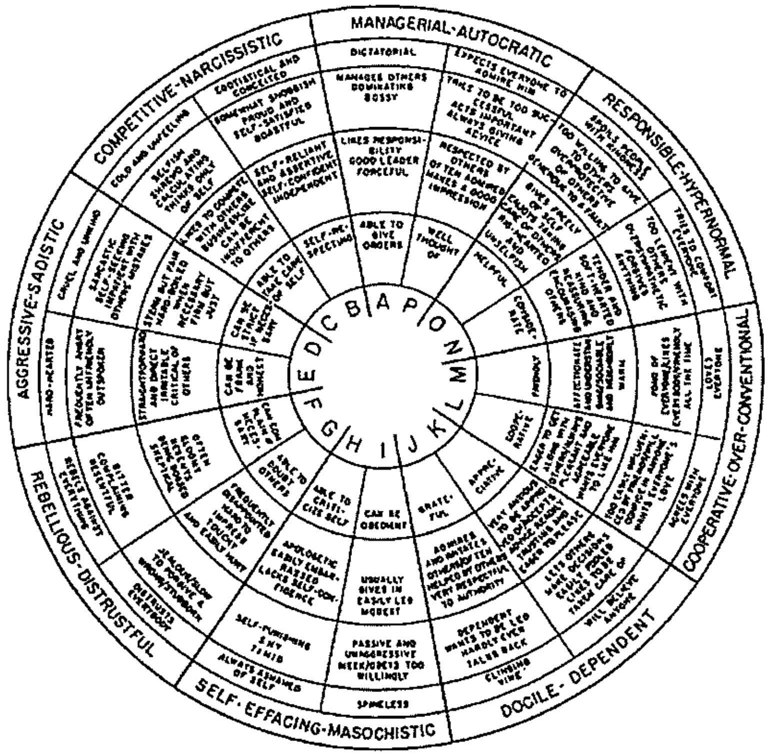


Figure 2.2. Level two classification of interpersonal behaviours into sixteen variable categories.

(Source: Leary, 1957, p. 135)

The interpersonal behaviour work of Leary occurred within the clinical psychology field and was described as being related to communication that was overtly, consciously, ethically or symbolically transmitted to another human being (real, collective or imagined). The way people communicate with other humans represents their personality. Anxiety is defined to be a major component shaping interpersonal behaviour of a person according to Leary, and as such is a strong force. Communication can reduce anxiety for the person, and will become a major factor in their personality (Cresswell & Fisher, 1996).

Therefore, an individual shows more interpersonal behaviours that reduce anxiety and increase or maintain self-esteem. A pattern of communication is then constructed based on this assumption. The 16 dimension model, developed by Leary and his co-workers, was then reduced to the eight-dimensional model of interpersonal behaviour and plotted on a two-dimensional coordinate system as shown in Figure 2.3 (Wubbels, Créton, & Hooymayers, 1985). The two-dimensional coordinate system of interpersonal behaviours was labeled as "Affection-Hostility" and "Dominance-Submission" (Leary, 1957).

Wubbels, Brekelmans, and Hermans (1987) adapted this version of the Leary model in a general framework of eight dimensions, but some labels were redefined and modified. This model referred to two primary dimensions: an Influence dimension (Dominance, D - Submission, S) and a Proximity dimension (Cooperation, C - Opposition, O). The Influence dimension was described as measuring dominance and submissiveness in a relationship. The Proximity dimension was described as measuring the degree of cooperative or oppositional behaviour between those communications. Figure 2.3 shows the two-dimensional model as adapted by Wubbels and Levy (1993).

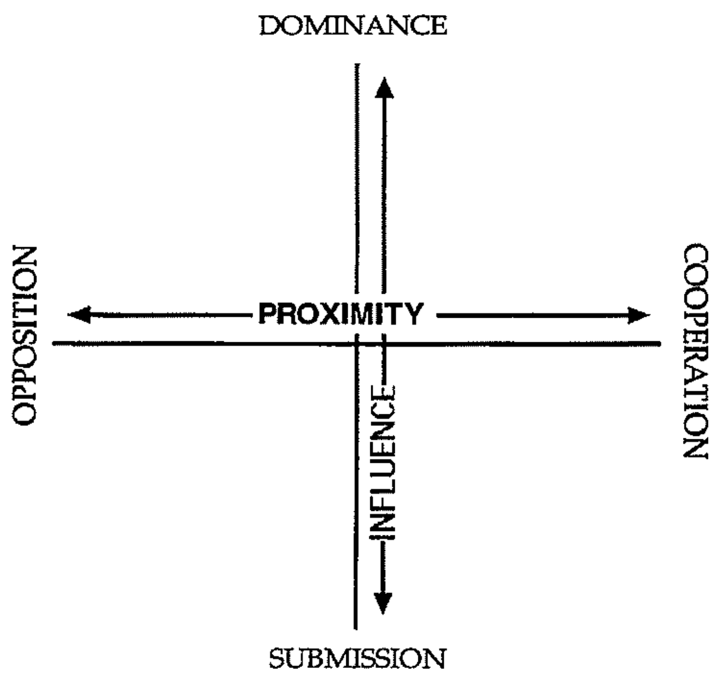


Figure 2.3. The two-dimensional coordinate system of the Leary model.
(Source: Wubbels, Créton, Levy, & Hooymayers, 1993, p. 15)

2.9 THE DEVELOPMENT OF THE MODEL FOR INTERPERSONAL TEACHER BEHAVIOUR

From Figure 2.3, the two primary dimensions can be divided into eight sections in a coordinate system as shown in Figure 2.4.

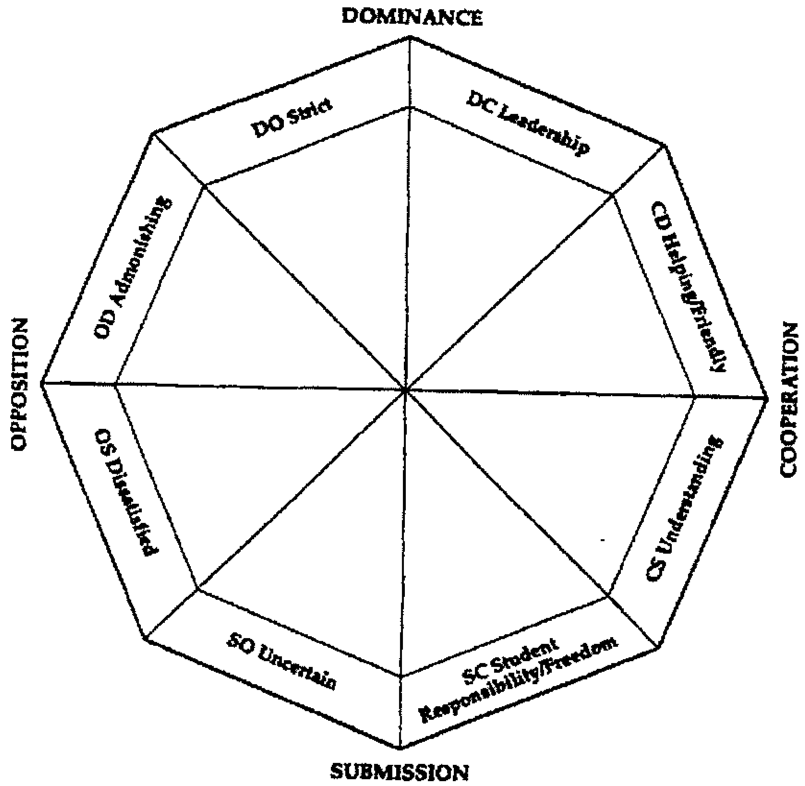


Figure 2.4. The model for interpersonal teacher behaviour.
(Source: Wubbels, 1993)

Each sector in Figure 2.4 describes the different types of teacher behaviour. Each instance of the teacher behaviour can be placed in eight sectors when this model is used. DC, CD, CS, SC, SO, OS, OD and DO labels in the sections of the model for interpersonal teacher behaviour are defined in terms of typical behaviours within a category. For example, the DC label is the Dominant-Cooperative sector, but more dominant than cooperative for the teacher perceived by students. The DC label indicates a strong leadership character of the interpersonal behaviour in this sector (Goh & Fraser, 2000). This model is called a circumplex model because adjacent sectors in this model represent similar interpersonal behaviours whilst opposite sectors represent the opposite behaviours. This model led to the development of the Questionnaire on Teacher Interaction (QTI) (Wubbels & Levy, 1993).

2.10 THE DEVELOPMENT OF THE QUESTIONNAIRE ON TEACHER INTERACTION (QTI)

The QTI was first developed in The Netherlands (Wubbels, Créton, & Hooymayers, 1985). The original form was written in Dutch, but it has been translated into English and used both in the USA (Wubbels & Levy, 1989, 1991) and Australia (Fisher, Fraser, Wubbels, & Brekelmans, 1993). The QTI originally consisted of 77 items by incorporating about 10 items in each scale, and reduced to 64 items in an English version and then administered in the USA. Both the 77 item and 64 item variations of the QTI were developed for educational research in secondary schools and used a five-point response format (Wubbels, 1993). Later, it was modified into a 48-item English version, the eight scales consisting of six items each, enabling secondary school teachers to obtain feedback on their own interpersonal relationships in classrooms (Goh & Fraser, 2000). This version has been used increasingly in Australia (Fisher, Fraser, & Rickards, 1997; Fisher, Fraser, & Wubbels, 1993; Fisher, Henderson, & Fraser, 1995; Wubbels, 1993). This 48-item version formed the basis of the Thai version used for my study.

The eight sectors shown in Figure 2.4 are explained in Table 2.3 that characterises interpersonal behaviour in each sector by providing a scale description, along with a sample item for each scale. In all versions of the QTI, responses to the items are given on a five-point Likert scale, scoring from 0 (Almost Never) to Very Often (4) on the questionnaire.

Table 2.3
Description of Scales and Sample Items for Each Scale of the QTI

Dimension or scale name	Description of scale (the extent to which the teacher...)	Sample item
Leadership	...leads, organises, gives orders, determines procedure and structures the classroom situation	This teacher talks enthusiastically about his/her subject
Helping/Friendly	...show interest, behaves in a friendly or considerate manner and inspires confidence and trust.	This teacher helps us with our work.
Understanding	...listens with interest, empathises, shows confidence and understanding	This teacher trusts us and is open with students.
Student Responsibility& Freedom	...gives opportunity for independent work, gives freedom and responsibility to students.	We can decide some things in this teacher's class.
Uncertain	...behaves in an uncertain manner and keeps a low profile.	This teacher seems uncertain.
Dissatisfied	...expresses dissatisfaction, looks unhappy, criticises and waits for silence.	This teacher thinks that we cheat.
Admonishing	...gets angry, express irritation and angry, forbids & punishes.	This teacher gets angry unexpectedly.
Strict	...checks, maintains silence and strictly enforces the rules.	This teacher is strict.

Items are scored 0, 1, 2, 3, and 4, respectively, for the responses Almost Never, Seldom, Sometimes, Often, Very Often.

(Source: adapted from Wubbels, 1993)

The QTI has also been developed in an Actual, a Teacher and an Ideal Teacher Form. The Actual Form examines the students' perception of the actual teacher-student interpersonal behaviour whilst the Teacher Form examines the teachers' perceptions of his/her own behaviour and the Ideal Teacher Form examines what relationships the student would like to see in his/her ideal teacher. There are differences of the words that are used among the three forms of the QTI. For example, "This teacher trusts us", the item in the Actual Form is, "I trust students" in the Teacher Form and is, "This teacher would trust us" in the Ideal Teacher Form. Appendices C and D of this thesis have copies of the Actual and Ideal Forms, respectively, of the QTI.

The three forms of the QTI can be used to collect data for describing various teachers' behaviours, teachers' self perceptions and ideal teacher behaviour. Figure 2.5 represents the details of a teacher in graphical type showing how he/she sees himself/herself, the teacher's perception of an ideal teacher and how his/her students see him/her.

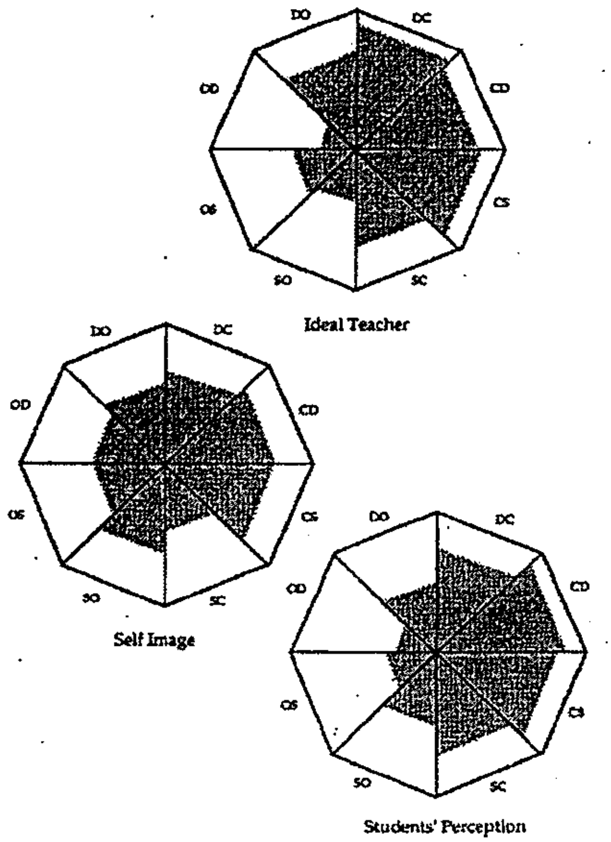


Figure 2.5. Use of three profiles.
(Source: Fisher, Fraser, & Cresswell, 1995, p. 13)

2.11 THE DEVELOPMENT OF THE PRINCIPAL INTERACTION QUESTIONNAIRE (PIQ)

Not only, can the QTI be used to measure a teacher's interpersonal behaviour with students, but the *Principal's Interaction Questionnaire* (PIQ) can be used to measure a principal's interpersonal style with teachers. For measuring the principal's interaction style with the teachers, the PIQ was developed from a 48-item version of the QTI, and has the same eight scales as the QTI. The PIQ was first devised in

Dutch and American versions by Kremer-Hayon and Wubbels (1993). Then, these versions were translated into Hebrew with 62 items, and the 62 items were responded to by 96 teachers in Israel. The final form of PIQ consists of six items within each of eight scales for measuring interpersonal behaviour (Cresswell & Fisher, 1996).

2.12 REVIEW OF PAST STUDIES USING THE QTI

This section discusses use of the QTI in similar ways and purposes to the SLEI, and is divided into three sub-sections: Australian studies, overseas studies and sex and cultural differences in students' perceptions of teacher interpersonal behaviour.

2.12.1 Australian Studies

Fisher and Rickards (1996) studied teacher-student interpersonal behaviour with 405 students in nine schools with their 21 teachers of mathematics classes in Australia using the QTI. Students' attitude scores were higher in classrooms when they perceived greater leadership, helpful/friendly and understanding behaviours from their teachers. However, the students' attitude scores were lower when students perceived greater admonishing, dissatisfaction, uncertain and strict behaviours from their teachers. In addition, the results also showed that the teachers' own perceptions and teachers' ideal behaviour were an important base for the teachers' self-reflection on teaching performance in order to create a more desirable classroom environment.

Rickards and Fisher (1998) also assessed a sample of 153 teachers and their 3,515 students from 164 secondary school science classes in 35 schools in Australia by using three forms of the QTI (Actual, Teacher and Ideal Teacher). Teachers had a tendency to perceive their classes more positively than did the students, and the students perceived ideal teachers more positively than their actual teachers.

Rawnsley (1997) focused on 490 grade 9 mathematics students in 23 classrooms in 14 schools in Adelaide, South Australia in order to examine student perceptions of mathematics learning environments by using the QTI. The results revealed that the significant associations between student perceptions of mathematics learning environment and attitudinal outcomes was stronger than it was for cognitive outcomes.

Use was made of the QTI to compare students' profiles and teacher's profile of interpersonal teacher behaviours. These two profiles can be used as the basis for reflection and subsequent action between teachers. The QTI was used in an Australian study with science teachers in order to provide the teacher with opportunity for professional development. After having completed the QTI, the science teachers were stimulated to reflect on their own teaching and verbal communication in a classroom. As one teacher said, she had become more aware of her students' need for clear communication, and arrived at a new point in improving her teaching strategies (Fisher, Rickards, & Fraser, 1996).

Kent, Fisher, and Fraser (1995) used the QTI to assess the relationships between teachers and students in classrooms in the secondary college sector (grades 11 and 12) in Australia. The QTI was used to compare the teacher's own perceptions with students' perceptions. The individual teacher's personality was found to be associated with teachers being friendly, helpful and giving freedom, responsibility and opportunity for independent work in class. As well, teacher personality seemed to be related to teacher self-perceptions of uncertainty in the classroom, of maintaining a low profile, and being passive.

When the QTI (Fisher, Fraser, Wubbels, & Brekelmans, 1993) was used with the School Level Environment Questionnaire (SLEQ) to investigate associations between teachers' perceptions of their environments and students' and teachers' perceptions of their classroom interactions (Fisher & Fraser, 1990), no significant scores between the SLEQ and QTI were found. It was suggested that teachers had the freedom to adapt their individual classrooms despite the school environments (Fisher, Fraser, & Cresswell, 1995).

Rickards, den Brok and Fisher (2005) used the QTI to examine students' perceptions of teacher–student interpersonal behaviour in Australia and generated science teacher typologies. This study investigated the extent to which typologies found in earlier studies (The Netherlands and the USA) also applied to a sample of Australian secondary school science teachers. This finding result was that the Australian typologies were comparable these with the earlier studies.

2.12.2 Overseas Studies

The QTI was used to develop typologies with student perceptions of interpersonal teacher behaviours in The Netherlands (Wubbels, Brekelmans, Créton, & Hooymayers, 1990). A cluster analysis distinguished characteristic teacher types as directive, authoritative, tolerant/authoritative, tolerant, uncertain/tolerant, uncertain/aggressive, repressive, and drudging. The teacher types associated with greatest cognitive and affective achievement of students, were the directive and tolerant/authoritative types. In contrast, the uncertain/aggressive and uncertain/ tolerant teacher types were associated with lowest student gains (Fisher, Fraser, & Cresswell, 1995).

Studies in The Netherlands have indicated that teachers who demonstrate, strict, leadership and helpful/friendly behaviour enhance the cognitive outcome scores of their students. On the other hand, student responsibility and freedom, uncertain and dissatisfied behaviour are negatively related to cognitive achievement (Wubbels, Brekelmans, & Hooymayers, 1991). Student attitudes also are strongly related with interpersonal teacher behaviours (Wubbels & Levy, 1993). Teachers who show more cooperative behaviour in classrooms can enhance student attitudes (Wubbels, Brekelmans, & Hooymayers, 1991). This means that student attitudes relate positively to student responsibility and freedom, understanding, helping/friendly and leadership behaviours. However, student attitudes relate negatively to uncertain, dissatisfied admonishing and strict behaviours (Wubbels & Levy, 1993).

Wubbels and Levy (1991) undertook a cross-cultural study in order to compare students' perceptions of the interpersonal teacher behaviours between American and Dutch teachers, by using the QTI. Few differences were found, but the American teachers perceived greater emphasis on strictness than the Dutch teachers, and the American teachers perceived less emphasis on student freedom and responsibility than did the Dutch teachers.

Using the QTI in the USA, Levy, Créton, and Wubbels (1993) investigated students' ratings of their best and worst teachers. Students' opinions indicated the best teachers as being strong leaders, friendly and understanding, and the worst teachers as being more admonishing and dissatisfied. Students' perceptions of their actual teacher did not reach their ideal teacher.

Slater (2000) tested the Transactional Analysis (TA) process in order to improve student outcomes in science and mathematics, enhance interpersonal relationships and promote positive behaviour. He used the QTI, the *Coopersmith Self-Esteem Inventory* (School Form) and the *Mooney Problem Checklist* in this study. A sample of 1,260 students in New Zealand indicated that academic results improved with better teacher-student interactions, Also, science teachers had better interpersonal relationships than did mathematics teachers. In addition, the students preferred the behaviour of an ideal teacher to be understanding, helping/friendly, and showing leadership and strict behaviours.

Kim, Fisher, and Fraser (2000) investigated associations between students' attitudes to science and perceptions of classroom environments with 543 students in 12 Korean schools. They reported that the interpersonal behaviour of science teachers was directive with less leadership, helping/friendly, and understanding behaviours than was shown in classrooms in Australia and Singapore (Rickards, Riah, & Fisher, 1997). When simple and multiple correlation analyses were investigated, positive relationships emerged with the Leadership, Helping/Friendly, Understanding and Student Responsibility/Freedom scales of the QTI but negative relationships emerged with the Uncertain, Dissatisfied, Admonishing and Strict scales of the QTI.

Scott and Fisher (2000) investigated students' perceptions of science teachers' interpersonal behaviour with a sample of 3,104 students in 136 classrooms in 23 typical, co-educational government primary schools in Brunei Darussalam by using the 48-item Australian version of the QTI. The students enjoyed science lessons, and perceived the teachers mostly as good leaders, helping/friendly, understanding and strict, seldom allowing student responsibility and freedom, seldom uncertain or dissatisfied and seldom admonishing. Moreover, a statistically significant correlation between external examination scores and helping/friendly, understanding and uncertain behaviour were indicated.

Soerjaningsih, Fraser, and Aldridge (2001) studied relationships between students' outcomes and the quality of teacher-student interactions using 422 students from 12 classes in a private university in Indonesia by using the QTI. They also examined associations between perceptions of students attending the Computer Science department and the Management department (in terms of a lecturer-student interpersonal behaviour) at this Information Technology University in Jakarta. It was found that positive interpersonal lecturer behaviour related to students' course achievement scores and to the Attitudes towards Internet scale. In addition, positive ability related to the Attitude towards Internet scale, and the students' perceptions to lecturer behaviours were not related to the Leisure Interest in Computer scale. Therefore, the lecturer-student interpersonal behaviour was most likely to enhance student outcomes in computer-related courses.

Levy, Wubbels, den Brok and Brekelmans (2003) also assessed variables associated with differences in students' perceptions of interpersonal teacher behavior. Samples of 3,023 students and 74 teachers in 168 classes in seven secondary schools were used in this study. This study found that: 1) several variables are significantly related to students' perceptions; 2) there were interaction effects between some variables, such as student ethnicity and student gender, as well as student and teacher gender; and 3) the outcomes generally confirmed earlier research, in particular the study provided further support for the complex and interactive nature of students' perceptions of the learning environment and researchers' understanding of it.

There was a study in school certificate examination to ascertain the quality and quantity of teacher-student-material interactions and the nature and extent of the relationships among classroom interaction patterns, teacher and student characteristics and students' learning outcomes in physics (Kalu & Ali, 2004). The study used seven research questions and 27 hypotheses to guide 516 Senior Secondary One (SSI) students (239 boys and 277 girls) and 15 physics teachers drawn from 15 selected secondary schools constituted through a purposive sampling technique. They collected data with six instruments and analysed the resulting data using simple percentages, Pearson product moment correlations and canonical analysis. They found that the interaction pattern during the physics lessons was directly influenced by the teacher. The mean frequency of teacher and student questions were, respectively, 11.32% and 0.69% of the total class time. Teachers' open and closed questions took about 2.99% and 8.33% of the class time, respectively. Students spent 7.49% of the class time responding to teachers' questions. Seven interaction behaviours occurred much more frequently in Girls-only schools while only four interaction behaviours occurred much more frequently in Boys-only schools. In mixed schools, boys had a greater proportional share of interactions in all the behavioural dimensions except teacher criticism and supervision of students. Physics teachers' experience and students' pre-instructional attitude towards physics correlated significantly with students' post-instructional attitude. Students' prior knowledge of physics, SES, achievement motivation, general ability and classroom interaction pattern correlated significantly with their academic achievement in physics. About 86% of the variance of the students' learning outcomes as a set was redundant with the variance of interaction patterns - the comparative affective/cognitive outcomes press, the low academic task achievement press, and the general academic achievement press. The three factors respectively contributed 38%, 21% and 27% of the common variance of the two sets (teacher and student characteristics) of variables.

Sztejnberg, Brok and Hurek (2004) investigated differences between students' perceptions of their best teachers in primary and higher education in Poland. They conceptualized the behaviour of the teacher in term of the teacher-student interpersonal relationship as described in terms of the eight behavioral sectors leadership, helpful/friendly, understanding, student responsibility/freedom, uncertain, dissatisfied, admonishing and strict and the two independent dimensions of Influence (teacher dominance vs. submission) and Proximity (teacher cooperation vs. opposition). Data were gathered from 199 higher education students, 173 students from a higher vocational institute and 26 students from one university, and 105 from primary education students. Results revealed that when students were asked for their preferred teaching, differences were found between the perceptions of students at the primary and tertiary levels of education.

2.12.3 Sex and Cultural Differences in Student Perceptions of Teacher Interpersonal Behaviour

Rawnsley (1997) reported that some studies reported on ways in which cultural and language factors influenced students' perceptions of interpersonal teacher behaviour. As an example, Levy, Wubbels, Brekelmans, and Morganfield (1994) investigated the perceptions of students from different cultures in America. Their results indicated that the students who were from Hispanic or Asian cultures brought cultural understandings into a classroom, and this influenced their perceptions of the teachers' behaviours. Moreover, teachers were often unaware of the influence of culture, and the students often perceived the teachers' behaviours differently from the perception of other students. Therefore, culture was significant variable influencing students' perceptions of teachers' communication.

The research of Rickards, Fisher, and Fraser (1996), namely, "gender and cultural differences in teacher-student interpersonal behaviour" investigated lower secondary science and mathematics classrooms with 3,994 students in 182 classes in 35 schools in Tasmania and Western Australia by using the QTI. Combining qualitative and quantitative methods of data collection, this study found that the females perceived the teacher-student interpersonal behaviour in a more positive way than did the males. Also, the results from this study indicated that students from an Asian background perceived their teachers more positively than did those from other cultural groups.

Ferguson (1998) studied students' perceptions of a generalist learning environment in the final stage of primary school compared to same students in the initial term of secondary school with 1,500 students in Tasmania, Australia using the MCI and the QTI. The student perceptions of learning environments changed across transition, and some scales of the student perceptions changed with school size, pathways and with student sex. This study indicated that changes from grade 6 to grade 7 science classes, boys perceived a greater reduction of the MCI in the Friction scale whilst girls perceived a greater reduction in the Difficulty and Cohesiveness scales. For the QTI, girls perceived a much greater reduction in the Understanding scale and a greater increase in the Dissatisfied scale. Boys perceived a reduction in the Admonishing scale from grade 6, but girls perceived an increase.

It can be concluded that there are many ways in which the QTI can be used by researchers and teachers in classroom settings. Information from the QTI can be a valuable source of data for researchers or teachers regarding interpersonal behaviours between a student and teacher, and self-interpersonal behaviour by the teachers, enabling the teachers to improve their teaching methods. Also, differences between groups in the classroom can be investigated.

2.13 ASSOCIATIONS BETWEEN CLASSROOM ENVIRONMENT AND STUDENT OUTCOMES INCORPORATING THE SLEI AND QTI

Some research studies have investigated associations between student outcomes and classroom environments both in science laboratory class settings, and in general science classrooms. Although much research has been done on educational environments, less has been done involving the incorporation of two questionnaires in the same research, especially in Thailand.

Henderson, Fisher, and Fraser (1995) included student perceptions of interpersonal teacher behaviour and student perceptions of laboratory environment in one study that involved investigating outcome-environment association with a sample of 489 students in 28 biology classes in Tasmania, Australia. Many aspects of teacher interpersonal behaviours and the laboratory learning environments were found to be associated with students' attitudinal outcomes. Student perceptions of the teacher's strong leadership, a greater degree of integration of practical and theory work in a course, and a higher level of rule clarity were particularly associated with favourable student attitudes. As well, the students preferred a more positive learning environment than they actually perceived. According to this study, the teachers' leadership, students' perceptions of more responsibility and freedom and the integration of practical and theory components in the course were associated with favourable achievement outcomes. On the other hand, a more strict behaviour of the teacher, more rule clarity and a more open-ended approach to the course were negatively associated with student achievement.

Use was made of the QTI associated with the SLEI for studying chemistry laboratory classroom environments in secondary schools in Singapore by Wong and Fraser (1996). They noted that students from different streams differed in their preferred perceptions, and student affective outcomes were associated with perceived environments of chemistry laboratories. As well, gender differences in perceptions emerged in that females had more favourable perceptions than did males.

A research study, using the SLEI and QTI, and involving a sample of 644 grade 10 chemistry students from 23 schools in Brunei Darussalam (Riah & Fraser, 1997, 1998) revealed that the students perceived chemistry theory classes and laboratory classroom environments in a positive way, and students' perceptions of chemistry classroom environments were associated with students' learning outcomes. The Understanding scale of the QTI was positively associated with students' attitudinal and cognitive outcomes. Also, the Open-Endedness scale of the SLEI was positively associated with the students' attitudinal outcomes. However, the Open-Endedness scale was negatively associated with achievement in chemistry. The Student Cohesiveness scale of the SLEI was also positively associated with the students' cognitive outcomes, but it was negatively associated with the students' attitudinal outcomes.

One learning environment research study, namely, "assessment description and effects of science classroom environments in Korea" was undertaken by Lee (2001), who used the SLEI and QTI in order to investigate associations between students' attitude towards science and their perceptions of the classroom environment. In addition, the Test Of Science Related Attitudes questionnaire (Fraser, 1981) was also employed. The sample included: 99 students from a science-independent stream, 195 students from a science-oriented stream and 145 students from a humanities stream. The results showed that typical laboratory lessons in Korean high school were closed-ended and highly integrated with theory lessons; equipment was in poor condition; and Korean high schools students were taught by directive and strict teachers. Moreover, the science-independent students perceived their environments more favourably than did student classes in other two streams. The science-oriented stream students perceived more cooperative behaviours and less opposition behaviours than did the students in the other two streams. This study also included a survey, interview and observations for obtaining a comprehensive picture of the Korean science classroom.

The study of Quek, Wong, and Fraser (2001) involved 497 final year secondary school chemistry students from 18 classes in three independent single-sex schools in Singapore. Nine classes consisted of gifted students in the Gifted Education Programme (GEP) and nine classes consisted of non-gifted students in an Express stream. The study also confirmed the reliability and validity of the SLEI and the QTI for use in gifted chemistry laboratory classrooms. Associations occurred between the nature of the laboratory classroom environment and students' attitudes towards chemistry, and between interpersonal behaviour of chemistry teachers and students' attitudes towards chemistry. Findings from the SLEI indicated educators need to create a more open-ended learning environment for teaching and learning chemistry in their secondary school. Thus, a chemistry curriculum might be redesigned to reduce the amount of direct instruction, and infusing creative and critical thinking skills into both theoretical and laboratory work. Additionally, the result of the study suggested that teachers should incorporate more real-life investigation work into laboratory activities and build in more opportunities for co-worker learning among the gifted students in their classroom, so helping the teachers to encourage more positive attitudes to chemistry in the students. Because the teachers found the Open-Endedness dimension positively associated with the students' attitude outcomes towards the gifted, the gifted should be taught by such divergent approaches for a thriving study (Quah & Teo, 1994).

A recent study identified and created learning environments for improving participation, achievement, and gender equity in science subjects in Tasmanian secondary colleges by using the SLEI and QTI (Horsham, 2001). The research plan was divided into three phases. A data collection of phase 1 involved science student learning, achievements, and attitudes and retention rates in year 11 students. The purpose of this part was to interview science and non-science students for guiding questionnaire development. In phase 2, data were included describing the validation of questionnaires and the investigation of associations between actual learning environment, actual-preferred congruence and outcome measurement, and an integration of quantitative and qualitative information. During phase 2, interviews were completed with a total of 80 students, (10 students were from each secondary college) who did not continue with their study in year 12. The students were interviewed to ascertain reasons for their dropping out of science or from secondary college. Some said their reason was that they no longer needed science to pursue their chosen career path while others had lost interest in their science classes and thought another subject would be more interesting. An intervention phase involved attempts to change the classroom learning environments of four typical science teachers from each secondary college (32 classes altogether). The 32 teachers had a meeting to discuss and interpret, the results of the quantitative and qualitative data. This research combined the quantitative and qualitative methods in the classroom environment research as suggested by Fraser and Tobin (1991), Fisher and Fraser (1997) and Tobin and Fraser (1997).

Puacharearn (2004) assessed the effectiveness of constructivist teaching on improving learning environments in Thai secondary school science classrooms using the Student Actual and Preferred Forms of the Constructivist Learning Environment Survey (CLES). She completed the study in three phases. First, the CLES was used to assess students' perceptions of the actual and preferred classroom environment through the constructivist perspective and validated for use in Thailand; Secondly, Thai secondary school science classrooms were described using quantitative and qualitative methods. Thirdly, she evaluated the use of constructivist teaching for promoting improvement in classroom environments through an action research process, involving the use of feedback on actual and preferred classroom environments. The sample consisted of seven secondary school science teachers and their 17 classes of 606 students in Nakornsawan Province, Thailand. The results showed that changes in classrooms could improve classroom learning environments and students' attitudes towards science in Thailand.

Chantavong (2005) examined the efficiency of a computer-assisted instruction software package along with students' opinions about the use of this software with 1,285 students in 38 statistics classes in Rajabhat Institute, Thailand using the Questionnaire on Teacher Interaction (QTI) and the College and University Classroom Environment Inventory (CUCEI). He adopted a quantitative methodology supported by the collection of some qualitative data for use in the study. Pre and post-test score means, along with qualitative feedback from students confirmed that the computer-assisted instruction software unit *Hypothesis Testing* was shown to be an effective resource for encouraging students' knowledge of statistics.

Overall, it can be noted from research studies that it is more useful for teaching and learning if we incorporate the SLEI and QTI in a same study involving laboratory chemistry environment. Because classroom environments strongly influence student achievement, it should be recognised that interpersonal behaviours between students and teachers are important determinants of student outcomes. By adapting the nature of the interpersonal relationships between students and teachers in classrooms, and by presenting laboratory activities that promote class cohesion and relate to what students learn in theory classes, student outcomes can be enhanced. As well, a combination of the qualitative and quantitative methods in the same study will be helpful for researchers wishing to undertake a more comprehensive study.

2.14 CHAPTER SUMMARY

This chapter has discussed the historical background and development of the SLEI and QTI, and noted previous studies which used the SLEI and QTI for gauging students' perceptions of their classroom environment and teacher-student interpersonal behaviour. Effects on students' cognitive achievement, practical outcomes and their attitudes to the subject were also noted. As well, it has discussed incorporating both the SLEI, the QTI and student outcomes in the same study. Again, it has underlined the value of including qualitative methods in the studies in order to provide a wider more comprehensive picture.

The research described in this thesis is distinctive because it associates the response of students to the SLEI and the QTI with the assessment of student science attitudes and measurement of cognitive and practical outcomes. In addition, this research is unique in that it investigates tertiary science classes in Thailand and has practical applications in classrooms. The value of this research study is enhanced by previous research findings that there are associations between teacher-student interpersonal behaviours, learning environment classrooms, science attitudes, and cognitive and practical achievements.

The next chapter of this thesis describes the methodology used in the study, including details about how the study was administered.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The previous chapter of this thesis provided a literature review which centred on studies describing learning environment research. In addition, the development of the SLEI and QTI was detailed, and associations between students' perceptions of the classroom environment and student outcomes were revealed.

With recent developments in the field of learning environment of research in mind, quantitative and qualitative methods have been introduced into this study to provide a more comprehensive picture of classroom learning environments. This chapter will reveal how this study was carried out with validity, clarity and precision. This is the first study that has been conducted with a sample of tertiary students at Rajabhat Universities in Thailand using the *Chemistry Laboratory Environment Inventory* (CLEI) and the Questionnaire on Teacher Interaction (QTI) with students in physical chemistry laboratories. Qualitative methods of data collection also were employed.

3.2 PREPARATION FOR THE STUDY

As mentioned previously in the introduction, this study used some of the variables and methodologies of previous studies in this investigation. The physical chemistry laboratory is a central aspect of this study, and the investigation of students' perceptions of the classroom-learning environments is a goal of this study. Two different methodologies are employed in this study to achieve a more complete picture of physical chemistry laboratory learning environments. The advantage of the quantitative method is to measure students' perceptions and students' outcomes and the questionnaires used for these quantitative measurements are the CLEI (Wong, Young, & Fraser, 1997), the QTI, attitudes to physical chemistry laboratory class, performance on an external examination test and performance on a practical test. In addition, qualitative methods, which included interviews and stories written about classroom environments provide a more comprehensive descriptive of the learning environments.

Initially, the English versions of the CLEI and QTI were translated to Thai versions by Thai teachers from Nakhon Sawan Rajabhat University. Then, an independent back translation of the Thai versions to the English versions was done by an individual who was not involved in the original translation. This was to ensure that items retain their original meanings. Two forms of the CLEI and the QTI, the actual and the ideal/preferred, were used in this study.

After that, the supervisor and I checked the back translations against the original English versions and modified the Thai translation where necessary. This ensured that items suited the Thai students, to whom English is a second language.

The students' attitudes to their physical chemistry laboratory class were assessed with a ten-item scale based on the Test Of Science Related Attitudes (TOSRA) (Fraser, 1981; Fisher, Henderson, & Fraser, 1995). The English version of the Attitude Scale was translated into a Thai version using the same translation procedure as mentioned before. Moreover, the word "science" in those scales was replaced with "physical chemistry laboratory".

The external examination and practical test performances were included in order to investigate students' cognitive achievement and practical outcomes. The practical test for the performance, which was used in this study, was based on the Practical Test Assessment Inventory (PTAI) (Tamir, Nussinovitz, & Friedler, 1980, 1982). Thai versions of these tests were also sent to five experts for comment, then taken to students for trial, and finally modified to ensure greater validity and reliability.

3.3 RESEARCH QUESTIONS

The purpose of this section is to transform the objectives shown in Section 1.4 into research questions for this study. Since the QTI and CLEI have not been validated with a tertiary science sample in Thailand beforehand, the validation of the CLEI and the QTI with the student sample is worthy of investigation in this study. This leads to the first research question.

> Research Question 1
> Are the Actual and Preferred Forms of the CLEI and the QTI valid in terms of reliability, discriminant validity and ability to differentiate between classes in physical chemistry laboratory classrooms in Thailand?

Previous research studies have investigated the perceptions of the learning environment in classrooms and teacher-student interactions, such as the studies of Henderson, Fisher, and Fraser (1995), Wong and Fraser (1996), and Quek, Wong, and Fraser (2001), therefore, it was timely to investigate perceptions of classroom environment and teacher-student interactions in physical chemistry laboratory classrooms in Thailand. This was the focus of the second research question.

> Research Question 2
> What are students' perceptions of their physical chemistry laboratory classes and their teacher-student interactions?

As this is the first study to measure students' perceptions of classroom environments in physical chemistry laboratory classrooms and students' perceptions on teacher interaction, a comparison between students' perceptions of their actual and preferred learning environments and students' perceptions on teacher interaction in their actual and ideal environments are important. These comparisons provide the following question.

Research Question 3

What differences are there between students' perceptions of their actual and preferred learning environments, and students' perceptions of their actual and ideal on teacher-student interactions?

Moreover, previous studies (McRobbie & Fraser, 1993a, 1993b; Wong & Fraser, 1994) have shown that attitudes that science students have, and their perceptions of their learning environments can be associated with their learning outcomes, and is the focus of Research Questions 4 and 5.

Research Question 4

What attitudes do students have towards their subject of physical chemistry laboratory?

Research Question 5

What associations are there between students' perceptions of their learning environments in physical chemistry laboratory classrooms, and their attitudinal and cognitive achievement and practical outcomes, and of their laboratory teacher's interpersonal behaviour?

Examining the changes which could be made in students' classroom environment perceptions in physical chemistry laboratory classrooms following changes in teacher interaction is considered important and this led to Research Question 6.

Research Question 6

Can the students' perceptions of their physical chemistry learning environment and teacher interaction be changed towards their preferred learning environment?

All of the six questions, which are presented above were addressed in this research. The next section describes instrument selection for this study.

3.4 INSTRUMENT SELECTION

The final survey forms of the SLEI and the QTI, which are the 35-item CLEI (the modified version of SLEI) and the 48-item version of the QTI respectively, were used for the study. In addition, a ten-item Attitude Scale (Fraser, 1981; Fisher, Henderson, & Fraser, 1995) was used to examine learning environment outcomes. This section will note the selection of Attitude Scale and the development of the PTAI and the use of these instruments for the construction of reliable measurement scales.

3.4.1 Selection of Attitude Scale

Henderson, Fisher, and Fraser (1995) investigated biology students' perceptions of classroom and laboratory learning environments. They used a ten-item Attitude to this Class, adapted from the TOSRA (Fraser, 1981) for examining students' attitudes. They found that the Attitude to this Class scale had an alpha reliability of 0.68 when the individual student was used as the unit of analysis, and of 0.74 when the class means were used. It was decided to use this scale in the study as it has been used in a number of previous learning environment studies.

3.4.2 The Practical Test Assessment Inventory (PTAI)

Many years ago, national and international assessments were used to evaluate student performance in science classes. Tamir (1972) suggested that student learning in laboratory classrooms was not the same as other kinds of classroom learning, and he used a practical laboratory examination for evaluating student performance in laboratory classrooms. In addition, some research studies revealed that the results of paper-and-pencil tests for the assessment of science learning related poorly in the laboratory performance results (Ben-Zvi, Hofstein, Samuel, & Kempa, 1977; Robinson, 1969; Tamir, 1972). As a result, Tamir, Nussinovitz, and Friedler, (1982) created the *Practical Test Assessment Inventory* (PTAI), and subsequently, a procedure-based scoring system was developed by Baxter, Shavelson, Goldman, and Pine (1992) to assess student performance. The advantages of the PTAI are that it includes tasks where students record data, analyse data, draw conclusions, and provide evidence.

Henderson, Fisher, and Fraser (1995) used the PTAI with 489 students in Tasmania, Australia, and the PTAI was further extended by Germann and Aram (1996), then field tested with 364 seventh-grade students from seven different schools in Missouri, America. Results of these studies indicate that the PTAI has been proved to be useable in many countries. It was decided to use the PTAI in the research described in this thesis; it was assembled and conducted by the researcher.

3.5 RELIABILITY AND VALIDITY OF THE SLEI

In this section, the reliability and validity of the SLEI is discussed by using examples from previous studies.

Fraser, Giddings, and McRobbie (1992) revealed that when the Actual Form of the SLEI was administered to an Australian sample, the reliabilities (alpha coefficients) were 0.80 for Student Cohesiveness, 0.80 for Open-Endedness, 0.91 for Integration, 0.76 for Rule Clarity and 0.74 for Material Environment. These reliability values were similar to the reliability value of the Preferred Form of the SLEI for the Australian sample, and similar to the reliability values of Actual and Preferred Forms for the five-country samples (USA, Canada, England, Israel and Nigeria).

Internal consistency reliability is a convenient way of estimating reliability because it only requires a single form of a test administered on a single occasion. The most reported internal consistency estimates and one of the most commonly reported reliability estimates in the language testing literature is Cronbach alpha (Brown, 2002). Henderson, Fisher, and Fraser (1995) reported the reliability and validity of the SLEI in Tasmania, Australia using both the individual student and the class mean as the unit of analysis. Table 3.1 shows these reliability coefficients.

An analysis of variance (one-way ANOVA) has been used to determine the ability of each classroom environment scale to differentiate between perceptions of students in different classrooms. The eta^2 statistic is defined as a ratio of variability to total variability being a proportion of variation explained through class membership. Table 3.1 indicates that previous studies have shown that the scales of the SLEI significantly differentiate between classes.

The mean correlation of a scale with other scales has been used as a measurement of discriminant validity the extent that each scale assesses a unique dimension distinct from the other scales. The mean correlation is seen as a convenient index for describing discriminant validity. Smaller values of each scale of the mean correlation are shown. This means that this questionnaire measures distinct although somewhat overlapping aspects of the laboratory environment (Evans, 1998; Pohl, 1999).

Henderson, Fisher, and Fraser (1995) further noted that the reliability figures (in Table 3.1) were similar to the reliability values for a cross-national student sample in six countries when they were previously reported by Fraser, McRobbie, and Giddings (1993). As well, the discriminant validity and eta^2 figures were also similar.

Table 3.1
Internal Consistency (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with other Scales) and Ability to Differentiate between Classrooms for the SLEI

Scale	Unit of Analysis	Alpha Reliability		Mean Correlation with Other Scales		ANOVA Results (Eta^2)
		Actual	Preferred	Actual	Preferred	Actual
Student Cohesiveness	Individual	0.81	0.76	0.38	0.43	0.22*
	Class Mean	0.91	0.81	0.52	0.46	
Open-Endedness	Individual	0.58	0.58	0.10	0.17	0.16*
	Class Mean	0.73	0.67	0.18	0.11	
Integration	Individual	0.85	0.76	0.41	0.33	0.17*
	Class Mean	0.92	0.87	0.57	0.46	
Rule Clarity	Individual	0.72	0.62	0.33	0.26	0.18*
	Class Mean	0.88	0.64	0.52	0.40	
Material Environment	Individual	0.77	0.71	0.39	0.40	0.22*
	Class Mean	0.85	0.86	0.52	0.51	

* $p<0.001$. The sample consisted of 489 senior biology students in 28 classes

(Source: Henderson, Fisher, & Fraser, 1995, p.7)

The SLEI also has been field tested and validated with 3,182 Papua New Guinea secondary students (Waldrip, 1994), 1,594 Australian students in 92 classes (Fraser

& McRobbie 1995), 489 senior high school biology students in Australia (Fisher, Henderson, & Fraser 1997), 1,592 grade 10 chemistry students in Singapore (Wong & Fraser, 1995, 1996), 580 students were from water quality and non-water quality-monitoring schools in Australia (Pohl, 1999), 497 chemistry students in Singapore (Quek, Wong, & Fraser, 2001), 439 high school science students in Korea (Lee & Fraser, 2001) and 644 chemistry students in Brunei Darussalam (Riah & Fraser, 1998).

Wong and Fraser (1996) also reported that when the Personal Form of the SLEI was administered to 1,592 grade 10 chemistry students in 56 classes in Singapore, alpha reliability figures were found to be similar to alpha reliability figures of a Queensland sample with either the individual student or the class mean as the unit of analysis.

The reliabilities for the SLEI which Fraser, Giddings, and McRobbie, (1992) noted as above, are similar to those reported by Fraser, Fisher, and McRobbie (1996) when the SLEI was field tested with students in Queensland, Australia. For the Actual Form of the SLEI, the alpha reliability figures were found to range from 0.71 to 0.86 when the individual student was used as a unit of analysis, and from 0.74 to 0.91 when the class mean was used as the unit of analysis. The alpha reliability figures for the Preferred Form of the SLEI were found to range from 0.64 to 0.84 when the individual student was used as the unit of analysis, and from 0.70 to 0.85 when the class mean was used as the unit of analysis. Fraser, Fisher, and McRobbie (1996) further analyzed the eta^2 statistic for the Personal Form of the SLEI and figures ranged from 0.23 to 0.28. Each scale of the SLEI hence differentiated between perceptions of students in different classes.

A modified version of the SLEI named the Chemistry Laboratory Environment Inventory (CLEI) (Wong, Young, & Fraser, 1997) was used in this study to assess students' perceptions of learning environments in physical chemistry laboratory classes. In this version of the SLEI, the word 'science' was change to 'physical chemistry'. For example, a sample item in the SLEI scale such as 'I get on well with students in this laboratory class' will be changed in the CLEI scale to 'I get on well with students in this physical chemistry laboratory class'. Fraser, Giddings, and

McRobbie (1995) were the designers for this modification. Although the CLEI was modified from the SLEI, most scales of the CLEI were found to be reliable as shown in Table 3.2, except for Open-Endedness, the values with a Singaporean sample were much lower.

Table 3.2
Internal Consistency Reliability (Cronbach Alpha Coefficient) for CLEI and Original SLEI Scales for Two Units of Analysis

Scale Name	No. of Items	Unit of Analysis	Alpha Reliability	
			CLEI[a]	SLEI[b]
Student Cohesiveness	7	Student	0.68	0.78
		Class	0.83	0.80
Open-Endedness	6	Student	0.41	0.71
		Class	0.54	0.80
Integration	7	Student	0.69	0.86
		Class	0.87	0.91
Rule Clarity	6	Student	0.63	0.74
		Class	0.84	0.76
Material Environment	7	Student	0.72	0.76
		Class	0.82	0.74

[a] For the CLEI, the sample consisted of 1,592 upper secondary chemistry students in 56 classes in Singapore.
[b]For the SLEI, the sample consisted of 516 senior high school students in 56 chemistry classes in Australia.
(Source: Wong, Young, & Fraser, 1997)

Overall, the results of reliability and validity tests as revealed could lead educators and researchers to use the SLEI and the CLEI with confidence.

3.6 RELIABILITY AND VALIDITY OF THE QTI

The QTI has been confirmed as a valid and reliable questionnaire in various countries, such as The Netherlands, the USA and Australia. As such the 48-item QTI used with an Australian study (Wubbels, 1993) involved 792 students and 46 teachers and the reliability for both the students' and teachers' responses ranged from 0.68 to 0.85, showing a satisfactory level of reliability (Cresswell & Fisher, 1996). When a 64-item version of the QTI was used in the USA (Wubbels & Levy, 1993) with 1,606 students and 66 teachers, the Cronbach alpha coefficient was found to range from 0.76 to 0.84 for the student responses and from 0.74 to 0.84 for the teacher responses (Rickards, Fisher, & Fraser, 1996).

Evans (1998) reported internal consistency values for three sample sizes of students and teachers, 1,105 and 66, 1,606 and 66, and 72 and 46 for The Netherlands, the USA and Australia, respectively, (as shown in Table 3.3). Figures indicated that the internal consistency values for both the students and teachers were acceptable with both the students' and teachers' response, the internal consistency figures were never lower than 0.60.

Table 3.3
Internal Consistency (Alpha Reliability) for QTI Scales for Students and Teachers in Three Countries.

Scale	Students/ Teachers	Alpha Reliability		
		Netherlands	USA	Australia
DC Leadership	Students	0.83	0.80	0.94
	Teachers	0.81	0.75	0.74
CD Helping/Friendly	Students	0.90	0.88	0.95
	Teachers	0.78	0.74	0.82
CS Understanding	Students	0.90	0.88	0.94
	Teachers	0.83	0.76	0.78
SC Student Responsibility/ Freedom	Students	0.74	0.76	0.80
	Teachers	0.72	0.82	0.60
SO Uncertain	Students	0.79	0.79	0.92
	Teachers	0.83	0.79	0.78
OS Dissatisfied	Students	0.86	0.83	0.93
	Teachers	0.83	0.75	0.62
OD Admonishing	Students	0.81	0.84	0.92
	Teachers	0.71	0.81	0.67
DO Strict	Students	0.78	0.80	0.90
	Teachers	0.61	0.84	0.78

(Source: Evans, 1998, p 34)

Because the QTI is based on a circular model of a two-dimensional circumplex model for interpersonal behaviour on which its scales are arranged, this pattern has been validated by measuring the interscale correlations between the scales. The highest correlations have been found between adjacent scales (for example, between Admonishing and Dissatisfied behaviour), and the lowest correlations between opposite scales (for example, Admonishing and Understanding behaviour) on the model (Evans, 1998). It means that each scale within the QTI model shows a high positive correlation with those scales adjacent to it but shows a low positive correlation with those not adjacent but are in the same sector of the model, and shows a highly negative correlation with those scales in opposite sectors (Rawnsley, 1997).

As for other learning environment questionnaires, the ability of the QTI to differentiate between classrooms was considered to be important. Table 3.4 shows the variance in QTI scores using the ANOVA *eta*^{2} statistic with class membership as the main effect. Each scale of the QTI significantly differentiated between the perceptions of students in different classrooms in three different countries.

Table 3.4
The Amount of Variance Accounted for by Class Membership (Eta^2) in Three Countries

Scale	*Eta*^{2}		
	USA (a) n=1,606	Australia (b) n=489	Netherlands (c) n=1,105
DC Leadership	0.41*	0.48**	0.59*
CD Helping/Friendly	0.22*	0.33**	0.48*
CS Understanding	0.28*	0.29**	0.43*
SC Student Responsibility/Freedom	0.29*	0.28**	0.36*
SO Uncertain	0.38*	0.38**	0.59*
OS Dissatisfied	0.19*	0.20**	0.39*
OD Admonishing	0.25*	0.25**	0.39*
DO Strict	0.43*	0.30**	0.45*

n* is sample sizes, *$p<0.01$, **$p<0.001$
(a & c) Source: Wubbels & Levy, 1991, p.10 (b) Source: Henderson, Fisher, & Fraser, 1995, p.7
(Source: Rickards, 1998, p. 80)

Additionally, the QTI has been field tested and then validated with 489 students in 28 biology classes in Tasmania, Australia by Henderson, Fisher, and Fraser (1995) as shown in Table 3.5. Alpha reliabilities for the Actual Form of the QTI ranged from 0.63 to 0.83 when the individual student was used as the unit of analysis, and ranged from 0.74 to 0.95 when the class mean was used as the unit of analysis; figures for the Ideal Form of the QTI ranged from 0.59 to 0.76 when the individual student was used as the unit of analysis, and from 0.62 to 0.87 when the class mean was used as the unit of analysis. As well, each scale of the QTI could differentiate between the perceptions of students in 28 classrooms in Australia. These reliability and validity values led to the desirability of further investigative research involving the QTI.

Table 3.5
Internal Consistency (Cronbach Alpha Coefficient) and Ability to Differentiate between Classrooms for the QTI

Scale	Unit of Analysis	Alpha Reliability		ANOVA Results (Eta^2)
		Actual	Ideal	Actual
DC Leadership	Individual	0.83	0.74	0.48*
	Class Mean	0.95	0.76	
CD Helping/Friendly	Individual	0.82	0.76	0.33*
	Class Mean	0.91	0.82	
CS Understanding	Individual	0.78	0.70	0.29*
	Class Mean	0.92	0.87	
SC Student Responsibility/Freedom	Individual	0.66	0.70	0.28*
	Class Mean	0.81	0.67	
SO Uncertain	Individual	0.77	0.66	0.38*
	Class Mean	0.91	0.62	
OS Dissatisfied	Individual	0.75	0.59	0.20*
	Class Mean	0.85	0.76	
OD Admonishing	Individual	0.71	0.72	0.25*
	Class Mean	0.77	0.82	
DO Strict	Individual	0.63	0.69	0.30*
	Class Mean	0.74	0.74	

*p<0.001
The sample consisted of 489 senior biology students in 28 classes.
(Source: Henderson, Fisher, & Fraser, 1995, p.6)

The QTI was also field tested and cross-validated in a number of other studies. For example, 405 students in nine schools with their 21 teachers in Australia (Fisher & Rickards, 1996), 490 grade 9 mathematics students in 23 classrooms in 14 schools in Adelaide, South Australia (Rawnsley, 1997), 1,500 students in Tasmania, Australia (Ferguson, 1998), 2,986 science students in 153 classes in 48 Australian secondary schools in two Australian states, Victoria and Western Australia (Evans, 1998), 3,589 students in 173 classes in Tasmania and Western Australia (Rickards & Fisher, 1998), a random sample of 1,512 boys and girls from government elementary schools in Singapore (Goh & Fraser, 2000), 1,260 students in a New Zealand Registered State (Slater, 2000), a sample of 422 students from 12 classes in a private university in Indonesia (Soerjaningsih, Fraser, & Aldridge, 2001), 543 Korean science students (Kim, Fisher, & Fraser, 2000), and 3,104 students in 136 classrooms in 23 typical, co-educational government primary schools in Brunei Darussalam (Scott & Fisher, 2001).

Therefore, the QTI can be regarded as a reliable and valid questionnaire that can be used with confidence.

3.7 SELECTION AND DESCRIPTION OF THE SAMPLE

The purpose of this research was to investigate whether students could achieve better cognitive and affective outcomes in classrooms where classroom climates were perceived to be more favourable.

Two samples were used for the investigation of different research questions. For Research Question 1 (as discussed in Section 3.3), the sample consisted of 198 Thai physical chemistry students in nine classes from seven Rajabhat Universities in Thailand, namely, Uttaradit, Kanchanaburi, Nakhon Sawan, Kamphaeng Phet, Phitsanulok, Phanakhon and Maha Sarakham. The students were in their second year at those Rajabhat Universities, and the physical chemistry laboratory is an obligatory course at each university. Research Question 1 addresses the validity and reliability of the two forms of the CLEI and the QTI and the ability of the CLEI and the QTI to differentiate between classes when use in physical chemistry laboratory classrooms in Thailand.

Not only was the sample size of 198 students used to confirm reliabilities, but it was also used to compare students' perceptions of their actual and preferred learning environments and students' perceptions of actual and ideal teacher interactions. Such comparisons were used to address Research Question 3.

Research Questions 2, 4, 5 and 6 involved a sample of 100 tertiary students in four Rajabhat Universities in Thailand, namely, Kamphaeng Phet, Phitsanulok, Phanakhon and Maha Sarakham. Research Questions 2, 4, 5 and 6 were concerned with: 1) students' perceptions of their physical chemistry laboratory classes; 2) students' attitudes towards their physical chemistry laboratory; 3) associations between the students' perceptions of their learning environments in physical chemistry laboratory classrooms, and their attitudinal and cognitive achievement outcomes; and 4) whether the students' perceptions of their physical chemistry learning environment and teacher interaction change towards their preferred learning environment.

Rajabhat Universities were chosen that had physical chemistry laboratory teaching in classrooms at that time. I chose physical chemistry laboratory for investigation since I am an instructor in physical chemistry laboratory classes as described in Chapter One of this thesis. The laboratory is independent of the lectures. As well this laboratory class is worth one credit for student taking in their learning. Generally, instructors who lecture in physical chemistry have to teach in the physical chemistry laboratory as well. All of the chosen Rajabhat University are co-educational universities. Students who participated in this investigation were studying a physical chemistry laboratory course. Because the teaching, learning and curriculum administration in every Rajabhat University in Thailand is different, selecting a sample of students was difficult. That is, the students had to study the physical chemistry laboratory course at the same time as the data were being collected. As well, not many students study the physical chemistry laboratory course at Rajabhat Universities. Hence the sample of selected students was restricted in size.

First of all, direct contact by telephone was made between the researcher and instructors who were teaching a physical chemistry laboratory course in Rajabhat Universities in order to request data collection. Positive responses were received from Kamphaeng Phet, Phitsanulok, Phanakhon, Maha Sarakham, Nakhon Sawan, Kanchanaburi and Uttaradit Rajabhat Universities. Letters of consent of the presidents of the Rajabhat Universities were then sent to request the collection of data early in that semester.

The next step involved mailing out to these seven Rajabhat Universities, early in the semester the following: the Actual and Preferred Forms of the CLEI, the Actual and Ideal Forms of the QTI, the Attitude Scale, the cognitive test and the practical test, a pre-paid envelope with the return address of the researcher, and a letter of consent. The practical test which included description of laboratory direction, was explained in writing by the researcher. That is the scores and where students record data, analyse data, draw conclusions, and provide evidence, were written on the actual the practical test.

The Preferred/Ideal Form that measures the perceptions of the classroom environments in terms of preferred or ideal environment, is slightly different from Actual Form in item wording. For example, an item in the Actual Form of the CLEI such as 'There is a recognized way for me to do things safely in this physical chemistry laboratory' will be changed in the Preferred Form to 'There would be a recognized way for me to do things safely in this physical chemistry laboratory'. Both Actual and Preferred Forms of the CLEI are presented in Appendix E and F. Similar to the CLEI, an item in the Actual Form of the QTI such as 'This teacher trusts us' will be changed in the Ideal Form to 'This teacher would trusts us'.

The Attitude Scale which examines attitudes to their physical chemistry laboratory class, consists of ten items and based on the TOSRA (Fraser, 1981; Fisher, Henderson, & Fraser, 1995). Each item of this Attitude Scale has a three-point response format (Disagree, Not Sure and Agree). One example of the item in the Attitude Scale is 'physical chemistry laboratory lesson is fun'. The Attitude Scale is presented in Appendix G.

The cognitive test of the physical chemistry laboratory course was constructed in multiple choice format by me and was comprised of five factors to be considered: Knowledge, Comprehension, Application, Analysis and Synthesis (Getsa & Amornratanasak, 1999). There are seven topics in the physical chemistry laboratory course: Heat of Reaction, Viscosity, Refractive Index, Specific Gravity, Molar Volume of Gas, Gas Constant and Electrochemistry. An example of a cognitive test item of the physical chemistry laboratory course is the comprehension factor as follows:

Which one of these equations represents the heat of solution.

a. $C(s) + 2S(s) \longrightarrow CS_2(s)$, $\Delta H = 25.4$ kcal

b. $HCl(g) + aq \longrightarrow HCl(aq)$, $\Delta H = -17.96$ kcal (correct)

c. $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$, $\Delta H = -135$ kcal

d. $1/2H_2(g) + 1/2I_2(g) \longrightarrow HI(g)$, $\Delta H = 6.2$ kcal

The cognitive test is presented in Appendix H.

The practical test of physical chemistry laboratory course was based on the Practical Test Assessment Inventory (PTAI) (Tamir, Nussinovitz, & Friedler, 1980, 1982). The PTAI was designed to assess student performance in laboratory classes, and includes data recording, data analysing, data conclusions and evidence providing from students. The gas constant topic was used for this practical test. This laboratory has been covered with four skills: manipulation, observation, interpreting experiment data and experimental planning skills (Johnstone & Al-Shuaili, 2001). One example for this test is that after the reaction between HCl solution and a Mg metal is complete, students observe the changes of this reaction and write them in the blank space (observing skill and one mark). The practical test is presented in Appendix I.

When the students had completed the questionnaires and tests, the documents were sent back to the researcher in a pre-addressed and reply-paid envelope.

In addition, three students from each class were selected for an interview and to provide written stories in the middle of the semester. The example of questions in this qualitative data collection is shown in Table 3.6 (Section 3.8.2). Of the three students, one had gained a high score, one had gained a mid score, and one had gained a low score; the students were expected to perceive different classroom climates because they gained different scores. Before the interviews and written stories a letter of consent was received.

At the appropriate time, the intervention strategies were implemented by the researcher and instructors in an attempt to change the actual environment to make it more congruent with the preferred environment. The scores of questionnaires and three tests, after the students completed them in the early semester, were taken to the instructors by the researcher to guide intervention strategies in changing the classroom environments.

At the end of the semester, Actual Forms of the CLEI and the QTI, the Attitude Scale, the cognitive test and the practical test were sent to four Rajabhat Universities, namely Kamphaeng Phet, Phitsanulok, Phanakhon, Maha Sarakham for student responses. The letters from the researcher were again sent to instructors and presidents for consent and to thank them for allowing the collection of data.

3.8 DATA COLLECTION

The data collection in this study consisted of two parts; quantitative and qualitative. The data were collected in a way to ensure consistency of collection procedures, and the researcher was personally involved with the process so that all students dealt with the questions in similar ways.

3.8.1 Quantitative Data Collection

The Actual and Preferred Forms of the CLEI, Actual and Ideal Forms of the QTI, the Attitude Scale, and two tests for cognitive and skill outcomes were administered with students early in the semester or during week 2 of the study.

The Actual Forms of the CLEI and QTI, the Attitude Scale and the tests for cognitive and skill outcomes were again administered with students at the end of semester or during weeks 14 and 15 of the course.

3.8.2 Qualitative Data Collection

Student interviews were used in relation to the CLEI and written stories were collected on the QTI. Each student was asked to participate in both the interviews and written stories. It was decided to use a different qualitative method for each questionnaire to avoid the students becoming fatigued by using the same method twice.

In this stage, the contact with instructors for the student interview and stories written about classroom environments was made in mid semester. The researcher again phoned each instructor in order to identify the students and choose suitable times for the students. Also, letters of consent and thanks were posted to instructors so that the desired number of students was obtained at this stage. Three of the 12 students from each Rajabhat University were selected to participate. Similar questions were asked to each student. Sometimes, examples of questions were provided to them to ensure that they did not misinterpret the questions.

In the interviews, students were invited to reflect on their previous completed responses to the CLEI in their classrooms. Each question was read, and sometimes discussion was used to motivate student reflection in order to obtain their responses. In these questions, the students were also encouraged to expand on answers and provide clarification if answers were important. For example, when the students were asked to comment on the learning environments of their classes, they were told that, "The research shows that the environment influences students; can you generally summarize on the learning environment in your classrooms?" The students were further asked to comment on their responses to each individual item of those scales.

It was apparent in the interviews that the students were able to reveal and describe the learning environments of their classrooms. In the meantime, the researcher used notes and audio tape recordings of each interview to ensure the complete wording of the students was retained.

Additionally, the students wrote stories in brief journals. These stories provided various views about teacher behaviours as they related to behaviours assessed by the QTI. Examples of questions used in the qualitative data collection are shown in Table 3.6.

Table 3.6
Examples of Qualitative Data Collection

Interview	Written Story
1. Did you like your physical chemistry laboratory classroom? Why?	1. Did your teacher always encourage you to discuss while he/she was teaching physical chemistry laboratory? Could you describe what happens?
2. Did you have safety precautions before starting laboratory?	2. How was your teacher's mood whilst he/she was in the class. What did you think?
3. Did your friends always help you during laboratory activities?	3. Did you ever break a glassware in a laboratory Class? How did your teacher response? How did you feel? Please, discuss.

The results of all the data collection led the researcher to recognise more and more avenues for improvement in the teaching and learning occurring in physical chemistry classrooms.

3.9 DATA ANALYSIS

The data analysis focused on the objectives of the study in order to achieve the main goals of the research. The quantitative and qualitative data were analyzed and then interpreted.

3.9.1 Analysis of Quantitative Data

When the questionnaires and three tests (attitude test, practical test and cognitive test) were returned to the researcher, they were checked and the responses were manually scored by the researcher. Data from the CLEI and QTI, which were missing or had invalid scores by any student, were treated as missing values by the SPSS program.

In the analysis of quantitative data, an Excel program (version 98) (Microsoft Corporation, 1998) was used to construct graphs. An SPSS software package (version 10) (Norusis, 1998) was used to calculate simple and multiple correlations, internal consistency (Cronbach alpha coefficient), and eta^2 statistic (one-way ANOVA).

Simple and multiple correlation analyses were used to determine associations between students' perceptions of learning environment and students' attitudinal, cognitive and practical performance outcomes. The simple correlation (r) describes a bivariate association between two variables whereas the multiple correlation (R) indicates the association between two variables when all other variables are controlled (Henderson, Fisher, & Fraser, 1995).

3.9.2 Analysis of Qualitative Data

Both notes and audio tape recordings were made during each interview. Moreover, students were encouraged to write stories in a brief journal about the classroom climate in which the researcher gathered the classroom climate data. Both notes and audio tape recording were transcribed into worded sentences for further analysis. These interviews and written stories were also translated into English.

3.10 CHAPTER SUMMARY

This chapter provides details of the methodologies used in this research. Initially, translations of the English versions of CLEI, QTI and Attitude Scale to Thai versions were conducted, and followed by the construction of cognitive and practical tests in the Thai language. Besides the 35 items of the CLEI and 48 items of the QTI selected for this study, a 10-item Attitude Scale was chosen. As well, cognitive and practical tests were used to examine the students' outcomes. The validity and reliability of the QTI, CLEI, Attitude Scale, cognitive test and practical test were shown to be sufficient for the researcher to use them with confidence. Moreover, selection and description of student samples were noted prior to valid data collection. It should be noted that in this research, consent was obtained from the people who participated, ensuring standards of ethics were met. Furthermore, all who participated were advised that they had the right to withdraw at any time.

CHAPTER 4

RELIABILITY AND VALIDITY OF THAI VERSIONS OF THE CLEI AND QTI

4.1 INTRODUCTION

In the previous chapter, preparation for this study and the research questions to be addressed were described. In addition, the reliabilities of the CLEI and QTI which were used in earlier studies were revealed, and statistical procedures used to analyse the data were also noted.

This chapter examines the research question referred in Section 3.3, by showing the validity and reliability of the CLEI and QTI when used with a Thai sample of tertiary science classrooms. Both ideal and actual perceptions of students are also noted.

4.2 RESULTS FOR THE CLEI

The Thai validation sample consisted of 198 students in nine classrooms in seven Rajabhat Universities who responded to a 35-item Thai version of the CLEI. Of the 198 students, 63 students were from Phitsanulok, 10 from Uttaradit, 22 from Phanakhon, 14 from Kanchanaburi, 38 from Kamphaeng Phet, 27 from Maha Sarakham and 24 from Nakhon Sawan Rajabhat Universities.

Table 4.1 shows the reliability and validity figures for the CLEI when used with 198 science students at Thai universities. If the reliability is estimated from the consistency of responses to all items in a scale, it is referred to as internal consistency reliability (Cronbach, 1970).

There are many ways in which internal consistency reliability is estimated [for example the Spearman-Brown prophecy formula (Brown, 2001), Kuder-Richardson formulae 20 and 21 (Kuder & Richardson, 1937) and Cronbach alpha (Cronbach, 1970)]. The Cronbach alpha is the most frequently used in learning environment research to report internal consistency and therefore was used in this study (Brown, 2002).

The reliabilities of individual student and class mean scores for each CLEI scale are reported in Table 4.1. The alpha reliability figures of the different CLEI scales ranged from 0.61 to 0.71 for the Actual Form and from 0.60 to 0.67 for the Preferred Form when the individual student was used as the unit of analysis, and from 0.63 to 0.88 for the Actual Form and from 0.62 to 0.90 for the Preferred Form when the class mean was used as the unit of analysis. Typically, the reliabilities with the class mean as the unit of analysis were higher than the reliabilities of those when the individual student was used. These figures show satisfactory internal consistency of the CLEI scales when either the individual student or the class mean is used as the unit of analysis, and show the suitability of the CLEI for use with the science students for whom English is a second language in Thailand. These results are comparable with previous research with the CLEI. For example, Wong, Young, and Fraser (1997) reported that the reliabilities of the CLEI ranged from 0.41 to 0.72 when the individual student was used as the unit of analysis, and from 0.54 to 0.87 when the class mean was used as the unit of analysis; and Quek, Wong, and Fraser (2001) revealed that the reliabilities of the CLEI ranged from 0.53 to 0.76 for the Actual Form and from 0.69 to 0.86 for the Preferred Form when the individual student was used as the unit of analysis.

The mean correlation of each scale with the other scales was used as a means of measuring the discriminant validity of the CLEI and are also shown in Table 4.1. These scores range from 0.12 to 0.35 when the individual student was used as the unit of analysis, and from 0.47 to 0.63 when the class mean was used as the unit of analysis. These results show that each of the CLEI scales is to some extent independent of each of the other scales when the individual student was used as the unit of analysis. That is each of them measures distinct aspects of the classroom learning environments. The discriminant validity figures of all the scales in the

Actual Form of the CLEI in this study were higher than those reported for the Actual Form of the CLEI in a previous study by Quek, Wong, and Fraser (2001) with Singaporean students (Actual Form ranged from 0.11 to 0.24 and Preferred Form ranged from 0.22 to 0.45).

Table 4.1 also shows, that the mean within-class perceptions of students in different classrooms towards the CLEI were different, and the perceptions of the students in the same class were relatively similar. The eta^2 statistic ranged from 0.07 to 0.19 for the different scales and most of the CLEI scales distinguished significantly between classes ($p<0.05$). Therefore, the CLEI is able to differentiate between the perceptions of students in different classrooms, with one exception, the Open-Endedness scale where the perceptions of students in different classrooms do not differ significantly. These results are similar to the previous study of Quek, Wong, and Fraser (2001) using the CLEI with Singaporean students where the eta^2 value ranged from 0.06 to 0.21 and all the scales distinguished between classes.

Table 4.1
Internal Consistency (Cronbach Alpha Coefficient) and Ability to Differentiate Between Classrooms for the CLEI.

Scale	No of Items	Unit of Analysis	Alpha Reliability		Mean Correlation with Other Scales	ANOVA Results (Eta^2)
			Actual	Preferred		Actual
Student Cohesiveness	7	Individual	0.62	0.61	0.26	0.09*
		Class Mean	0.75	0.70	0.55	
Open-Endedness	7	Individual	0.62	0.61	0.12	0.07
		Class Mean	0.63	0.63	0.59	
Integration	7	Individual	0.71	0.67	0.34	0.10**
		Class Mean	0.88	0.90	0.47	
Rule Clarity	7	Individual	0.61	0.60	0.31	0.08*
		Class Mean	0.72	0.62	0.50	
Material Environment	7	Individual	0.71	0.61	0.35	0.19***
		Class Mean	0.88	0.77	0.63	

*$p<0.05$, ** $p<0.01$, ***$p<0.001$.
The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

Clearly, the descriptive statistics mentioned above indicate that the modified version of SLEI is a valid and reliable questionnaire for gauging science students' perceptions of their learning environments in a physical chemistry laboratory setting at tertiary level in Thailand. These results are consistent with previous studies on non-modified and modified versions of the SLEI (Quek, Wong, & Fraser, 2001).

4.3 RESULTS FOR THE QTI

The 48-item version of the QTI was used to examine students' perceptions of student-teacher interpersonal behaviour in this study. The sample of 198 students responded to the 48-item Thai version of the QTI as well as responding to the 35-item Thai version of the CLEI.

Table 4.2 provides results for the QTI when used in this study. The internal consistency ranged from 0.60 to 0.78 for the Actual Form of the questionnaire and from 0.61 to 0.78 for the Ideal Form when the individual student was used as the unit of analysis, and from 0.68 to 0.94 for the Actual Form and 0.65 to 0.91 for the Ideal Form when the class mean was used as the unit of analysis. The reliability figures are quite consistent with previous studies when the 48-item version of the QTI was used. Fisher and Rickards (1996) reported that the reliability figures ranged from 0.62 to 0.88 when the individual student was used as the unit of analysis, and from 0.60 to 0.96 when the class mean was used as the unit of analysis; Soerjaningsih, Fraser, and Aldridge (2001) reported that the reliability figures ranged from 0.65 to 0.87 when the individual student was used as the unit of analysis, and from 0.83 to 0.99 when the class mean was used as the unit of analysis; and in another study Rickards and Fisher (1998) revealed that the reliability figures ranged from 0.63 to 0.88 when the individual student was used as the unit of analysis, and from 0.78 to 0.96 when the class mean was used as the unit of analysis. These results show the QTI to be a reliable questionnaire for the present sample of Thai students.

Moreover, the eta^2 data shown in Table 4.2 imply that the QTI is able to differentiate between the perceptions of students in different classrooms ($^*p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$). The eta^2 value, which represents the amount of variance explained by class membership, ranges from 0.05 to 0.18. Accordingly, students in the same classes responded to each item similarly, but those in other classes responded to them differently. These results support the validity seen in previous studies when the 48-item version of the QTI was used. For example, Wubbels and Levy (1991) reported that eta^2 ranged from 0.36 to 0.59; Fisher, Henderson, & Fraser (1995) noted that eta^2 ranged from 0.07 to 0.35; and Rickards, Fisher, and Fraser (1996) revealed that eta^2 ranged from 0.22 to 0.35. However, the eta^2 values of 0.05 and 0.07 for the Student Responsibility/Freedom and Strict scales were not significant and imply that perceptions of students in different classes are not differentiated by these two scales of the QTI.

Table 4.2
Internal Consistency (Cronbach Alpha Coefficient) and Ability to Differentiate Between Classrooms for the QTI

Scale	Unit of Analysis	Alpha Reliability		ANOVA Results (Eta^2)
		Actual	Ideal	Actual
DC Leadership	Individual	0.78	0.74	0.16***
	Class Mean	0.94	0.91	
CD Helping/Friendly	Individual	0.77	0.72	0.13***
	Class Mean	0.89	0.85	
CS Understanding	Individual	0.73	0.78	0.08*
	Class Mean	0.82	0.89	
SC Student Responsibility/Freedom	Individual	0.60	0.61	0.05
	Class Mean	0.68	0.65	
SO Uncertain	Individual	0.77	0.71	0.11**
	Class Mean	0.83	0.87	
OS Dissatisfied	Individual	0.72	0.71	0.14***
	Class Mean	0.82	0.72	
OD Admonishing	Individual	0.75	0.67	0.18***
	Class Mean	0.89	0.84	
DO Strict	Individual	0.67	0.63	0.07
	Class Mean	0.81	0.73	

*$p<0.05$, **$p<0.01$, ***$p<0.001$
The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

Section 3.6 indicated that the scales of the QTI are arranged in a circular manner and based on a two-dimensional circumplex model for interpersonal behaviour. This pattern has been validated by measuring the inter-scale correlation, using simple correlation. Table 4.3 and 4.4 report the inter-scale correlation of the actual and ideal QTI scales for both the individual and the class mean as the unit of analysis respectively. The pattern in Table 4.3 is illustrated in Figures 4.1 and 4.2 that use the Helping/Friendly scale as an example.

Table 4.3
Figures of Inter-Scale Correlation of Actual QTI Scales for Two Units of Analysis.

Scale	Unit of Analysis	DC	CD	CS	SC	SO	OS	OD	DO
DC Leadership	Student	1.00	0.63	0.72	0.16	-0.36	-0.30	-0.46	0.04
	Class Mean	1.00	0.79	0.89	-01.9	-0.68	-0.68	-0.82	0.29
CD Helping/Friendly	Student		1.00	0.63	0.14	-0.34	-0.25	-0.40	0.12
	Class Mean		1.00	0.94	-0.28	-0.70	-0.86	-0.70	0.57
CS Understanding	Student			1.00	0.22	-0.28	-0.26	-0.36	0.04
	Class Mean			1.00	-0.15	-0.62	-0.80	-0.73	0.39
SC Student Responsibility/Freedom	Student				1.00	0.31	0.29	0.25	-0.01
	Class Mean				1.00	0.54	0.37	0.61	-0.74
SO Uncertain	Student					1.00	0.62	0.69	0.07
	Class Mean					1.00	0.79	0.91	-0.53
OS Dissatisfied	Student						1.00	0.67	0.33
	Class Mean						1.00	0.80	-0.49
OD Admonishing	Student							1.00	0.19
	Class Mean							1.00	-0.50
DO Strict	Student								1.00
	Class Mean								1.00

The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

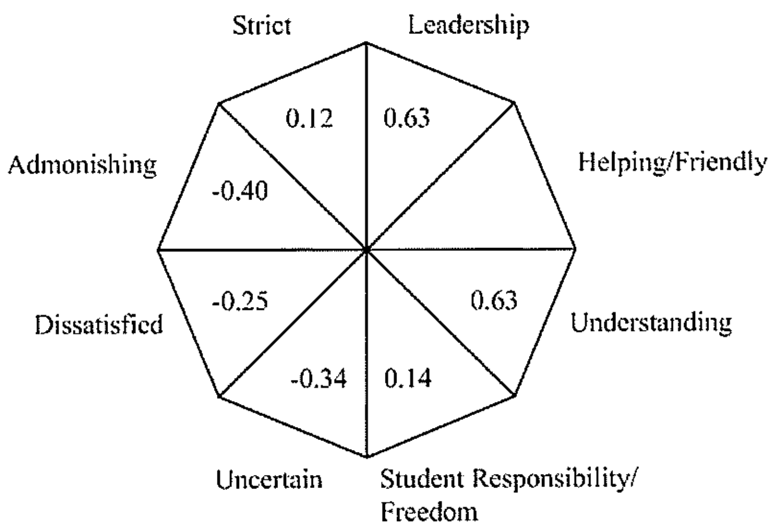


Figure 4.1. Correlations between Helping/Friendly and the other scales of the Actual QTI using the student as the unit of analysis.

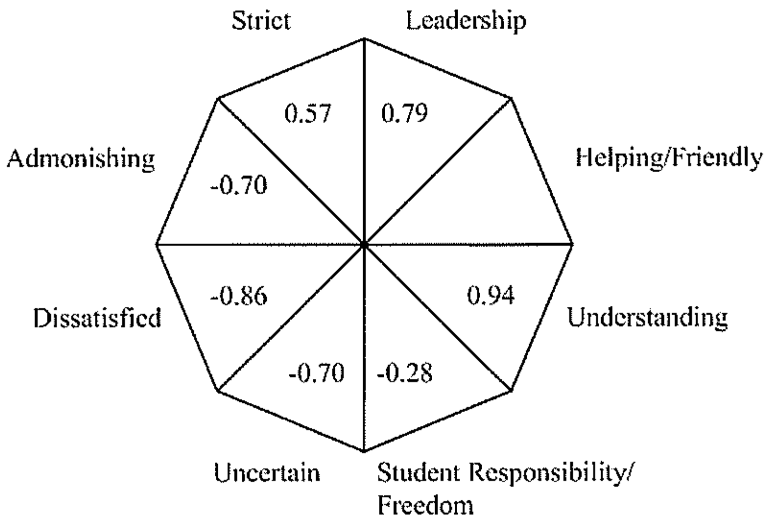


Figure 4.2. Correlations between Helping/Friendly and the other scales of the Actual QTI using the class mean as the unit of analysis.

The pattern in Table 4.4 is again represented, using the Helping/Friendly scale as an example, in Figures 4.3 and 4.4.

Table 4.4
Figures of Inter-Scale Correlation of Ideal QTI Scales for Two Units of Analysis.

Scale	Unit of Analysis	DC	CD	CS	SC	SO	OS	OD	DO
DC Leadership	Student	1.00	0.62	0.78	-0.09	-0.43	-0.29	-0.37	0.08
	Class Mean	1.00	0.91	0.93	-0.29	-0.75	-0.41	-0.71	0.53
CD Helping/Friendly	Student		1.00	0.60	0.10	-0.27	-0.24	-0.30	0.04
	Class Mean		1.00	0.90	-0.27	-0.77	-0.62	-0.72	0.41
CS Understanding	Student			1.00	-0.01	-0.26	-0.28	-0.30	0.04
	Class Mean			1.00	-0.20	-0.58	-0.38	-0.58	0.32
SC Student Responsibility/Freedom	Student				1.00	0.40	0.33	0.29	0.10
	Class Mean				1.00	0.66	0.62	0.75	-0.35
SO Uncertain	Student					1.00	0.52	0.67	0.05
	Class Mean					1.00	0.78	0.96	-0.67
OS Dissatisfied	Student						1.00	0.59	0.33
	Class Mean						1.00	0.83	-0.14
OD Admonishing	Student							1.00	0.14
	Class Mean							1.00	-0.50
DO Strict	Student								1.00
	Class Mean								1.00

The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

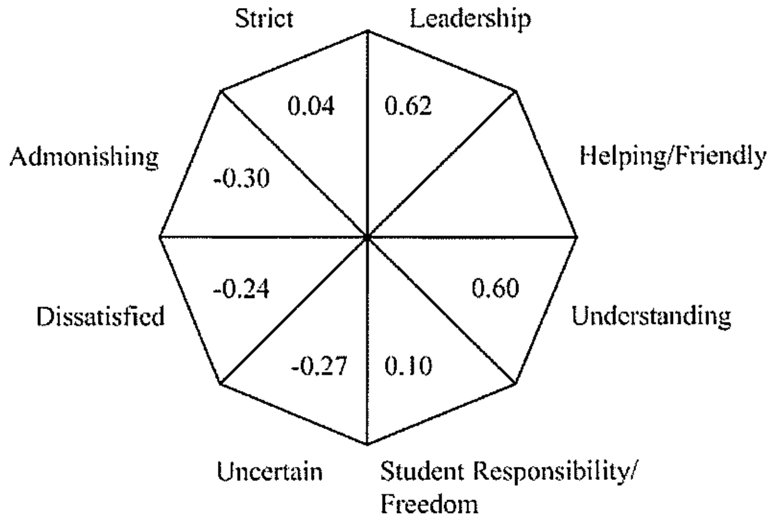


Figure 4.3. Correlations between Helping/Friendly and the other scales of the Ideal QTI using student as the unit of analysis.

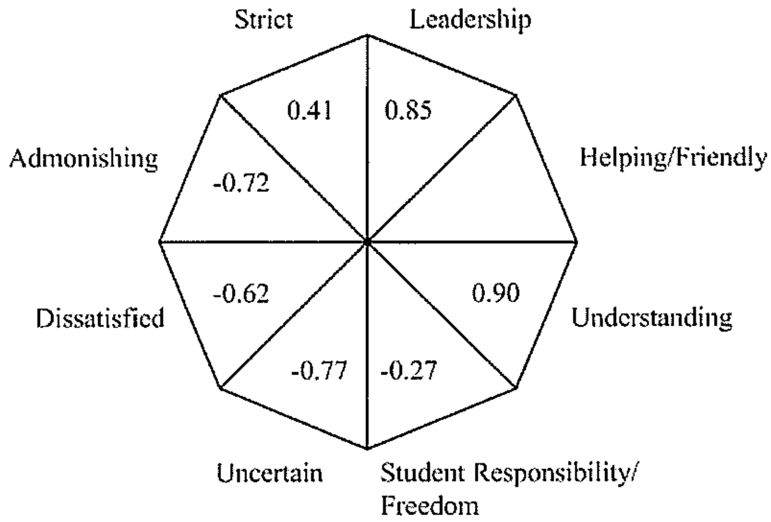


Figure 4.4. Correlations between Helping/Friendly and the other scales of the Ideal QTI using the class mean as the unit of analysis.

It can be seen from Figures 4.1 to 4.4 that there are high correlations with scales adjacent to Helping/Friendly scale (Leadership and Understanding) and low correlations with the Dissatisfied scale which is opposite to Helping/Friendly scale. These results confirm the circumplex nature of the QTI model supporting its validity for use in Thailand.

Consequently, the validity and reliability results of the QTI from this study are consistent with the results from previous studies, for example in a number of the studies elsewhere with teachers and their students in The Netherlands, secondary colleges in Tasmania, secondary colleges in Australia, lower secondary classes in Australia, and students and teachers in the USA (Brekelmans, Wubbels, & Créton, 1990; Fisher, Henderson, & Fraser, 1995; Kent, Fisher, & Fraser, 1995; Rickards, Fisher, & Fraser, 1996; and Wubbels & Levy, 1991).

4.4 RELIABILITY OF THE ATTITUDE SCALE

The Attitude Scale consisted of a ten-item scale, which was used at the beginning and at the end of the semester as were the CLEI and QTI. This scale, which was based on the Test Of Science Related Attitudes (TOSRA) was adapted for physical chemistry laboratory class as noted in Chapter 3.

The alpha reliability of the Attitude Scale was found to be 0.71, when the individual was used as the unit of analysis, and 0.91 when the class mean was used as the unit of analysis. As with the CLEI and QTI, the reliability of class means was higher than the reliability when the individual student was used as the unit of analysis.

4.5 CHAPTER SUMMARY

This chapter describes the validity and the reliability of 35-item CLEI (the Actual and Preferred Forms), 48-item QTI (the Actual and Ideal Forms) through the use of analyses. As well, the reliability of the Attitude Scale was also noted.

For the CLEI, it was found that the reliability was suitable and the CLEI could be used with confidence in this study. As well figures of the mean correlations with the other scales indicated that each of the CLEI scales measured distinct aspects of the physical chemistry laboratory environments in classrooms. The eta^2 also showed the perceptions of students in different classrooms differ significantly except with the Open-Endedness scale.

For the QTI, the reliability figures were higher than those for the CLEI. The eta^2 indicated that perceptions of students in different classrooms are differentiated except with the Student Responsibility/Freedom and Strict scales. Additionally, inter-scale correlation, which showed for both the individual and the class mean as the unit of analysis were a high correlation between adjacent scales and a low correlation between opposite scales in the model.

The Attitude Scale can also be used in this study with confidence because the figure of reliability is quite high.

It can be seen that the CLEI, QTI and the Attitude Scale are suitable for use in this research study as indicated with this Thai sample. As well, previous research studies have reported similar results. The next chapter describes the application of the CLEI and QTI in this study in Thailand.

CHAPTER 5

QUANTITATIVE RESULTS

5.1 INTRODUCTION

The previous chapter described the validation and reliability of the CLEI and QTI, which addressed Research Question 1 referred to in Section 3.3 of Chapter 3 of this thesis. This chapter presents students' perceptions of their actual and preferred learning environments, and their actual and ideal teacher interpersonal behaviours. It also presents the data describing associations between students' perceptions of the classroom environment and their attitudinal outcomes, and between perceptions of classroom environment and cognitive and practical achievement outcomes. As well, this chapter notes the mean scores of the attitude and achievement tests. Additionally, the associations between the students' perception of their teacher's interpersonal behaviour and students' attitude, and between perceptions of this interpersonal behaviour and cognitive and practical achievement outcomes are also included in this chapter.

5.2 STUDENTS' PERCEPTIONS OF THEIR ACTUAL AND PREFERRED LEARNING ENVIRONMENTS

As mentioned in Chapter Two, more congruence between actual and preferred classroom environments could enhance students' outcomes (Fraser & Fisher, 1983a, 1983b; Fraser, 1994). Therefore, one of the aims of the study was to establish the degree of congruence between students' actual and preferred learning environments.

5.2.1 The Laboratory Learning Environment

This section details students' perceptions of their actual and preferred learning environments at the beginning of the semester by using the CLEI (Chemistry Laboratory Environment Inventory) that was modified from the SLEI (Science Laboratory Environment Inventory). The *t* test is a useful technique for comparing mean values of two number sets. In this study, the paired sample *t* test was used to determine whether the differences between actual and preferred means were statistically significant. The actual-preferred difference for the Material Environment scale was the only statistically significant difference on the scales of the CLEI. As shown in Table 5.1 and Figure 5.1, at the beginning of the semester the students preferred a physical chemistry laboratory environment with a higher level of material environment to the actual level they perceived in the physical chemistry laboratory.

Table 5.1
Actual and Preferred Means and Differences on Scales of the CLEI (Beginning of Semester)

	Preferred	Actual	Difference (Preferred-Actual)	*t* test
Student Cohesiveness	27.80	27.84	-0.04	0.14
Open-Endedness	21.53	21.26	0.27	0.63
Integration	26.85	26.54	0.31	0.82
Rule Clarity	26.44	26.04	0.40	1.09
Material Environment	26.38	24.79	1.59	4.31*

*$p<0.001$, n = 100

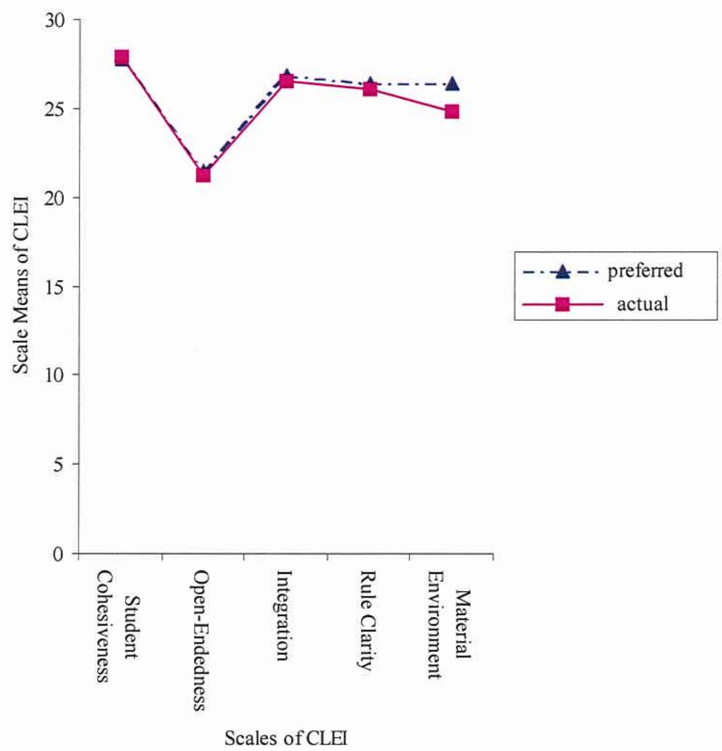


Figure 5.1. Scale means for the actual and preferred forms of the CLEI (Beginning of Semester).

The end of the semester results are shown in Table 5.2 and Figure 5.2. These results allow a comparison of students' perceptions of their actual learning environments at the end of the semester with what they actually perceived at the beginning of the semester. It indicates that the students perceived a laboratory environment with higher levels of student cohesiveness and open-endedness at the end of the semester than what they perceived to be present at the beginning of the semester. Paired sample *t* tests showed that the differences on those scales were significantly different.

Table 5.2
Pre Actual and Post Actual Means and Differences on Scales of the CLEI

	Pre Actual	Post Actual	Difference (Post-Pre Actual)	*t* test
Student Cohesiveness	27.84	28.87	1.03	2.11*
Open-Endedness	21.26	22.39	1.13	2.37*
Integration	26.54	27.53	0.99	1.71
Rule Clarity	26.04	26.79	0.75	1.57
Material Environment	24.79	24.09	-0.70	1.17

*$p<0.05$, n = 100

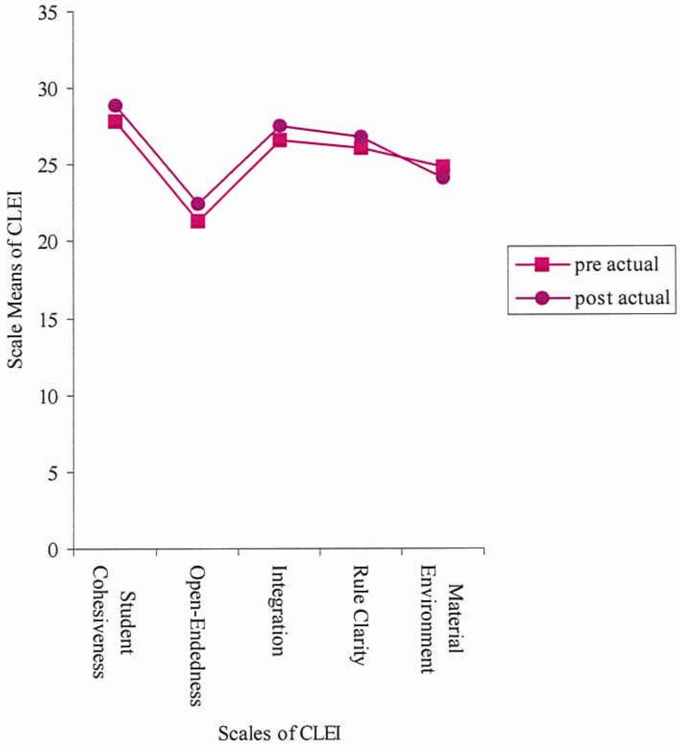


Figure 5.2. Scale means for pre and post actual forms of the CLEI.

A comparison of students' perceptions of their actual learning environments at the end of the semester with their preferred environments at the beginning of the semester is shown in Table 5.3 and Figure 5.3. It can be seen that the students actually perceived a laboratory environment at the end of the semester with a higher level of student cohesiveness than what they preferred at the beginning of the semester. However, the students actually perceived a laboratory environment at the end of the semester with a lower level of material environment than what they preferred at the beginning of the semester. The paired sample *t* tests indicated that these differences were statistically significant, It is noteworthy that for the scale of Student Cohesiveness the students' perception of their actual situation exceeded their previously preferred environment. Also, the material environment provided in these laboratories is still unsatisfactory.

Table 5.3
Preferred and Post Actual Means and Differences on Scales of the CLEI

	Preferred	Post Actual	Difference (Preferred-Post Actual)	*t* test
Student Cohesiveness	27.80	28.87	-1.07	2.20*
Open-Endedness	21.53	22.39	-0.86	1.76
Integration	26.85	27.53	-0.68	1.22
Rule Clarity	26.44	26.79	-0.35	0.77
Material Environment	26.38	24.09	2.29	4.16**

*$p<0.05$, **$p<0.001$, n = 100

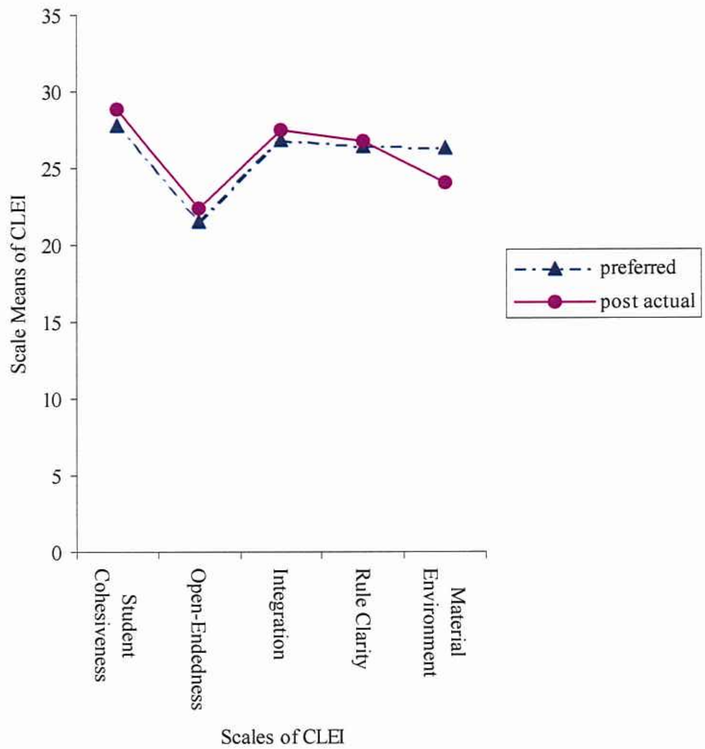


Figure 5.3. Scale means for preferred and post actual forms of the CLEI.

Overall, Thai chemistry teachers should attempt to improve the open-endedness of activities and improve the material environment to create a better classroom environment. In the mean time, the improved cohesion of the students should be maintained in the laboratory classrooms.

5.2.2 The Interpersonal Teacher Behaviour

This section describes students' perceptions of their teachers' actual and ideal interpersonal behaviours at the beginning and end of the semester by using the QTI. Teachers could use such information to modify their behaviours. Table 5.4 and Figure 5.4 present these results.

Paired sample *t* tests shown in Table 5.4 reveal that, the differences on the Leadership, Dissatisfied and Strict scales were significantly different. At the beginning of the semester, students preferred their ideal teacher to have higher levels of leadership behaviour to the actual teacher behaviour they perceived to be present. However, students preferred their ideal teacher to have lower levels of dissatisfied and strict behaviours than what they observed in their actual teacher. These results are similar to those of Levy, Créton, and Wubbels (1993) for a sample of Dutch and American students. Moreover, Henderson, Fisher, and Fraser (1995) revealed that teachers, who showed strong leadership and less dissatisfaction were preferred by Australian students.

Table 5.4
Ideal and Actual Means and Differences on Scales of the QTI (Beginning of Semester)

	Ideal	Actual	Difference (Ideal-Actual)	*t* test
Leadership	20.86	19.94	0.92	3.29**
Helping Friendly	20.01	19.55	0.46	1.65
Understanding	20.24	19.76	0.48	1.64
Student Resp./Freedom	13.37	13.58	-0.21	0.53
Uncertain	7.76	7.6	0.16	0.47
Dissatisfied	8.35	9.10	-0.75	2.44*
Admonishing	6.84	7.43	-0.59	1.76
Strict	14.56	15.95	-1.39	3.44**

*$p<0.05$, **$p<0.01$, n=100

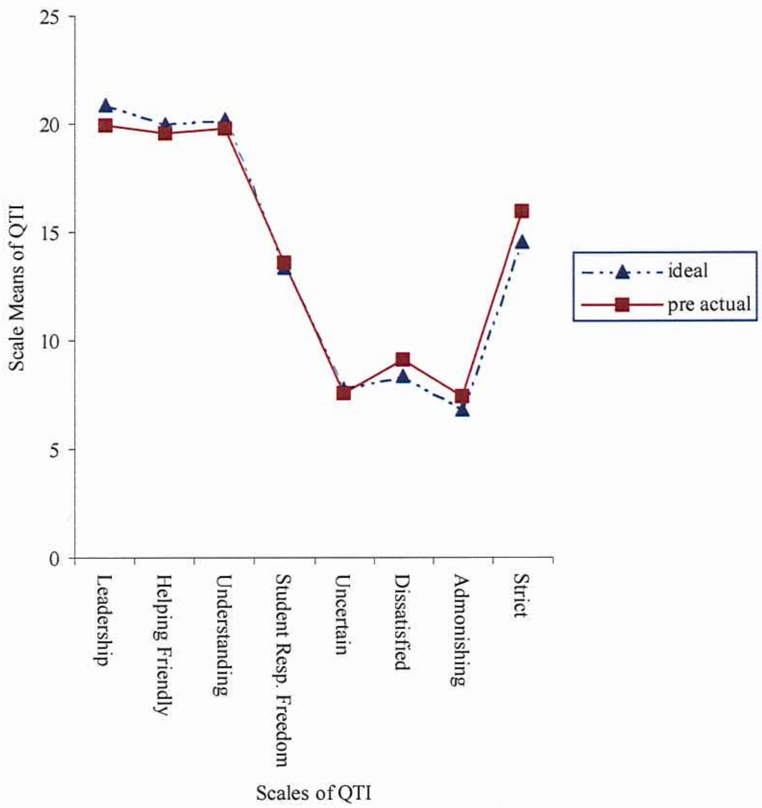


Figure 5.4. Scale means for ideal and actual forms of the QTI (Beginning of Semester).

The end of the semester results shown in Table 5.5 and Figure 5.5, indicate that the students observed that their teachers at the end of the semester had a level of admonishing behaviour lower than what they observed at the beginning of the semester. The difference in the means on the Admonishing scale was significantly different, but there were no significant differences on any of the other scales of the QTI.

Table 5.5
Pre and Post Actual Means and Differences on Scales of the QTI

	Pre Actual	Post Actual	Difference (Post-Pre Actual)	*t* test
Leadership	19.94	20.07	0.13	0.30
Helping Friendly	19.55	19.01	-0.54	1.11
Understanding	19.76	19.74	-0.02	0.05
Student Resp./Freedom	13.58	12.88	-0.7	1.51
Uncertain	7.6	7.03	-0.57	0.93
Dissatisfied	9.10	8.40	-0.7	1.25
Admonishing	7.43	5.86	-1.57	2.60*
Strict	15.95	15.19	-0.76	1.28

*$p<0.05$, n=100

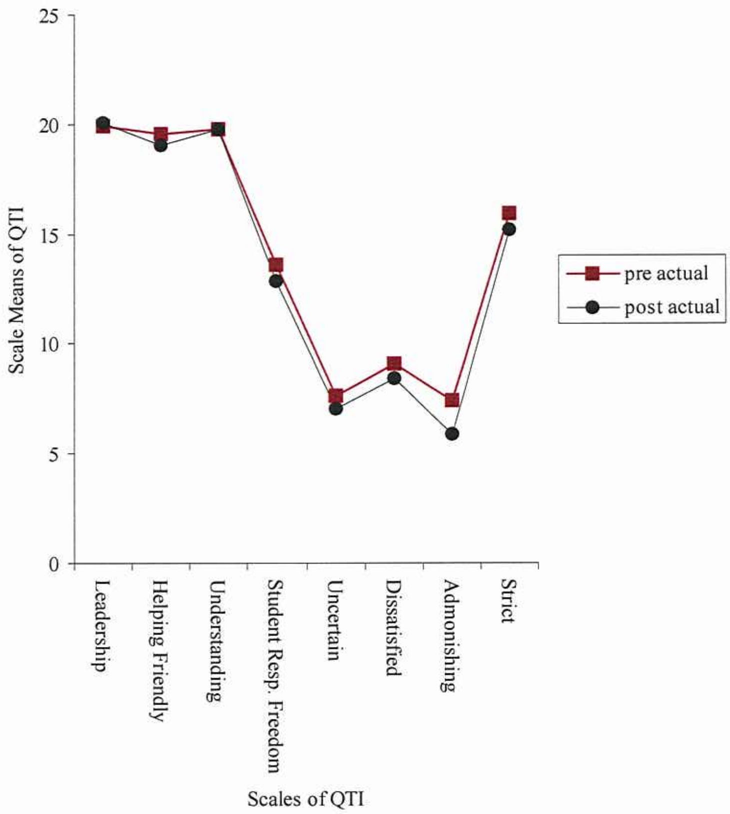


Figure 5.5. Scale means for pre and post actual forms of the QTI.

As with the CLEI, students' perceptions of their teachers' interpersonal behaviour at the end of the semester were compared with their ideal teachers' behaviours. These results are presented in Table 5.6 and Figure 5.6. Paired sample *t* tests reveal that the differences on the Leadership and Helping/Friendly scales were significantly different. Students preferred their ideal teacher at the beginning of the semester to have higher levels of leadership and helping friendly behaviours than their teachers showed at the end of the semester. These results are similar to the previous research (Fraser, 1991; Henderson, Fisher, & Fraser, 1995; Levy, Créton, & Wubbels, 1993; Wong & Fraser, 1994) in which there were differences in students' perceptions of their actual and ideal teacher behaviours.

Table 5.6
Ideal and Post Actual Means and Differences on Scales of the QTI

	Ideal	Post Actual	Difference (Ideal-Post Actual)	*t* test
Leadership	20.86	20.07	0.79	2.1*
Helping Friendly	20.01	19.01	1.00	2.19*
Understanding	20.24	19.74	0.5	1.13
Student Resp./Freedom	13.37	12.88	0.49	1.01
Uncertain	7.76	7.03	0.73	1.14
Dissatisfied	8.35	8.40	-0.05	0.09
Admonishing	6.84	5.86	0.98	1.84
Strict	14.56	15.19	-0.63	1.09

*$p<0.05$, n=100

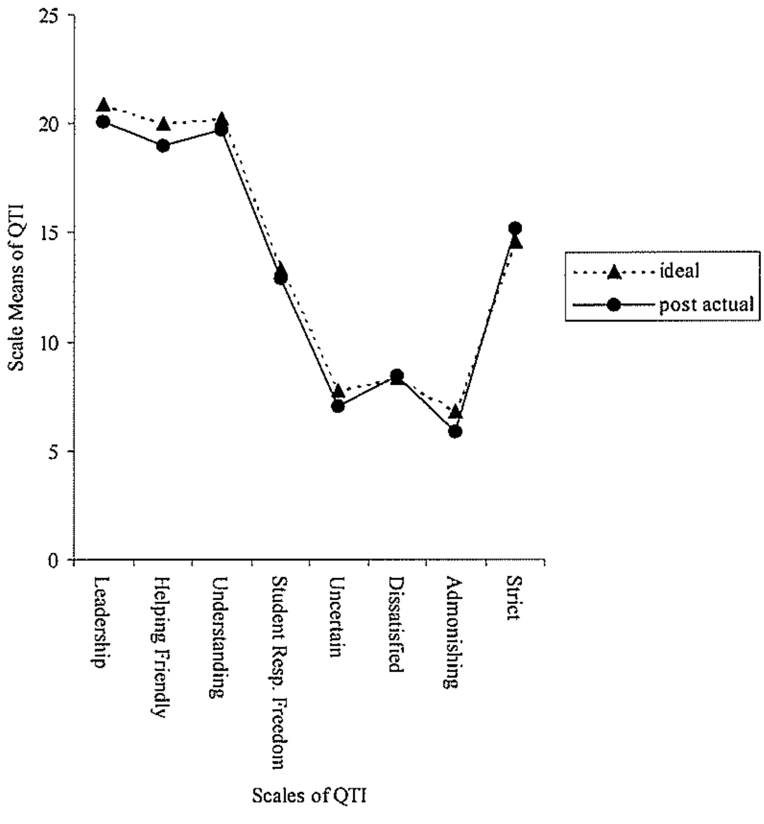


Figure 5.6. Scale means for post actual and ideal forms of the QTI.

As the students observed their actual teacher at the end of the semester to have the levels of leadership and helping/friendly behaviour lower than they preferred, teachers should attempt to increase their leadership and helping/ friendly behaviours. As well, the teachers might decrease the level of admonishing behaviour. This way, the quality of teaching might be enhanced in the future.

5.3 MEAN SCORES OF THE ATTITUDE AND ACHIEVEMENT TESTS

This section presents the mean scores and standard deviations of the attitudinal, cognitive and practical results for physical chemistry obtained from 100 students. The results of the attitude scores toward the physical chemistry laboratory are presented in Tables 5.7 and 5.8. The results in Table 5.8 obtained from the students were used to construct the graph shown in Figure 5.7. The results presented in Table 5.7 show that there was a significant improvement in attitudes toward the physical chemistry class. The standard deviations show that there was a greater deviation from the mean on the pretest than among the posttest scores. The pretest score of 22.03 when converted to an item mean score is 2.23 which is between 'Not Sure' and 'Agree". The post-test score as an item mean is 2.40. Therefore, the students have quite a positive attitude towards their class. Similarly, Henderson (1995) in a study of Biology classes in Australia found the students' attitude to be at the same level of 2.40.

The results shown in Table 5.8 indicated that the greatest improvement occurred in Classes 3 and 4. In fact, the improvement shown in Classes 1 and 2 were not statistically significant. Figure 5.7 shows this graphically.

Table 5.7
Means and Standard Deviations (SD.) of Attitude Scores in Physical Chemistry Laboratory Obtained from the Whole Sample

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test	SD (Pretest)	SD (Posttest)
Attitude score	22.03	24.03	2.00	4.76*	3.17	2.68

* p<0.001, n = 100

Table 5.8
Means and Differences of Attitude Scores in Physical Chemistry Laboratory Obtained from Students in Four Classes

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test
Attitude score for Class 1	23.09	24.65	1.56	1.57
Attitude score for Class 2	22.57	23.30	0.73	1.01
Attitude score for Class 3	21.40	23.83	2.43	4.64**
Attitude score for Class 4	20.76	24.82	4.06	3.06*

*p<0.01, **p<0.001, n = 100

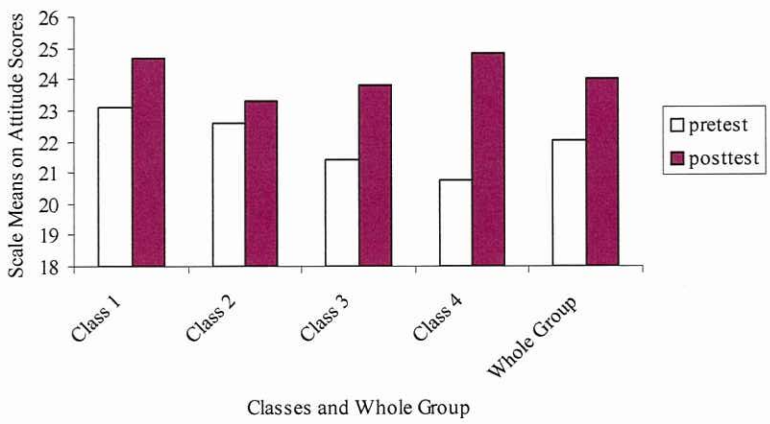


Figure 5.7. The mean attitude scores in physical chemistry laboratory at the beginning and end of the semesters obtained from students in four classes.

The results of the cognitive tests in physical chemistry are shown in Table 5.9 and Figure 5.8. Furthermore, class by class differences are shown in Tables 5.10 and Figure 5.8. It can be noted in Table 5.9 that there was a significant improvement in cognitive results.

It can be seen in Table 5.10 and Figure 5.8, the greatest improvement in students' cognitive performance was in Classes 1 and 3. No statistically significant improvement occurred in the other two classes.

Table 5.9
Means and Standard Deviations (SD.) of Cognitive Scores in Physical Chemistry Obtained from the Whole Sample

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test	SD (Pretest)	SD (Posttest)
Cognitive score	11.70	12.70	1.00	2.20*	2.97	3.46

*p<0.05, n = 100

Table 5.10
Means and Differences of Cognitive Scores in Physical Chemistry Obtained from Students in Four Classes

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test
Cognitive score for Class 1	10.73	12.45	1.72	2.08*
Cognitive score for Class 2	11.84	11.39	-0.45	0.49
Cognitive score for Class 3	11.29	12.74	1.45	2.07*
Cognitive score for Class 4	13.86	15.93	2.07	1.63

*$p<0.05$, n = 100

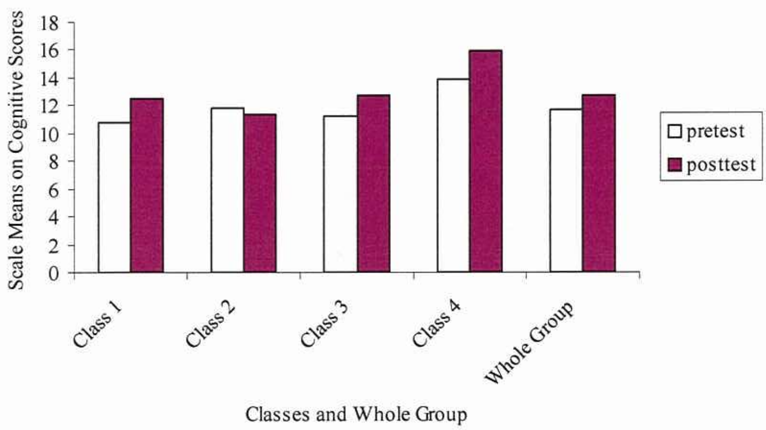


Figure 5.8. The mean cognitive scores in physical chemistry at the beginning and end of the semesters obtained from students in four classes.

Similarly, the results of the practical tests in physical chemistry obtained from students are shown in Tables 5.11 and 5.12 and Figure 5.9. The results in Table 5.11 show that there was a significant improvement in practical scores across the whole sample. As well, the standard deviations of those scores were the smallest when they were compared with that of the other outcomes. This implies that the scores for the practical tests were least spread from the mean score.

As shown in Table 5.12 and Figure 5.9, the improvement in practical test results was greatest in Classes 1 and 4, especially those in Class 1.

Table 5.11
Means and Standard Deviations (SD.) of Practical Scores in Physical Chemistry Obtained from the Whole Sample

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test	SD (Pretest)	SD (Posttest)
Practical score	10.84	11.47	0.63	4.27*	1.51	1.94

*p<0.001, n = 100

Table 5.12
Means and Differences of Practical Scores in Physical Chemistry Obtained from Students in Four Classes

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test
Practical score for Class 1	11.87	13.43	1.56	4.52**
Practical score for Class 2	10.23	10.39	0.16	0.60
Practical score for Class 3	9.77	10.23	0.46	1.17
Practical score for Class 4	12.32	12.89	0.57	2.80*

**p<0.001, *p<0.05, n = 100

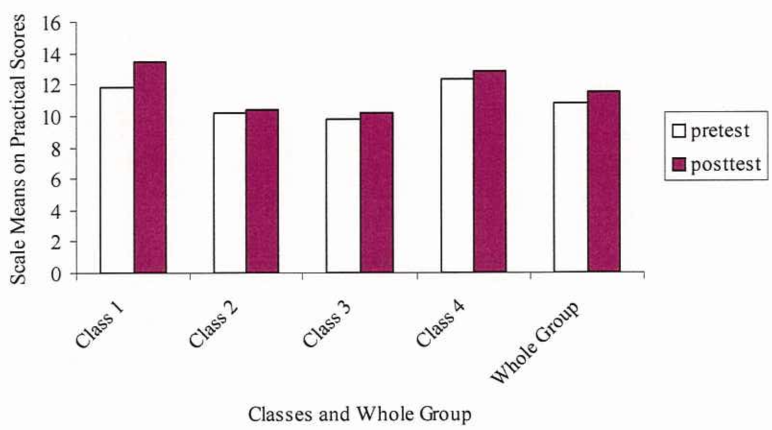


Figure 5.9. The mean practical scores in physical chemistry at the beginning and end of the semesters obtained from students in four classes.

The results shown in Table 5.13 and Figure 5.10 indicated that, on the average students did improve their practical skills and cognitive achievement as well as having better attitudes to their physical chemistry classes.

Table 5.13
Means and Differences of the Three Tests in Physical Chemistry Obtained from the Whole Sample

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test
Attitude Test	22.03	24.03	2.00	4.76**
Cognitive Test	11.70	12.70	1.00	2.20*
Practical Test	10.84	11.47	0.63	4.27**

$^{**}p<0.001$, $^{*}p<0.05$, n = 100

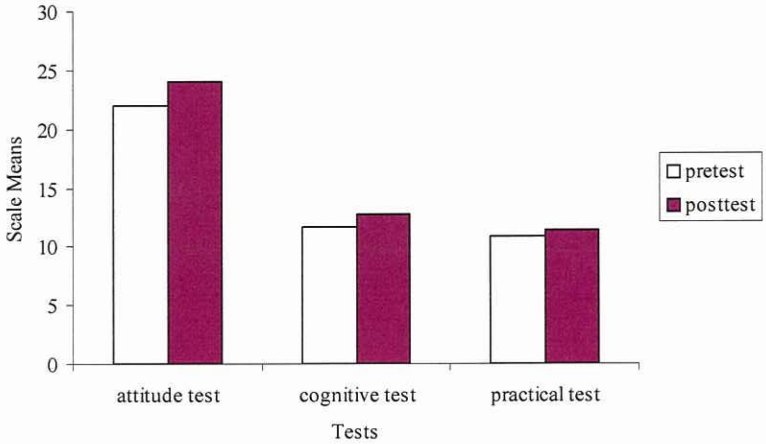


Figure 5.10. The mean scores on the three tests in physical chemistry at the beginning and end of the semesters obtained from the whole sample.

5.4 ASSOCIATIONS BETWEEN THE STUDENTS' PERCEPTIONS OF THE CLASSROOM ENVIRONMENT AND STUDENT OUTCOMES

This research study also investigated associations between the students' perceptions of the learning environment and their attitudinal and achievement outcomes. The associations were analyzed by simple and multiple correlations, and results were reported separately for attitude and cognitive achievement outcomes.

Associations between the students perceptions of the learning environment and students' attitude are discussed in Section 5.4.1, whilst the associations between the learning environment and students' cognitive achievement are described in Section 5.4.2.

5.4.1 Associations Between Students' Perceptions of the Laboratory Learning Environments and Students' Attitude

This section discusses the simple and multiple correlations used to analyze associations between the classroom environment scales of the CLEI and students' attitude.

Table 5.14 shows that the associations between the students' perceptions of the laboratory learning environment and a ten-item Attitude Scale based on the Test Of Science Related Attitudes (TOSRA) (Fisher, Henderson, & Fraser, 1995; Fraser, 1981) as measured by simple and multiple correlation. The simple correlation figures were statistically significant for the Student Cohesiveness, Open-Endedness and Material Environment scales, suggesting that student' attitudes were more likely to be positive where students perceived greater student cohesiveness, open-endedness and material environment. These findings were similar to those of previous studies. For example, Quek, Wong and Fraser (2001) revealed statistically significant correlations between students' attitudes and the Student Cohesiveness and Open-Endedness scales among gifted students in Singapore. Moreover, this was similar to the previous study of Kijkosol (2005) in which the Student Cohesiveness scale related to students' attitudes in biology classes in Thailand.

Table 5.14
Simple Correlation (r) and Multiple Regression (β) for Associations Between Students' Attitude and CLEI Scale

CLEI Scale	Attitude to Physical Chemistry Laboratory	
	r	β
Student Cohesiveness	0.20*	0.08
Open-Endedness	0.20*	0.21*
Integration	0.18	0.10
Rule Clarity	0.11	-0.08
Material Environment	0.25*	0.22*
Multiple Correlation, R		0.35*
R^2		0.12

*$p<0.05$, $n = 100$

The beta weight (β) which indicates the association between an outcome and a particular scale when other scales are controlled, reveals two statistically significant results ($p<0.05$) for the Open-Endedness and Material Environment scales. Both these scales were positively associated with the attitude scores when other CLEI scales were controlled. This was similar to the previous study of Quek, Wong and Fraser (2001) in which the Open-Endedness scale showed a significant association with students' attitudes when other scales are controlled.

The multiple correlation, R of 0.35 was significant and positive. The R^2 figure shows that 12% of the variance in students' attitudes was accounted for by students' perceptions of their laboratory learning environments.

In current teaching involving science laboratory environment, the students' perceptions of their laboratory learning environments should be taken into account more. Laughlin (2003) also recommended that positive attitudes to education should be developed in children in Thailand.

5.4.2 Associations Between the Students' Perceptions of the Laboratory Learning Environments and Cognitive and Practical Achievement

This section discusses the results of simple and multiple correlations used to analyze associations between the classroom environment scales of the CLEI and students' cognitive achievement. Students' examination scores were used as measures of cognitive achievement.

For exam scores in physical chemistry (Table 5.15), the simple correlation was only statistically significant for the negative figure of the Rule Clarity scale, indicating that students' exam scores were lower where the students perceived stronger rule clarity. The negative significance of the Rule Clarity scale similarly replicated the previous study of Henderson, Fisher, and Fraser (1995) using the SLEI for biology students in Tasmania, Australia.

Table 5.15
Simple Correlation (r) and Multiple Regression (β) for Associations Between Student Cognitive and Practical Achievement and CLEI Scales

Scale	Cognitive Score		Practical Score	
	r	*β*	*r*	*β*
Student Cohesiveness	-0.13	-0.04	0.20*	0.15
Open-Endedness	0.04	0.09	0.32**	0.31**
Integration	-0.05	0.11	-0.03	-0.15
Rule Clarity	-0.21*	-0.27*	0.05	-0.03
Material Environment	0.01	0.15	0.13	0.15
Multiple Correlation, *R*		0.27		0.39**
R^2		0.08		0.15

*$p<0.05$, **$p<0.01$, n = 100

The beta weight (*β*) reveals one statistically significant figure ($p<0.05$). The multiple regression analysis indicates that the Rule Clarity scale retained its significance when other CLEI scales were controlled.

The multiple correlation (*R*) was not significant with a value of 0.27. This figure indicates that associations were not strong between students' perception of the learning environment and their cognitive achievement. This was similar to a previous study of Henderson, Fisher, and Fraser (1995) when they assessed students in Tasmania, Australia using the SLEI.

Table 5.15 also reports the simple correlations of associations between the classroom environment scales of the CLEI and student scores on a practical test. The simple correlation was statistically significant for the Student Cohesiveness and Open-Endedness scales, suggesting that the students' result for the practical test was higher when they perceived more cohesion and open-endedness.

The beta weight (*β*) reveals one significant figure ($p<0.01$). The multiple regression analysis indicates that the Open-Endedness scale was positively associated with the practical test when other CLEI scales were controlled.

The multiple correlation R and R^2 resulted in positive figures of 0.39^{**} and 0.15 respectively. The R^2 figure shows that 15% of the variance in student practical test scores was accounted for by students' perceptions of their laboratory learning environments.

Results such as these, involving associations between classroom environments that were related to student outcomes should be used in laboratory classrooms. Rule clarity and open-endedness are particularly important in laboratory situations. Teachers should use their knowledge of classroom environments to bring about improvement of achievement outcomes and attitudes to students. The College of Education also suggested that Thai science teachers should recognize the importance of the classroom environment while teaching their students (MSU Cross-University collaboration helps build environmental education in Thailand, 1996)

5.5 ASSOCIATIONS BETWEEN STUDENTS' PERCEPTIONS OF THEIR TEACHER'S INTERPERSONAL BEHAVIOUR AND STUDENT OUTCOMES

The previous section showed associations between the students' perceptions of the learning environment and their outcomes. This section discusses associations between students' perceptions of their teacher's interpersonal behaviour and outcomes. These associations again were analyzed by simple and multiple correlations, and results were then reported separately for attitude and achievement outcomes.

Associations between interpersonal behaviour and attitude are discussed in Section 5.5.1, whilst associations between interpersonal behaviour and cognitive achievement are later described in Section 5.5.2.

5.5.1 Associations Between Interpersonal Behaviour and Student Attitude

Table 5.16 shows the association data between interpersonal behaviour and a ten-item of Attitude Scale based on the Test Of Science Related Attitudes (TOSRA)

(Fraser, 1981; Fisher, Henderson, & Fraser, 1995). The Leadership and Understanding scales were positively related to student attitudes, indicating that students' attitude scores were likely to be higher where teachers exhibited more leadership and understanding of students. These findings were broadly similar to the study of Wubbels, Brekelmans, and Hooymayers, (1991) and of Henderson, Fisher and Fraser (1994) who found that the Leadership and Understanding scales were significantly correlated with students' attitudes using the QTI with students in The Netherlands and Australia respectively.

Table 5.16
Simple Correlation (r) and Multiple Regression (β) for Associations Between Students' Attitude and QTI Scales

CLEI Scale	Attitude to Physical Chemistry Laboratory	
	r	β
Leadership	0.20*	0.11
Helping Friendly	0.14	-0.05
Understanding	0.23*	0.20
Student Resp./Freedom	0.05	0.02
Uncertain	-0.06	0.01
Dissatisfied	-0.05	0.05
Admonishing	-0.06	-0.04
Strict	-0.05	-0.08
Multiple Correlation, R		0.25
R^2		0.06

*$p<0.05$, n = 100

The multiple correlation shows the positive figures as 0.25, which was not significant. The result was similar to a previous study of Quek, Wong, and Fraser (2001) using the QTI to students in Singapore.

5.5.2 Associations between Interpersonal Behaviour and Student Cognitive and Practical Achievement

Table 5.17 presents the association data between interpersonal behaviour and achievement outcomes.

Table 5.17
Simple Correlation (r) and Multiple Regression (β) for the Associations Between Student Cognitive and Practical Achievement and QTI Scales

Scale	Cognitive Score		Practical Score	
	r	β	r	β
Leadership	-0.01	-0.09	0.23*	-0.05
Helping Friendly	0.08	0.08	0.29**	0.24
Understanding	0.07	-0.03	0.31**	0.29*
Student Resp./Freedom	0.04	0.14	0.14	-0.06
Uncertain	-0.08	0.14	0.07	0.28
Dissatisfied	-0.25*	-0.42*	0.03	0.10
Admonishing	-0.12	0.03	0.01	-0.19
Strict	-0.05	0.07	0.03	0.02
Multiple Correlation, R		0.32*		0.40*
R^2		0.10		0.16

$^{*}p<0.05$ $^{**}p<0.005$, n = 100

The Dissatisfied scale was negatively associated with the exam scores. This indicates that students' exam scores were lower where teacher enforced stronger dissatisfied behaviour in laboratory classrooms. This finding was similar to the previous study of Rickards (1998) using the QTI to Australian students.

The beta weights (*β*) revealed one significant figure ($p<0.01$). The multiple regression analysis indicates that the Dissatisfied scale retained its significance when other QTI scales were controlled.

The multiple correlation (R) of 0.32 indicates that associations between students' perception of interpersonal behaviours and exam scores were not strong with only 10% of the variance in cognitive achievement being predicted by students' perception of their teacher' s interpersonal behaviour.

Table 5.17 also reports the simple and multiple correlation analyzing associations between the interpersonal behaviour scales of the QTI and students' practical test. For the practical test, the simple correlation was statistically significant and positive for the Leadership, Helping/Friendly and Understanding scales. These figures indicated that students' practical test was higher where the teacher provided more leadership, helping/friendly, and understanding behaviours in laboratory classrooms.

This finding was different to the previous study of Henderson, Fisher, and Fraser (1995) in which no significance of simple correlation scales was found except the Student Responsibility/Freedom and Strict scales.

The beta weights (β) revealed one significant figure ($p<0.05$). The multiple regression analysis indicates that the Understanding scale was positively associated with students' practical test scores. This means that students' practical test scores were higher where teacher were more understanding of students. These findings were different to the previous study of Henderson, Fisher, and Fraser (1995) in which the only significant beta weight was with the Strict scale.

The multiple correlation was significant with a value of 0.40. The R^2 figure also shows that 16% of the variance in student practical test results was accounted for by students' perceptions of their teachers' interpersonal behaviours.

From the associations' results, it should be underlined that Thai physical chemistry teachers should give more attention to their interpersonal behaviour with their students. This might result in higher student achievement in physical chemistry.

5.6 CHAPTER SUMMARY

Associations between students' perceptions of classroom environment and teacher interpersonal behaviour with attitude, cognitive and practical achievement outcomes have been reported in this chapter. Also, differences between students' perceptions at the beginning and end of the semester were given.

The results from students' perceptions of classroom environments indicated that: 1) students preferred a better material environment from what they actually perceived to be present at the beginning of the semester; 2) an improvement was found in the students' perception of their actual classroom environment in terms of student cohesiveness and open-endedness at the end of the semester; and 3) students' perceived actual environments at the end of the semester was higher on student cohesiveness and lower on material environment than the preferred environments at the beginning of the semester.

Also, students' perceptions of teacher-student interactions revealed; 1) students felt that at the beginning of the semester, teachers exhibited higher levels of dissatisfied and strict behaviours, and a lower level of leadership than they thought would be present in ideal teachers; 2) students agreed that the teachers actually interacted with students at the end of the semester with a level of admonishing behaviour lower than that at the beginning of the semester; 3) at the end of the semester, students perceived that the levels of leadership and helping friendly behavious of actual teachers were lower than what they expected in ideal teachers.

In terms of student attitudes to their physical chemistry laboratory, attitudinal outcomes were positively associated with the Student Cohesiveness, Open-Endedness and Material Environment scales. Furthermore, the Open-Endedness and Material Environment scale retained their significance in the regression analysis. Also, a negative association between the Rule Clarity scale and cognitive achievement was found, and this was conserved in the regression analysis. In relation to practical outcomes, positive associations were found between the Student Cohesiveness and Open-Endedness scales and outcomes. In addition, the regression analysis revealed that Open-Endedness retained its significance.

In teacher-student interactions, attitudinal outcomes were positively associated with the Leadership and Understanding scales. However, in the regression analysis no significant association was retained with these two scales. However, a negative association between the Dissatisfied scale and cognitive achievement was found. Positive associations between the Leadership, Helping/Friendly and Understanding scales, and practical achievement were also found.

An examination of differences between pre and posttests indicated that on the whole, students were able to improve their achievement outcomes.

These results are discussed further in the last chapter. The next chapter presents the qualitative results obtained from twelve students in four Rajabhat Universities.

CHAPTER 6

QUALITATIVE DATA FROM STUDENTS

6.1 INTRODUCTION

The previous chapter detailed the quantitative data results from students in four Rajabhat Universities in Thailand and addressed research questions 2 to 6 proposed in Section 3.3 of this thesis. This chapter reports qualitative results from twelve students in four Rajabhat Universities, namely Kamphaeng Phet, Phitsanulok, Phanakhon and Maha Sarakham Rajabhat Universities. Information from both written accounts and oral interviews was collected in this study. The purpose of the qualitative data was to provide clarification of the results from the questionnaires and to provide additional viewpoints on the laboratory learning environment and teacher behaviour.

6.2 INTERVIEW RESULTS

When quantitative methods are combined with qualitative methods, they provide a more complete examination of classrooms and schools at the present. During the interviews, students were asked to comment on aspects of the learning environments of their classes that related to the scales of the CLEI.

As discussed in Chapter 5, the results from the use of the CLEI (see Table 6.1) showed that students perceived cohesiveness, integration, rule clarity, material environment and open-endedness, with item means of 4.02, 3.87, 3.75, 3.74 and 3.01, respectively.

Table 6.1
Item Means and Standard Deviations for the CLEI

Scale	Item Mean	Standard Deviation
Student Cohesiveness	4.02	0.50
Open-Endedness	3.01	0.56
Integration	3.87	0.59
Rule Clarity	3.75	0.55
Material Environment	3.74	0.65

n = 198

In this chapter, Section 6.2.1 presents the opinions of the students based on their responses to interview questions about aspects of the laboratory classrooms measured by the CLEI. Moreover, these results provide additional qualitative data that support its validation of the CLEI.

6.2.1 Questions and Answers of Student Interviews

Questions asked by the researcher were the same to each student and requested information on each scale in turn. The students' comments are grouped according to their universities. In this section, the letters and numbers are used behind each interview sentence: A, B, C and D referring to each of the four universities; and 1, 2 and 3 referring to the three students who participated in the interviews.

6.2.1.1 Student Cohesiveness

This section deals with the cohesion of students, such as whether the students help and support each other in the laboratory classroom. The students provided their opinions in relation to the following question:

Did your friends help, know or support you during laboratory activities? (Item mean was 4.02.)

> *Yes, I could say that because most of the students in the laboratory classroom were good and cooperative. (A1)*
>
> *Indeed, cooperation in the physical chemistry laboratory classroom occasionally happened after we started doing laboratory work. (A2)*

It was very good while my friends and I got to know each other in the short time we had in the physical chemistry laboratory classroom. (A3)

When I had some problems in laboratory sessions, my friends always helped me in the physical chemistry laboratory classroom. (B1)

Whenever the teacher asked me a question, we cooperated and consulted each other. So I liked this situation in this laboratory classroom. (B2)

In the laboratory classroom, I thought that it was very warm because most of us got to know each other well. (B3)

Yes, I always had a good time in the laboratory class. Moreover, most of us go on well in the physical chemistry laboratory classroom. (C1)

I had some cooperation and unity with my friends in the physical chemistry laboratory classroom. (C2)

Sometimes, a direction made us confused so everybody tended to depend on each other during the physical chemistry laboratory sessions. (C3)

Certainly, we worked cooperatively in the physical chemistry laboratory classroom so that we often got new knowledge whilst we were doing laboratory work. (D1)

I perceived the good learning environment in the physical chemistry laboratory classroom, such as my friends. So I got to know everybody in the short time we had in that classroom. (D2)

Every student in the physical chemistry laboratory classroom was like me in that they got on well with their friends in that classroom. (D3)

From the results of the interview, it appeared that most students were likely to know, help and support other students. It would appear that in the physical chemistry laboratory, the students got on well together. This reflects the item mean of 4.02 for the Student Cohesiveness scale.

6.2.1.2 Open-Endedness

This scale assesses the extent to which an open-ended, divergent approach is taken to laboratory activities. This approach would allow students the freedom to do different alternative experiments to those prescribed. Students were asked the following question:

Were your physical chemistry experiments designed in an open-ended manner? Were you able to design some of your experiments? (Item mean was 3.01.)

> *My teacher often set his laboratory activities and said that he had to be hurried for teaching. So I was not able to plan the best way of doing physical chemistry experiments. (A1)*
>
> *When my teacher was busy, such as he would have a meeting, he did not decide a good way of doing physical chemistry experiments unless I asked him. (A2)*
>
> *I was left to do some physical chemistry experiments on my own because my teacher expected me to have a skill on laboratory work. (A3)*
>
> *I often found that the data of my physical chemistry experiments were different from my friends when we were working on the same problem. (B1)*
>
> *There were many laboratory activities in one semester which were very heavy, therefore, I could decide by myself to do physical chemistry experiments. (B2)*
>
> *Although there were many laboratory activities in one semester which were very heavy, I could collect data the same as my friends in the physical chemistry laboratory class. (B3)*
>
> *I was interested in deciding the best way that my teacher encouraged me in the physical chemistry laboratory class. (C1)*
>
> *I did not like the way of doing physical chemistry experiments that was decided from my teacher because I preferred to show my creative thinking in the laboratory class. (C2)*
>
> *I had a good chance to do physical chemistry laboratories on my own in the laboratory class if I had the free time. (C3)*
>
> *Yes, it was a good to do it myself. I had a good chance of doing physical chemistry experiments on my own which was interesting. (D1)*
>
> *Although my teacher set his laboratory activities in a laboratory room, I was able to proceed with physical chemistry experiments on my own. (D2)*
>
> *My teacher did not really decide on good physical chemistry experiments in the laboratory classroom because he was not interested me while I was doing the laboratory work. (D3)*

The results of the interview indicated that six students had some opportunity to decide their experiment directions, however, one student considered that he/she did not have such an opportunity. Another student disliked such experimental direction decided by a teacher, and two students did not receive good direction from him/her. Some students responded about working with their friends rather than in relation to open-endedness. Therefore, some of the students perceived that an open-ended, divergent approach was taken with some experimental work. Overall, these comments are a reflection of the unsure response of 3.01 on the questionnaire.

6.2.1.3 Integration

The Integration scale assesses the extent to which the practical activities of the laboratory course are integrated with the non-laboratory or theory classes. Students expressed their opinions as follows:

Did your physical chemistry laboratory relate to your regular science classes? (Item mean was 3.87.)

> *I actually found the theory of regular science classes related to the physical chemistry laboratory topics. I was satisfied because I could get more knowledge. (A1)*
>
> *After I finished the physical chemistry class, I was able to use that knowledge for the physical chemistry laboratory proceeding which was interesting. (A2)*
>
> *The physical chemistry laboratory was occasionally related to the physical chemistry theory so sometimes I did not make sense of the laboratory work. (A3)*
>
> *The physical chemistry laboratory knowledge helped me understand more of the physical chemistry theory while I was studying that theory class. (B1)*
>
> *I liked integrating the physical chemistry class and the laboratory work so that I could expand my knowledge on the science topic. (B2)*
>
> *I did not use the physical chemistry laboratory to understand theory in a regular science class. It would be better, if my teacher gave me information to increase that understanding. (B3)*
>
> *I found that the physical chemistry topics were occasionally integrated with laboratory activities. Some topics reminded me of the laboratory knowledge class. (C1)*

I could say that there was a lot of laboratory work to do in a semester but I regcognised that some physical chemistry laboratory topics were integrated with the physical chemistry theory. (C2)

Truly, the physical chemistry laboratories helped me clarify the work of the theory class. Moreover, they made me understand more the general science. (C3)

I would say that... yes, the experiments were related to science classes if I did not forget. I now had increased skill for laboratory work. (D1)

Yes, I though that the theory was important to relate with the laboratory classes. During laboratory classes, I hence used my knowledge of theory to help my laboratory understanding. (D2)

I did not use the physical chemistry theory to help my physical chemistry laboratories. I could not explain...why I did not. Probably, my teacher did not give me information for that relation. (D3)

The results of the interviews indicated that seven students perceived a degree of integration between the laboratory and non-laboratory classes because they could use the theory gained from science class sessions during laboratory activities. Moreover, three students understood that such an integration seemed to present in a laboratory classroom. However, two students thought that the laboratory was not related with non-laboratory classes. Generally, students saw that the laboratory activities were integrated with non-laboratory and theory classes and these comments are a reflection of the response of 3.87 on the questionnaire.

6.2.1.4 Rule Clarity

The Rule Clarity scale assesses the extent to which behaviour in the laboratory is guided by formal rules. Students were asked the following questions in the interviews:

Do you have rules in the physical chemistry laboratory class, such as safety precautions? What do you think of these rules? Are they clear? (Item mean was 3.75.)

My teacher presented the safety precautions to me before I did physical chemistry experiments so that I could do things safely in the laboratory class. (A1)

In my opinion, my laboratory was not boring even though the teacher told me the rules of the physical chemistry laboratory class during laboratory activities. (A2)

The laboratory was occasionally under clear rules guiding my activities. I would like the teacher to tell me what happens when these rules are needed. (A3)

The physical chemistry laboratory course had clearer and more specific rules than the other lab classes. In this way, there was no danger to me during laboratory work because I made sense of all the rules. (B1)

I was not sure that there were certain rules in the physical chemistry laboratory classroom. I liked these rules because they could guide the laboratory activities to me. (B2)

I did not like most of the rules in the physical chemistry laboratory so I followed only a few rules in that physical chemistry laboratory classroom. (B3)

My teacher told me the safety rules during the time I did physical chemistry experiments. That was the important information that I needed while I was doing those experiments. (C1)

Well for me, there were safety rules in the physical chemistry laboratory class. These were safety precautions before my laboratory sessions. (C2)

I did not follow some rules in the physical chemistry laboratory class. Some of them were imposed on me, such as I should not eat food in the laboratory room. (C3)

There were clear rules in the physical chemistry laboratory class that I had to follow. I found that this did not trouble me. (D1)

My teacher described the safety rules for the laboratory classroom. Moreover, if I did not make sense of these rules, I could consult him.(D2)

My physical chemistry laboratory classroom had a few rules that were imposed on me compared with the other science laboratory classrooms. I did not know why? (D3)

It appears from the results of the interviews that on the whole students recognized and perceived that certain rules and safety precautions during laboratory sessions were enforced by their teachers. One student felt that the laboratory room seemed unclear in relation to the rules for work. One student appeared not to know that there were certain rules in the laboratory room and another student disliked most of the rules so he/she followed few of them. One other student did not understand some rules because some of the students were disturbing, and another could not see why the few rules were imposed on him/her. However, the majority of the students thought that behaviour in a laboratory class was guided by formal rules. This reflects the item mean of 3.75 on the questionnaire.

6.2.1.5 Material Environment

The Material Environment scale deals with the adequacy of laboratory equipment and material. Students expressed their opinions as follows:

Would you describe your physical chemistry laboratory classroom? Did you have enough equipment? Was the room clean and not too crowded? (Item mean was 3.74.)

> *Yes, I always found that the desks and equipment in the physical chemistry classroom were orderly, and that equipment was adequate for use in the laboratory work. (A1)*
>
> *The temperature in the physical chemistry laboratory classroom was sometimes hot so I always felt unhappy while I had a class. (A2)*
>
> *I liked my physical chemistry laboratory classroom because that laboratory classroom was quite new and clean. (A3)*
>
> *Some days, the physical chemistry laboratory class was crowded when laboratory work was proceeding. Hence, there were errors in my data collection. (B1)*
>
> *Some days, the equipment in the physical chemistry laboratory classroom was not working well. But some days it was available. (B2)*
>
> *I have studied at this university for more one year but I still had some equipment in the physical chemistry laboratory class insufficient for the experiments. (B3)*
>
> *I could say that the desks were not orderly and chemical compounds smelled in the physical chemistry laboratory classroom. I thought some officers should be careful to clean that classroom. (C1)*

> *There were enough physical chemistry laboratory rooms for work. That was good for every one to study, otherwise I could not do the good laboratory work. (C2)*
>
> *Some days, the climate in the physical chemistry classroom was stuffy and hot, but some days I found that it was fresh. (C3)*
>
> *Some days, the temperature in the physical chemistry laboratory classroom was hot. Some days, I found the equipment was just not available and this caused errors in my data collection. (D1)*
>
> *The shower rooms in the laboratory classroom were just not adequate for cleaning the bodies of students when chemical compounds splashed on them. (D2)*
>
> *I liked the physical chemistry laboratory classroom for studying because it was quite new. (D3)*

The results of the interviews related to the Material Environment scale showed that three students liked the laboratory room because it was quite new and had adequate equipment for work, and one student added that there were enough rooms for study. However, a student felt that the laboratory room smelled and another saw that the equipment was not adequate for the required work. As well, another four students indicated that the laboratory room was occasionally hot, stuffy, smelled and was too crowded. Moreover, two students occasionally perceived insufficient and unavailable of equipment for using in laboratory activities. Generally, about half of the students understood that the material environments seemed to be adequate reflecting the response of 3.74 on the questionnaire.

Overall, the answers on physical chemistry laboratory classroom environments from students (Sections 6.2.1.1 to 6.2.1.5) of each university were similar in relation to each scale, indicating that the physical chemistry laboratory classroom environments of the Rajabhat Universities are similar. For example, most of the students in each university did help, know and support each other in the classroom, the laboratory activities were related to the non-laboratory activities, and there were formal rules to follow. Open-ended activities were not quite so apparent and the adequacy of the equipment should be considered.

6.3 WRITTEN STORY RESULTS

As with the interview results, the written stories provided a more complete picture of school and classroom life. The students were asked to summarize their teachers' behaviour in their classroom. Section 6.3.1 discusses the written stories provided by the students. Section 6.3.2 confirms the validity of the QTI by considering the number of written story results related to scales of the QTI and whether that reflected the actual score on that scale.

6.3.1 Questions and Description of Written Stories

This section details students' descriptions of the interpersonal behaviour of their teachers to clarify the results from the QTI and provide further information on teacher behaviours. As with the interview section, the letters and numbers are used with each of the written stories; A, B, C and D refer to the four universities; and 1, 2 and 3 refer to students one, two and three who participated in the written stories.

The Leadership scale describes a teacher's behaviour in relation to how she/he leads, organises, gives orders, sets tasks, determines procedure, structures the classroom situation, explains, and holds attention in a classroom. The Helpful/Friendly scale describes the teacher's behaviour in relation to how he/she assists, shows interest, joints, behaves friendly and confident manners, can make a joke, and trusts to students. The Understanding scale is the extent to which the teacher shows he/she listens empathises, shows confidence and understanding, accepts apologies, looks for ways to settle differences, is patient, and is open to students. The Student Responsibility/Freedom scale describes the teacher's behaviour in relation to how he/she gives opportunity for independent work, waits for class to let off stream, and gives freedom and responsibility to students. The Uncertain scale describes the teacher's behaviour in relation to how he/she keeps a low profile, apologises wait, keeps a temper, and admits one is in the wrong. The Dissatisfied scale describes the teacher's behaviour in relation to how he/she waits for silence, considers pros and cons, keeps quite, and shows dissatisfaction to students. The Admonishing scale describes the teacher's behaviour in relation to how he/she gets angry, takes pupils to task, shows irritation and anger, forbids, corrects, and punishes. The Strict scale describes the teacher's behaviour in relation to how he/she keeps reins tight, checks judge, gets class silent, is strict, exact norms, and set rules to students.

Numbers are used behind each sentence to indicate to which scale of the QTI the student response refers. One means it is a leadership comment, 2 would indicate a helpful friendly behaviour, 3 is a comment about Understanding behaviour, 4 would refer to a student responsibility/freedom behaviour, 5 is a comment about uncertain behaviour, 6 is a dissatisfied comment, 7 is a comment about admonishing behaviour, and 8 would refer to a strict behaviour.

Twelve students from four Rajabhat Universities were asked for written stories about teacher-student interactions. They were asked about each scale with similar questions as follows:

Leadership: How would you describe your teacher's leadership qualities in the classroom? (Item mean was 3.43.)
Helpful/Friendly: Did your teacher help you and be friendly towards you? Please, describe. (Item mean was 3.27.)
Understanding: Did your teacher understand you and trust you? Did your teacher let you talk? Please, give details. (Item mean was 3.35.)
Student Responsibility/Freedom: Did your teacher always encourage you to discuss work with your friends while he/she was teaching in the physical chemistry laboratory? What opportunity did he/she give you for your own work in the physical chemistry laboratory class? Could you describe what happens? (Item mean was 2.22.)
Uncertain: Does your teacher's behaviour seem to be hesitant? (Item mean was 1.35.)
Dissatisfied: Did your teacher show his/her dissatisfaction of you? (Item mean was 1.54.)
Admonishing: How was your teacher's temper, whilst he/she was in the class? Did your teacher get angry easily? Was your teacher impatient? (Item mean was 1.20.)
Strict: Is your teacher strict with you? Are the exams hard? Did you ever break a glassware in a laboratory class? How did your teacher respond? How did you feel? Please, discuss (Item mean was 2.57.)

Students' Written Accounts

The following are extracts from the students' written accounts considered to be relevant.

When the teacher was teaching, he wanted his students to feel relaxed by speaking to them in a friendly way (2). It should be noted that he liked to teach in English and tried to give me some examples. This caused me to understand the work well (1). Also, he tried to keep the students under control, and was patient when he was interrupted in a classroom (3). I liked my teacher because sometimes he gave me some free time after I finished a discussion (4), and did not get angry easily when he had a class (7). I also liked him because he often remembered my assignment (5), and did not think that I was not able to do an experiment (6). However, I did not like his meeting time. Anyway, his test was not really hard (8). (A1)

The teacher used a projector for teaching. He always gave oral tests to us, but we were not able to do them because we were nervous. He let me do laboratory experiments (4), and seemed certain about what he was teaching (5). When he was angry, he tried to give a reason to me (7), so I liked him more. He would explain the laboratory experiments again if I did not understand (3), and was mostly satisfied with my answer about laboratory problems (6). On the other hand, I thought he was not really a good leader because he did not know about some things that went on in the classroom (1), and he was not a good helper because he was not interested in what he was teaching (2). Moreover, he often had a meeting which consumed my study time. Oh, his tests were not really easy (8). (A2)

The teacher liked to speak in a friendly manner and suggest to students that we should pay more attention in the lesson in order to be more successful (2). His dressing was very good and suitable. While we were doing experiments that were very dangerous, he was strict with us (8). Moreover, he mostly did not listen to what we were saying (3), and did not let me get away with anything while we were discussing the lessons (4). Despite the fact that he was strict with the students, he was very good at teaching (1). He tended to forget my exam timetable when he wanted to evaluate the physical chemistry laboratory course (5), and did not get *angry easily (7), also was not suspicious about my exam scores (6), so I respected him (1). (A3)*

Even though my teacher sometimes taught fast, his speech was exact and helpful (2). For example, he spoke English during teaching and always described science experts. If I did not understand lab experiments, he often explained through using the class (1), and he seemed to be satisfied with me while I was doing the experiments (6). Also, he let me decide what physical chemistry laboratory activities I could do on my own (4). Moreover, he trusted me when we had an exam (3), and he was sure to score my work (5). I liked him because he was patient when I broke a rule, sometimes he got a little angry while he was teaching (7) but he was not severe when I broke some glassware (8). (B1)

The teacher's dressing was very suitable, which was a good example to students. He liked to teach the physical chemistry laboratory in English, but we did not understand and did not like this (1). He let me have time to decide on experiments with my friends (4), and talked to me with soft tones and a friendly manner (2). He did not seem to trust me when he found something lost, he would not listen (3). While some students were brushing their hairs in a classroom, he became angry (6). Sometimes, it appeared that he was sure what to do while he was teaching (5). I liked him because he corrected me when I broke a rule (8), but I was afraid of my teacher when he was teaching because his face seemed unhappy (7). (B2)

I did not like it when he had a teacher's meeting because he did not take the class at that time. Before teaching, he liked to talk about other things to motivate us (1) and talked in an amusing way (2). He sometimes led me in the right progress direction, and sometimes let me give an opinion involving experiments in the classroom. I found it relaxing when he let me speak (4). He was willing to explain things when something was wrong in the classroom (3), and always knew what thing he would do (5). He did not think that I would cheat while I had an exam (6). I could say that he was even tempered in the classroom when some things went wrong (7) As well, this teacher's test was not really hard (8). (B3)

My teacher taught us well because she always explained things and took the time to update the knowledge of us (1). She consulted us, helped me as much as she could (2), and let me do an experiment that I decided upon (4). On the other hand, she was not a strict teacher when we were doing experiments (8). I thought she would be strict because most chemical compounds are toxic. I always found that she was confident when she was teaching (5), but found that she was often dissatisfied with my answers (6). In addition, she was even tempered in the classroom (7). In my opinion, I liked her advice when I asked her (3). (C1)

My teacher always motivated us to study, and taught and explained well (1). However, she did not help me to find a book to read (2). She was a great teacher because she understood my problems and listened to me (3), and was not suspicious in my test answers (6). She did not get angry unexpectedly while she was teaching (7). I liked her because sometimes she let me suggest the laboratory work to do (4). I could boss her about a test in a classroom (5). When she was teaching, she often liked me to stay silent in her class (8). (C2)

My teacher sometimes helped me with laboratory work (2) but her test exams were not easy (8). I did not decide many things about the laboratory work because she always did experiments on her own (4). Maybe, she though that I did not have laboratory knowledge so I did not have much opportunity to do experiments on my own (6). However, she knew everything that she was doing and did not have any problems in teaching and seemed to be sure about what to do when the experiment failed (5). As well, she did not get angry easily and when we could not do the experiments (7) well so she tried to talk and explain (1). She would let me say some things involving the experiments (3). (C3)

My teacher taught me in a friendly manner (2) and made clear explanations (1). Also, he was patient when I interrupted him (3). He was not really angry or did not really punish us when I was wrong, and if he did something wrong, he would apologize and restate (5). During an experiment class, I could talk loudly but sometimes he told us to keep quite (8). As well, he was even tempered when he was teaching, and sometimes he let me go away when I finished laboratory work (4).

However, sometimes he got angry when I did not follow the rules (7) and indicated that he was dissatisfied my work (6). (D1)

My teacher always suggested that I attend lessons (1) and took care of me (2). When I had a presentation in a classroom, my teacher gave me limited time (4). He understood me the same as he understood the physical chemistry laboratory (3). In everything that he taught, he was very confident (5). He often complained when I talked with my friend loudly (8). However, he was dissatisfied with my exam (6), and when I broke a rule in a laboratory class, he sometimes blamed me (7). (D2)

I liked my teacher because he knew the study that went on in a classroom (3), and he liked to talk about things in a friendly manner before he started teaching (2), and he seemed to remember the students' work that he had assigned (5). He always challenged me to ask a question whilst he was teaching (1), and to decide on what laboratory work to do in the classroom (4). My teacher was really patient because when somebody was wrong, he only warned him/her (7). He directed me to submit my homework on time (8). I respected him because he thought that I could do the experiments and did not fight with me (6). (D3)

From the results of the written accounts, it appeared that most students recognized their teachers' leadership behaviour in that they were good and attentive teachers. Moreover, most of the students inferred that their teachers were helpers with a friendly manner in the laboratory classrooms. As well, most of the students observed the teachers' understanding behaviour with appreciation when the teachers were patient and interested in their work. However, there were some students who were not so positive about the leadership, understanding and helping/friendly behaviours of their teachers. Possibly, these students would be better off in an individual program. For the student/responsibility and freedom behaviours, there were some students who had positive comments about such behaviours; and some of them had negative comments. Similarly, some students had positive comments about the strict behaviour of their teachers and some were negative about it. That is, the balance between the need for the strict behaviour and the need to give the student some responsibility and freedom were commented by the students. Generally, most of the students believed that the teachers were very confident, were not admonishing, and were not dissatisfied.

As with the interview results, the written stories on teacher-student interactions in the four Rajabhat Universities from students of each university were similarly summarized in relation to each scale, indicating that each group of Rajabhat University students similarly observed their teacher behaviours.

6.3.2 Discussion of Written Stories

It can be seen from the written stories in Section 6.3.1 that most of the students reported a high level of leadership behaviour demonstrated by their teachers in laboratory classrooms. Most of the students agreed that their teachers showed helping and friendly behaviours and were also understanding of them. Some of the students commented that they could decide something in the laboratory classrooms and they perceived some levels of strict behaviour from the teachers. As well, the teachers had low levels of uncertain, dissatisfied, and admonishing behaviours. Accordingly, the students' written stories substantiated the validity of the QTI, as reflected in the item means and standard deviations in Table 6.2.

Table 6.2
Item Means and Standard Deviations for the QTI

	Item Mean	Standard Deviation
Leadership (DC)	3.43	0.52
Helping/Friendly (CD)	3.27	0.56
Understanding (CS)	3.35	0.51
Student Responsibility/Freedom (SC)	2.22	0.64
Uncertain (SO)	1.35	0.75
Dissatisfied (OS)	1.54	0.73
Admonishing (OD)	1.20	0.70
Strict (DO)	2.57	0.72

n = 198

Therefore, written accounts can support the validity of the QTI, and teachers are able to use the QTI to address differences of teacher behaviours with confidence.

6.4 CHAPTER SUMMARY

From the interview results, it is likely that most of the students did know, help and support each other in the laboratory classrooms. Also, a large number of the students perceived an integration between laboratory and non-laboratory classes, and the rules and safety precautions during laboratory sessions. However, a smaller number of the students could do experiments in an open-ended way. Accordingly, the cohesion of students, the guiding and explanation of the results of experiments of the course, and clear guidelines about laboratory use should be preserved. More opportunities for designing experiments and using the results of those experiments to probe problems might be given to the students during laboratory sessions. To improve the laboratory physical environment, more adequate equipment and climate improvement features, such as fans, should be available. Additionally, if the laboratory classrooms are too crowed, the students could be divided into smaller groups for the laboratory sessions.

Most of the students were likely to have good relationships with their teachers. Most of the students perceived their teachers as good leaders, helping, kind, confident, and a person who admonished and expressed dissatisfaction rarely. The students had more moderate positive comments about the giving of responsibility and freedom to students and being strict.

Results such as these, reflect the quality of education being provided to these students in Rajabhat Universities in Thailand.

The interview and written story information has been helpful in describing the physical chemistry laboratory environments and the teachers' interpersonal behaviours. It has effectively added to the results obtained from the questionnaires.

The next chapter provides the conclusion for this research study.

CHAPTER 7

CONCLUSIONS

7.1 INTRODUCTION

This thesis was the first to investigate the learning environment, teacher-student interactions and educational outcomes in university physical chemistry classrooms and laboratories in Thailand. The research study involved 100 students from four Rajabhat Universities and examined relationships between students' perceptions of learning environments and their outcomes by combining quantitative and qualitative methods within the same study.

This final chapter concludes the research study in six sections as follows: a summary of this thesis is presented in Section 7.2; major findings that answer all of the research questions are presented in Section 7.3; implications of this research are discussed in Section 7.4; limitations of the study are noted in Section 7.5; possible future directions from the outcomes of this research are considered in Section 7.6; and a summary of the chapter and final conclusion are given in Section 7.7.

7.2 SUMMARY OF THIS THESIS

Chapter One which presents the rationale for the study, discussed the background of this thesis, gave a description of the classroom environment questionnaires, noted the purposes of the study, described the study's significance, pointed out some of the limitations of the study and ended with an overview of the thesis.

Chapter Two presented a discussion of the relevant literature in the learning environment area. Previous research studies on classroom environments were discussed and the development of questionnaires, including the SLEI and the QTI that have been used in environment research, were presented. Particular studies in science classrooms on associations between classroom environments and student outcomes involving the SLEI and QTI were summarized. Practical uses for these two questionnaires were suggested.

In Chapter Three, procedural information was provided including suitable qualitative and quantitative methods to answer the six research questions posed in this study. The quantitative data were collected by using the Actual and the Preferred Forms of the 35-item CLEI asking students to rate the real and favoured environments of their laboratory classrooms, respectively. As with the CLEI, the Actual Form of the 48-item QTI was used to assess students' perceptions of the actual interpersonal behaviour of their teachers. Also, the Ideal or Preferred Form of the QTI was employed to ask students about their ideal or preferred teachers in laboratory classrooms. As well, a 10-item Attitude Scale, and cognitive and practical tests of physical chemistry achievement were used to obtain students' outcomes. The qualitative data were obtained from students' interviews about their classroom environments. Written stories in relation to teacher-student interactions also provided qualitative information.

Statistical information was provided in Chapter Four to support the validity and reliability of the 35-item CLEI, the 48-item QTI and the 10-item Attitude Scale when used with 198 Thai physical chemistry students who made up the sample in this study. Each scale of the CLEI and QTI showed satisfactory internal consistency reliability with either the individual or the class mean score used as the unit of analysis. The Attitude Scale also displayed satisfactory internal consistency reliability with both the individual and the class mean as the unit of analysis. Moreover, mean correlations were used to confirm the discriminant validity of the CLEI scales. The circumplex nature of the QTI was also confirmed. An ANOVA with class membership as the main effect also confirmed that both the CLEI and the QTI could distinguish between classes.

In Chapter Five, students' perceptions of their actual and preferred learning environments were revealed, together with perceptions of actual and ideal teacher interpersonal behaviour. Additionally, mean scores of attitude and cognitive achievement, and practical tests were provided. The paired sample t test was used to differentiate between actual and preferred means of such students' perceptions, and between pretest and posttest means of the outcomes. It could be noted that students improved their attitudes and achievement outcomes. Furthermore, associations between the laboratory environments and students' outcomes, and between teacher interpersonal behaviours and students' outcomes were determined by using simple and multiple correlation analysis.

Qualitative results concerned with student interviews and written stories were described in Chapter 6. These results provided additional information regarding the validity of the questionnaires. As well, these qualitative findings provided richer insights into the learning environments and teacher-student interactions of the physical chemistry laboratory classroom.

7.3 MAJOR FINDINGS OF THE STUDY

Each of the research questions formulated in Chapter 1 is answered in this section.

Research Question 1:
Are the Actual and Preferred Forms of the CLEI and the QTI valid in terms of reliability, discriminant validity and ability to differentiate between classes in physical chemistry laboratory classrooms in Thailand?

Results from the study in Section 4.2 indicated that the CLEI is a valid and reliable instrument for the assessment of students' perceptions in physical chemistry laboratory classrooms in Thailand. As well, the QTI is a valid and reliable instrument for use in physical chemistry laboratory classrooms in Thailand as indicated in Section 4.3.

The alpha reliability of the scales of the CLEI ranged from 0.61 to 0.71 for the Actual Form and from 0.60 to 0.67 for the Preferred Form when the individual student was used as a unit of analysis. When the class mean was used as a unit of analysis, the alpha reliability of the scales ranged from 0.63 to 0.88 for the Actual Form and from 0.62 to 0.90 for the Preferred Form. It was also found that four of the

CLEI scales significantly differentiated between classes and the eta^2 statistic ranged from 0.08 to 0.19. Scores of the mean correlations ranged from 0.12 to 0.35 when the individual student was used as a unit of analysis, and from 0.47 to 0.63 when the class mean was used as a unit of analysis, indicating that the scales of the CLEI overlap somewhat.

When the individual student was used as a unit of analysis, the alpha reliability of the QTI scales ranged from 0.60 to 0.78 for the Actual Form, and from 0.61 to 0.78 for the Ideal Form. When the class mean was used as the unit of analysis, the alpha reliability of the QTI scales ranged from 0.68 to 0.94 for the Actual Form, and from 0.65 to 0.91 for the Ideal Form. The six QTI scales significantly differentiated between classes and the eta^2 statistic ranged from 0.08 to 0.18. As well, high correlations were found between neighbouring scales of the QTI and negative correlations between opposite scales confirming the circumplex nature of the QTI (for example, see Figures 4.1 to 4.4 in Chapter Four).

These validation results for the CLEI and QTI were supported by the qualitative data. For example, most students agreed that there was strong cohesion in the classrooms, which supported their high scores on the Student Cohesiveness scale in the CLEI. As well, students made highly appreciative comments about the understanding behaviour of their teachers and scored highly on the Understanding scale of the QTI. Generally, the student comments were consistent with the scores for all scales of the QTI; and most responses of classroom environments from the students were fairly consistent with the CLEI.

Hence, both quantitative and qualitative results confirmed that the CLEI and the QTI are suitable for use in physical chemistry laboratory classrooms in Thailand.

Research Question 2:
What are students' perceptions of their physical chemistry laboratory classes and their teacher-student interactions?

For students' perceptions of their learning environments (Table 5.2 and Figure 5.2), students perceived high levels of cohesiveness with one another but little open-ended opportunities in their work. There were no significant differences on the other three scale.

The high level of student cohesiveness in the physical chemistry laboratory perceived by students suggested that the students were likely to do their laboratory work in groups and support and help each other in laboratory classrooms. Possibly, the students were made to study many topics in physical chemistry in one semester, therefore, the students thought that they would become fatigued if they worked alone. By working together they were able to share the laboratory work load.

Students perceived a low level of open-endedness, indicating that they had few opportunities to make their own decisions about their laboratory experiments. Colburn (1997) and McComas (1997) suggested that students could decide on the problems and investigations in laboratory activities on their own in order to make such laboratory activities more open-ended. This rarely occurs in physical chemistry laboratory classrooms in Thailand. Maybe, Thai physical chemistry teachers do not have enough time in their laboratory sessions. Furthermore, Thai physical chemistry teachers are worried that they are not able to provide all the necessary knowledge in one semester.

It was also found that students agreed that their teachers demonstrated low levels of admonishing behaviour. The low level of admonishing behaviour suggests that Thai physical chemistry teachers are able to control their tempers by exhibiting less anger when something goes wrong in the laboratory classrooms. It probably means that Thai physical chemistry teachers are quite patient while they are interacting to students.

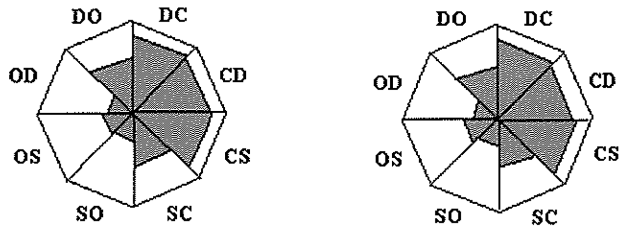
Research Question 3:
What differences are there between students' perceptions of their actual and preferred learning environments, and students' perceptions of their actual and ideal on teacher-student interactions?

Students indicated that they preferred a high level of student cohesiveness in their classrooms. This result supports information obtained from the interviews where most students indicated that they like to work in groups. Also, the students indicated that they would prefer a better material environment. They were dissatisfied with the level of laboratory equipment and materials, which apparently are not adequate for their work. To increase the level of material environment, the teachers should provide the students with more readily available equipment and materials. This result is consistent with information obtained from the interviews in which most students indicated that the laboratory conditions and equipment should be improved. The students suggested that more fans in laboratory classrooms would be one way to improve this situation.

With the QTI (Table 5.6 and Figure 5.7), students preferred teachers to exhibit more leadership and more helping/friendly behaviours. The students were discontented with the actual teacher behaviour since these behaviours of the teachers, leadership and helping/friendly were not insufficient in laboratory classrooms. The students agreed that on the other scales there were no differences between their ideal and actual teacher behaviours.

Information obtained about classroom environments and teacher behaviours could enhance the teaching quality in physical chemistry in Thailand in the future. Furthermore, Thai physical chemistry teachers should realize that it is advantageous to encourage free thought and creative thinking among their students and allow them to solve problems by themselves. Moreover, the teacher agency should not delay on improving the situation with regard to laboratory equipment and materials as they are currently inadequate in the physical chemistry laboratory classrooms in Rajabhat Universities in Thailand.

In a study in The Netherlands on professional development in classrooms (Wubbels, Brekelmans, Créton, & Hooymayers, 1990), the QTI was used to indicate typologies of teacher behaviours by using a cluster analysis. Eight teacher types were found to be present. The students' perceptions of Thai physical chemistry teachers are characterised by relatively high scores in the Leadership (DC), Helping/Friendly (CD) and Understanding (CS) sectors as shown in Figure 7.1 (b). This type of Thai physical chemistry teachers is described as having leading behaviour and a pleasant and supportive atmosphere in the classroom. Thai physical chemistry teachers closely match the Dutch type named tolerant and authoritative. Also, there is little difference in the scores of actual and ideal behaviours.



(a) (b)

Figure 7.1. Profiles of teacher. (a) Ideal teacher and (b) Actual teacher.

Research Question 4:
What attitudes do students have towards their subject of physical chemistry laboratory?

Students' attitudes toward physical chemistry laboratory were gauged using the Attitude Scale. It was found that, for the whole sample, the post score of attitude was 24.03 compared with a pre score of 22.03 (Table 5.7 and Figure 5.7). Thus, on the whole, there was very little change in the students' attitudes after the course in physical chemistry.

Research Question 5:
What associations are there between students' perceptions of their learning environments and of their teacher's interpersonal behaviour in physical chemistry laboratory classrooms, and their attitudinal and cognitive achievement and practical outcomes?

Positive associations were found between attitudinal outcomes and the Student Cohesiveness, Open-Endedness and the Material Environment scales (Table 5.14). Furthermore, the regression weights showed that the Open-Endedness and the Material Environment scales contributed most to students' attitudes. According to the R^2 figure, 12% of the variance predicted in students' attitudes could be attributed to their perceptions of their laboratory learning environment. In relation to associations between the CLEI and cognitive achievement outcome (Table 5.15), only the Rule

Clarity scale was negatively associated with this outcome. Additionally, the more conservative regression analysis showed that Rule Clarity still retained its significance. The R^2 figure could not be considered because the R value of 0.27 was not significant. Regarding associations between the CLEI scales and the practical outcome (Table 5.15), the Student Cohesiveness and Open-Endedness scales were positively associated with this outcome. Open-Endedness retained its significance in the regression analysis. The R^2 figure showed that the variance of 15% in student practical test scores could be attributed to their perceptions of their laboratory learning environments.

With regard to students' perceptions of teacher's interpersonal behaviour, the Leadership and Understanding scales were positively associated with students' attitudes toward their physical chemistry laboratory (Table 5.16). However, there was no significant association between these two scales and the outcome in the regression analysis. The multiple correlation was not significant. The Dissatisfied scale was negatively associated with cognitive achievement, and retained its significance in the regression analysis. A variance of 10% in cognitive achievement was accounted for by student learning environment perceptions according to the R^2 figure. The Leadership, Helping/Friendly, and Understanding scales were positively associated with the practical score whilst the Understanding scale contributed to the practical outcome after the regression. The R^2 figure showed that 16% of the variance in student practical test results could be accounted for by students' perceptions of their teachers' interpersonal behaviours.

It is apparent that, Thai physical chemistry teachers could use learning environment perceptions and perceptions of teacher interpersonal behaviours to improve outcomes in laboratory classrooms. For example, teachers could consider allowing students more freedom in selecting actualities and improving the adequacy of equipment during laboratory sessions.

Research Question 6:

Can the students' perceptions of their physical chemistry learning environment and teacher-student interactions be changed towards their preferred learning environment?

With students' perceptions of their actual learning environments at the end of the semester compared with their preferred environments at the beginning of the semester (Table 5.3 and Figure 5.3), the Student Cohesiveness and Material Environment scales were significantly different. Students perceived that there was an increased level of student cohesiveness in the learning environment. On the other hand, they perceived this environment to have a decreased level of material environment from what they preferred. They considered that the Open-Endedness, Integration and Rule Clarity scales were not significantly different

For the QTI (Table 5.6 and Figure 5.7), the students' perceptions of their ideal and actual teacher behaviours for the Leadership and Helping/Friendly behaviours were significantly different. Students perceived these teacher behaviours to have lower levels compared with their preference.

7.4 IMPLICATIONS OF THIS STUDY

This section addresses the implications of this research study to improve physical chemistry learning in Thailand. The implications of the study are discussed around the following three issues: the use of developed questionnaires; the use of qualitative data; and the effects of the classroom environment and teacher's interpersonal behaviour on students' outcomes.

Firstly, this study determined that both the CLEI and QTI are reliable and valid for measuring learning environments and teacher-student interactions in Thailand. Therefore, teachers can use these two questionnaires to improve classroom environments and the teacher-student interactions. For example, the teachers could use both Preferred/Ideal and Actual Forms of the CLEI and the QTI at the beginning of the semester. After knowing the results, the teachers could respond to the students' needs during the semester. At the end of the semester, the teachers could again use the Actual Forms of the CLEI and the QTI to compare the difference and similarity between Preferred/Ideal and Actual Forms of the CLEI and the QTI. These results could be used as a focus for reflection and discussion by teachers.

Secondly, teachers should talk with their students in an interview situation to gather material on which to reflect. The applicants would be providing more information on learning environments that expands on the quantitative information obtained from questionnaires.

Finally, results about associations between students' perceptions and students' outcomes in physical chemistry classes could help teachers to understand how the classroom environment and teacher behaviour are related to achievement outcomes. Teachers could endeavour to change their classroom environments and their behaviours based on information about those scales with the strongest associations. For instance, the Rule Clarity scale was negatively associated with the cognitive achievement outcome, and the Open-Endedness scale was positively associated with the practical test (Table 5.15). The teachers could carefully monitor students' activities and provide clearer rules for them in the period of laboratory work. Moreover, the teachers could indicate possible dangers if students ignore these rules in laboratory work. Meanwhile, opportunities for individual student to do experimental work should be promoted to raise the level of open-endedness. In 1997, Colburn and McComas indicated that if the teacher would like to provide laboratory activities that have more open-endedness, he/she should provide decisions to their students about solution of problems and investigation of laboratory activities.

7.5 LIMITATIONS OF THE STUDY

Because there were many items in the questionnaires with the Preferred and Actual Forms of the CLEI, the Ideal and Actual Forms of the QTI containing 35, 35, 48 and 48 items, respectively, and these were completed at the same time, some students became bored and confused. Therefore, there may be some students who did not actually concentrate on completing all the questionnaires as well as their cognitive and practical tests.

Also, due to time and budget constraints, there was limited opportunity for administering the questionnaires and interviews. Therefore, this had the effect of reducing the possible sample size.

7.6 FURTHER RESEARCH

This study provided information about students' perceptions of physical chemistry laboratory environments and student-teacher interactions by using the CLEI and QTI. Therefore, implications for further directions in research should be noted.

It is desirable to replicate the lines of past research in which the QTI has been used to provide teachers with a view of themselves. As such, Fisher, Fraser, and Cresswell (1995) have indicated that the QTI can be used to obtain teachers' perceptions of their own behaviour, how the teachers see themselves in classrooms. Accordingly, a further study could include a teacher self-perception version so that the teachers can gain insight through their self-reflection on their own teaching.

A further study could be extended to include a larger sample involving more universities. Co-workers in other Rajabhat Universities could be chosen so that they could easily communicate to students and collect data themselves. As well, a comparison study of classroom environments among Rajabhat Universities could be carried out so that we can learn more about diverse classroom environments in Thailand. A useful database on improving teaching and curriculum quality of science subjects in the future could be obtained.

It would be interesting to investigate other areas that use chemistry laboratories, such as general chemistry, organic chemistry or inorganic chemistry laboratory. Also other science laboratories, such as biology, genetic and biotechnology could be investigated. A comparison study among these subjects could be conducted in a similar way to this research so that information on students' perceptions of laboratory environments, and teacher behaviours in different subjects could be obtained.

7.7 CHAPTER SUMMARY

This chapter has concluded the identification of students' perceptions of learning environments and teacher-student interactions in physical chemistry laboratories using the CLEI and QTI, as well as students' interviews and written stories.

Associations between the students' perceptions of the classroom environments and their outcomes, and between teacher-student interactions and their outcomes were also determined. One hundred physical chemistry students in four Rajabhat Universities in Thailand composed the sample. Importantly, this thesis has validated the CLEI and QTI for use in Thailand. The study could be useful for teachers, who teach physical chemistry laboratory and are interested in improving attitudinal and achievement outcomes in their study.

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Appendix A: Student Actual Form of the SLEI English Version

Questionnaire on Learning Environment

Directions

This questionnaire contains statements about practices which could takes place in this laboratory class. You will be asked how often each practice actually takes place.

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

Think about how well each statement describes what this laboratory class is actually like for you. Draw a circle around

1	if the practice actually takes place	Almost Never
2	if the practice actually takes place	Seldom
3	if the practice actually takes place	Sometimes
4	if the practice actually takes place	Often
5	if the practice actually takes place	Very Often

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 fairly similar to other statements. Do not 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 whether you thought that you actually choose your partners *Almost Never, Seldom, Sometimes, Often* or *Very Often*. For example, if you selected *Very Often*, you would circle the number 5 on your answer sheet.

Do not forget to write your name and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Assessing the Climate of Science Laboratory Classes* authored by Barry J. Fraser, Geoffrey J. Giddings and Campbell J. McRobbie and published by the Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

NAME.........................UNIVERSITY...................MAJOR..........CLASS.....

Remember that you are describing your **actual** classroom	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1. I get on well with students in this laboratory class.	1 2 3 4 5	—
2. There is opportunity for me to pursue my own science interests in this laboratory class.	1 2 3 4 5	—
3. What I do in our regular science class is unrelated to my laboratory work.	1 2 3 4 5	R —
4. My laboratory class has clear rules to guide my activities.	1 2 3 4 5	—
5. I find that the laboratory is crowded when I am doing experiments.	1 2 3 4 5	R —
6. I have little chance to get to know other students in this laboratory class.	1 2 3 4 5	R —
7. In this laboratory class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	—
8. The laboratory work is unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R —
9. My laboratory class is rather informal and few rules are imposed on me.	1 2 3 4 5	R —
10. The equipment and materials that I need for laboratory activities are readily available.	1 2 3 4 5	—
11. Members of this laboratory class help me.	1 2 3 4 5	—
12. In my laboratory sessions, other students collect different data than I do for the same problem.	1 2 3 4 5	—
13. My regular science class work is integrated with laboratory activities.	1 2 3 4 5	—
14. I am required to follow certain rules in the laboratory.	1 2 3 4 5	—
15. I am ashamed of the appearance of this laboratory.	1 2 3 4 5	R —
16. I get to know students in this laboratory class well.	1 2 3 4 5	—
17. I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	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. There is a recognized way for me to do things safely in this laboratory.	1 2 3 4 5	—
20. The laboratory equipment which I use is in poor working order.	1 2 3 4 5	R —
21. I am able to depend on other students for help during laboratory classes.	1 2 3 4 5	—
22. In my laboratory sessions, I do different experiments than some of the other students.	1 2 3 4 5	—
23. The topics covered in regular science class work are quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R —
24. There are few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R —
25. I find that the laboratory is hot and stuffy.	1 2 3 4 5	R —
26. It takes me a long time to get to know everybody by his/her first name in this laboratory class.	1 2 3 4 5	R —
27. In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments.	1 2 3 4 5	R —
28. What I do in laboratory sessions helps me to understand the theory covered in regular science classes.	1 2 3 4 5	—
29. The teacher outlines safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	—
30. The laboratory is an attractive place for me to work in.	1 2 3 4 5	—
31. I work cooperatively in laboratory sessions.	1 2 3 4 5	—
32. I decide the best way to proceed during laboratory experiments.	1 2 3 4 5	—
33. My laboratory work and regular science class work are unrelated.	1 2 3 4 5	R —
34. My laboratory class is run under clearer rules than my other classes.	1 2 3 4 5	—
35. My laboratory has enough room for individual or group work.	1 2 3 4 5	—

For Teacher's Use Only: SC...........OE..............I.............RC.......... ME.........

Appendix B: Student Preferred Form of the SLEI English Version

Questionnaire on Learning Environment

Directions

This questionnaire contains statements about practices which could takes place in this laboratory class. You will be asked **how often** you would prefer each practice to take place.

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

Think about how well each statement describes what preferred laboratory class is like. Draw a circle around

1	if you would prefer the practice to takes place	Almost Never
2	if you would prefer the practice to takes place	Seldom
3	if you would prefer the practice to takes place	Sometimes
4	if you would prefer the practice to takes place	Often
5	if you would prefer the practice to takes place	Very Often

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 fairly similar to other statements. Do not worry about this. Simply give your opinion about all statements.

Practice Example. Suppose that you were given the statement: "I would choose my partners for laboratory experiments." You would need to decide whether you thought that you would **prefer** to choose your partners *Almost Never, Seldom, Sometimes, Often* or *Very Often*. For example, if you selected *Very Often*, you would circle the number 5 on your answer sheet.

Do not forget to write your name and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Assessing the Climate of Science Laboratory Classes* authored by Barry J. Fraser, Geoffrey J. Giddings and Campbell J. McRobbie and published by the Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

NAME....................UNIVERSITY..........................MAJOR.........CLASS.....

Remember that you are describing your **preferred** classroom	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1. I would get on well with students in this laboratory class.	1 2 3 4 5	—
2. There would be opportunity for me to pursue my own science interests in this laboratory class.	1 2 3 4 5	—
3. What I do in our regular science class would be unrelated to my laboratory work.	1 2 3 4 5	R —
4. My laboratory class would have clear rules to guide my activities.	1 2 3 4 5	—
5. I would find that the laboratory is crowded when I am doing experiments.	1 2 3 4 5	R —
6. I would have little chance to get to know other students in this laboratory class.	1 2 3 4 5	R —
7. In this laboratory class, I would be required to design my own experiments to solve a given problem.	1 2 3 4 5	—
8. The laboratory work would be unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R —
9. My laboratory class would be rather informal and few rules would be imposed on me.	1 2 3 4 5	R —
10. The equipment and materials that I need for laboratory activities would be readily available.	1 2 3 4 5	—
11. Members of this laboratory class would help me.	1 2 3 4 5	—
12. In my laboratory sessions, other students would collect different data than I would for the same problem.	1 2 3 4 5	—
13. My regular science class work would be integrated with laboratory activities.	1 2 3 4 5	—
14. I would be required to follow certain rules in the laboratory.	1 2 3 4 5	—
15. I would be ashamed of the appearance of this laboratory.	1 2 3 4 5	R —
16. I would get to know students in this laboratory class well.	1 2 3 4 5	—
17. I would be allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1 2 3 4 5	—
18. I would use the theory from my regular science class sessions during laboratory activities.	1 2 3 4 5	—
19. There would be a recognized way for me to do things safely in this laboratory.	1 2 3 4 5	—
20. The laboratory equipment which I use would be in poor working order.	1 2 3 4 5	R —
21. I would be able to depend on other students for help during laboratory classes.	1 2 3 4 5	—
22. In my laboratory sessions, I would do different experiments than some of the other students.	1 2 3 4 5	—
23. The topics covered in regular science class work would be quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R —
24. There would be few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R —
25. I would find that the laboratory is hot and stuffy.	1 2 3 4 5	R —
26. It would take me a long time to get to know everybody by his/her first name in this laboratory class.	1 2 3 4 5	R —
27. In my laboratory sessions, the teacher would decide the best way for me to carry out the laboratory experiments.	1 2 3 4 5	R —
28. What I do in laboratory sessions would help me to understand the theory covered in regular science classes.	1 2 3 4 5	—
29. The teacher would outline safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	—
30. The laboratory would be an attractive place for me to work in.	1 2 3 4 5	—
31. I would work cooperatively in laboratory sessions.	1 2 3 4 5	—
32. I would decide the best way to proceed during laboratory experiments.	1 2 3 4 5	—
33. My laboratory work and regular science class work would be unrelated.	1 2 3 4 5	R —
34. My laboratory class would be run under clearer rules than my other classes.	1 2 3 4 5	—
35. My laboratory would have enough room for individual or group work.	1 2 3 4 5	—

For Teacher's Use Only: SC...........OE..............I..............RC...........ME........

Appendix C: Student Questionnaire of the QTI English Version

Questionnaire on Teacher Interaction

Directions

This questionnaire asks you to describe the behaviour of your teacher. This is not a test. Your opinion is what is wanted.

This questionnaire has 48 sentences about the teacher. For each sentence, circle the number corresponding to your response. For example:

	Never				Always
This teacher expresses herself/himself clearly.	0	1	2	3	4

If you think that your teacher always expresses herself/himself clearly, circle the 4. If you think your teacher never expresses herself/himself clearly, circle the 0. You also can choose the numbers 1, 2 and 3 which are in-between. If you want to change your answer, cross it out and circle a new number. Please, answer all questions. Thank you for your cooperation.

In order for us to provide you with a report of the results, please write your name and other details at the top of the reverse side of this page.

NAME... ............UNIVERSITY......................MAJOR............CLASS.........

	Never				Always
1. This teacher talks enthusiastically about her/his subject.	0	1	2	3	4
2. This teacher trusts us.	0	1	2	3	4
3. This teacher seems uncertain.	0	1	2	3	4
4. This teacher gets angry unexpectedly.	0	1	2	3	4
5. This teacher explains things clearly.	0	1	2	3	4
6. If we do not agree with this teacher, we can talk about it.	0	1	2	3	4
7. This teacher is hesitant.	0	1	2	3	4
8. This teacher gets angry quickly.	0	1	2	3	4
9. This teacher holds our attention.	0	1	2	3	4
10. This teacher is willing to explain things again.	0	1	2	3	4
11. This teacher acts as if she/he does not know what to do.	0	1	2	3	4
12. This teacher is too quick to correct us when we break a rule.	0	1	2	3	4
13. This teacher knows everything that goes on in the classroom.	0	1	2	3	4
14. If we have something to say, this teacher will listen.	0	1	2	3	4
15. This teacher lets us boss her/him around.	0	1	2	3	4
16. This teacher is impatient.	0	1	2	3	4
17. This teacher is a good leader	0	1	2	3	4
18. The teacher realise when we do not understand	0	1	2	3	4
19. This teacher is not sure what to do when we fool around.	0	1	2	3	4
20. It is easy to pick a fight with this teacher.	0	1	2	3	4
21. This teacher act confidently.	0	1	2	3	4
22. This teacher is patient.	0	1	2	3	4
23. It is easy to make this teacher appear unsure.	0	1	2	3	4
24. This teacher makes mocking remarks.	0	1	2	3	4
25. This teacher helps us with our work.	0	1	2	3	4
26. We can decide some things in this teacher's class.	0	1	2	3	4
27. This teacher thinks that we cheat.	0	1	2	3	4
28. This teacher is strict.	0	1	2	3	4
29. This teacher is friendly.	0	1	2	3	4
30. We can influence this teacher.	0	1	2	3	4
31. This teacher thinks that we do not know anything.	0	1	2	3	4
32. We have to be silent in this teacher's class.	0	1	2	3	4
33. This teacher is someone we can depend on.	0	1	2	3	4
34. This teacher lets us decide when we will do the work in class.	0	1	2	3	4
35. This teacher puts us down.	0	1	2	3	4
36. This teacher's tests are hard.	0	1	2	3	4
37. This teacher has a sense of humour.	0	1	2	3	4
38. This teacher lets us get away with a lot in class.	0	1	2	3	4
39. This teacher thinks that we can not do things well.	0	1	2	3	4
40. This teacher's standards are very high.	0	1	2	3	4
41. This teacher can take a joke.	0	1	2	3	4
42. This teacher gives us a lot of free time in class.	0	1	2	3	4
43. This teacher seems dissatisfied.	0	1	2	3	4
44. This teacher is severe when marking papers.	0	1	2	3	4
45. This teacher's class is pleasant.	0	1	2	3	4
46. This teacher is lenient.	0	1	2	3	4
47. This teacher is suspicious.	0	1	2	3	4
48. We are afraid of this teacher.	0	1	2	3	4

Appendix D: Ideal Teacher of the QTI English Version

Questionnaire on Teacher Interaction

Directions

The following questionnaire asks for your view of an ideal teacher's behaviour. Think about your ideal teacher. For each sentence, circle the number corresponding to your response. For example:

	Never				Always
The teacher would express herself/himself clearly.	0	1	2	3	4

If you think that ideal teachers always express themselves clearly, circle the 4. If you think ideal teachers never express themselves clearly, circle the 0. You also can choose the numbers 1, 2 and 3 which are in-between. If you want to change your answer, cross it out and circle a new number. Thank you for your cooperation.

In order for us to provide you with a report of the results, please write your name and other details at the top of the reverse side of this page.

NAME..................UNIVERSITY.......................MAJOR............CLASS.........

	Never				Always
1. The teacher would talk enthusiastically about her/his subject.	0	1	2	3	4
2. The teacher would trust students.	0	1	2	3	4
3. The teacher would seem uncertain.	0	1	2	3	4
4. The teacher would get angry unexpectedly.	0	1	2	3	4
5. The teacher would explain things clearly.	0	1	2	3	4
6. If students did not agree with the teacher, they could talk about it.	0	1	2	3	4
7. The teacher would be hesitant.	0	1	2	3	4
8. The teacher would get angry quickly.	0	1	2	3	4
9. The teacher would hold the students' attention.	0	1	2	3	4
10. The teacher would be willing to explain things again.	0	1	2	3	4
11. The teacher would act as if she/he did not know what to do.	0	1	2	3	4
12. The teacher would be too quick to correct students when they broke a rule.	0	1	2	3	4
13. The teacher would know everything that goes on in the classroom.	0	1	2	3	4
14. If students had something to say, the teacher would listen	0	1	2	3	4
15. The teacher would let the students take charge.	0	1	2	3	4
16. The teacher would be impatient.	0	1	2	3	4
17. The teacher would be a good leader	0	1	2	3	4
18. The teacher would realise when students did not understand	0	1	2	3	4
19. The teacher would not be sure what to do when students fooled around.	0	1	2	3	4
20. It would be easy to have an argument with the teacher.	0	1	2	3	4
21. The teacher would act confidently.	0	1	2	3	4
22. The teacher would be patient.	0	1	2	3	4
23. It would be easy to make a fool out of the teacher.	0	1	2	3	4
24. The teacher would make mocking remarks.	0	1	2	3	4
25. The teacher would help students with their work.	0	1	2	3	4
26. Students could decide some things in the teacher's class.	0	1	2	3	4
27. The teacher would think that students cheat.	0	1	2	3	4
28. The teacher would be strict.	0	1	2	3	4
29. The teacher would be friendly.	0	1	2	3	4
30. Students could influence the teacher. .	0	1	2	3	4
31. The teacher would think that students did not know anything.	0	1	2	3	4
32. Students would have to be silent in the teacher's class.	0	1	2	3	4
33. The teacher would be someone students can depend on.	0	1	2	3	4
34. The teacher would let students decide when they would do work in class.	0	1	2	3	4
35. The teacher would put students down.	0	1	2	3	4
36. The teacher's tests would be hard.	0	1	2	3	4
37. The teacher would have a sense of humour.	0	1	2	3	4
38. The teacher would let students get away with a lot in class.	0	1	2	3	4
39. The teacher would think that students can not do things well.	0	1	2	3	4
40. The teacher's standards would be very high.	0	1	2	3	4
41. The teacher could take a joke.	0	1	2	3	4
42. The teacher would give students a lot of free time in class.	0	1	2	3	4
43. The teacher would seem dissatisfied.	0	1	2	3	4
44. The teacher would be severe when marking papers.	0	1	2	3	4
45. The teacher's class would be pleasant.	0	1	2	3	4
46. The teacher would be lenient.	0	1	2	3	4
47. The teacher would be suspicious.	0	1	2	3	4
48. Students would be afraid of the teacher.	0	1	2	3	4

Appendix E: Student Actual Form of the CLEI English Version

Chemistry Laboratory Environment Inventory

Directions

This questionnaire contains statements about practices which could takes place in this physical chemistry laboratory class. You will be asked how often each practice actually takes place.

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

Think about how well each statement describes what this physical chemistry laboratory class is actually like for you. Draw a circle around

1	if the practice actually takes place	Almost Never
2	if the practice actually takes place	Seldom
3	if the practice actually takes place	Sometimes
4	if the practice actually takes place	Often
5	if the practice actually takes place	Very Often

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 fairly similar to other statements. Do not worry about this. Simply give your opinion about all statements.

Practice Example. Suppose that you were given the statement: "I choose my partners for physical chemistry laboratory experiments." You would need to decide whether you thought that you **actually** choose your partners *Almost Never, Seldom, Sometimes, Often* or *Very Often*. For example, if you selected *Very Often*, you would circle the number 5 on your answer sheet.

Do not forget to write your name and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Assessing the Climate of Science Laboratory Classes* authored by Barry J. Fraser, Geoffrey J. Giddings and Campbell J. McRobbie and published by the Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

NAME...............UNIVERSITY......................MAJOR...............CLASS.........

Remember that you are describing your **actual** classroom	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1. I get on well with students in this physical chemistry laboratory class.	1 2 3 4 5	—
2. There is opportunity for me to pursue my own science interests in this physical chemistry laboratory class.	1 2 3 4 5	—
3. What I do in our regular science class is unrelated to my physical chemistry laboratory work.	1 2 3 4 5	R —
4. My physical chemistry laboratory class has clear rules to guide my activities.	1 2 3 4 5	—
5. I find that the physical chemistry laboratory is crowded when I am doing experiments.	1 2 3 4 5	R —
6. I have little chance to get to know other students in this physical chemistry laboratory class.	1 2 3 4 5	R —
7. In this physical chemistry laboratory class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	—
8. The physical chemistry laboratory work is unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R —
9. My physical chemistry laboratory class is rather informal and few rules are imposed on me.	1 2 3 4 5	R —
10. The equipment and materials that I need for physical chemistry laboratory activities are readily available.	1 2 3 4 5	—
11. Members of this physical chemistry laboratory class help me.	1 2 3 4 5	—
12. In my physical chemistry laboratory sessions, other students collect different data than I do for the same problem.	1 2 3 4 5	—
13. My regular science class work is integrated with physical chemistry laboratory activities.	1 2 3 4 5	—
14. I am required to follow certain rules in the physical chemistry laboratory.	1 2 3 4 5	—
15. I am ashamed of the appearance of this physical chemistry laboratory.	1 2 3 4 5	R —
16. I get to know students in this physical chemistry laboratory class well.	1 2 3 4 5	—
17. I am allowed to go beyond the regular physical chemistry laboratory exercise and do some experimenting of my own.	1 2 3 4 5	—
18. I use the theory from my regular science class sessions during physical chemistry laboratory activities.	1 2 3 4 5	—
19. There is a recognized way for me to do things safely in this physical chemistry laboratory.	1 2 3 4 5	—
20. The physical chemistry laboratory equipment which I use is in poor working order.	1 2 3 4 5	R —
21. I am able to depend on other students for help during physical chemistry laboratory classes.	1 2 3 4 5	—
22. In my physical chemistry laboratory sessions, I do different experiments than some of the other students.	1 2 3 4 5	—
23. The topics covered in regular science class work are quite different from topics with which I deal in physical chemistry laboratory sessions.	1 2 3 4 5	R —
24. There are few fixed rules for me to follow in physical chemistry laboratory sessions.	1 2 3 4 5	R —
25. I find that the physical chemistry laboratory is hot and stuffy.	1 2 3 4 5	R —
26. It takes me a long time to get to know everybody by his/her first name in this physical chemistry laboratory class.	1 2 3 4 5	R —
27. In my laboratory sessions, the teacher decides the best way for me to carry out the physical chemistry laboratory experiments.	1 2 3 4 5	R —
28. What I do in physical chemistry laboratory sessions helps me to understand the theory covered in regular science classes.	1 2 3 4 5	—
29. The teacher outlines safety precautions to me before my physical chemistry laboratory sessions commence.	1 2 3 4 5	—
30. The physical chemistry laboratory is an attractive place for me to work in.	1 2 3 4 5	—
31. I work cooperatively in physical chemistry laboratory sessions.	1 2 3 4 5	—
32. I decide the best way to proceed during physical chemistry laboratory experiments.	1 2 3 4 5	—
33. My physical chemistry laboratory work and regular science class work are unrelated.	1 2 3 4 5	R —
34. My physical chemistry laboratory class is run under clearer rules than my other classes.	1 2 3 4 5	—
35. My physical chemistry laboratory has enough room for individual or group work.	1 2 3 4 5	—

For Teacher's Use Only: SC...........OE..............I...........RC.........ME...........

Appendix F: Student Preferred Form of the CLEI English Version

Chemistry Laboratory Environment Inventory

Directions

This questionnaire contains statements about practices which could takes place in this physical chemistry laboratory class. You will be asked **how often** you would prefer each practice to take place.

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

Think about how well each statement describes what preferred physical chemistry laboratory class is like. Draw a circle around

1	if you would prefer the practice to takes place	Almost Never
2	if you would prefer the practice to takes place	Seldom
3	if you would prefer the practice to takes place	Sometimes
4	if you would prefer the practice to takes place	Often
5	if you would prefer the practice to takes place	Very Often

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 fairly similar to other statements. Do not worry about this. Simply give your opinion about all statements.

Practice Example. Suppose that you were given the statement: "I would choose my partners for physical chemistry laboratory experiments." You would need to decide whether you thought that you would **prefer** to choose your partners *Almost Never, Seldom, Sometimes, Often* or *Very Often*. For example, if you selected *Very Often*, you would circle the number 5 on your answer sheet.

Do not forget to write your name and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Assessing the Climate of Science Laboratory Classes* authored by Barry J. Fraser, Geoffrey J. Giddings and Campbell J. McRobbie and published by the Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

NAME..................UNIVERSITY.......................MAJOR...............CLASS......

Remember that you are describing your **preferred** classroom	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1. I would get on well with students in this physical chemistry laboratory class.	1 2 3 4 5	—
2. There would be opportunity for me to pursue my own science interests in this physical chemistry laboratory class.	1 2 3 4 5	—
3. What I do in our regular science class would be unrelated to my physical chemistry laboratory work.	1 2 3 4 5	R —
4. My physical chemistry laboratory class would have clear rules to guide my activities.	1 2 3 4 5	—
5. I would find that the physical chemistry laboratory is crowded when I am doing experiments.	1 2 3 4 5	R —
6. I would have little chance to get to know other students in this physical chemistry laboratory class.	1 2 3 4 5	R —
7. In this physical chemistry laboratory class, I would be required to design my own experiments to solve a given problem.	1 2 3 4 5	—
8. The physical chemistry laboratory work would be unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R —
9. My physical chemistry laboratory class would be rather informal and few rules would be imposed on me.	1 2 3 4 5	R —
10. The equipment and materials that I need for physical chemistry laboratory activities would be readily available.	1 2 3 4 5	—
11. Members of this physical chemistry laboratory class would help me.	1 2 3 4 5	—
12. In my physical chemistry laboratory sessions, other students would collect different data than I would for the same problem.	1 2 3 4 5	—
13. My regular science class work would be integrated with physical chemistry laboratory activities.	1 2 3 4 5	—
14. I would be required to follow certain rules in this physical chemistry laboratory.	1 2 3 4 5	—
15. I would be ashamed of the appearance of this physical chemistry laboratory.	1 2 3 4 5	R —
16. I would get to know students in this physical chemistry laboratory well.	1 2 3 4 5	—
17. I would be allowed to go beyond the regular physical chemistry laboratory exercise and do some experimenting of my own.	1 2 3 4 5	—
18. I would use the theory from my regular science class sessions during physical chemistry laboratory activities.	1 2 3 4 5	—
19. There would be a recognized way for me to do things safely in this physical chemistry laboratory.	1 2 3 4 5	—
20. The physical chemistry laboratory equipment which I use would be in poor working order.	1 2 3 4 5	R —
21. I would be able to depend on other students for help during physical chemistry laboratory classes.	1 2 3 4 5	—
22. In my physical chemistry laboratory sessions, I would do different experiments than some of the other students.	1 2 3 4 5	—
23. The topics covered in regular science class work would be quite different from topics with which I deal in physical chemistry laboratory sessions.	1 2 3 4 5	R —
24. There would be few fixed rules for me to follow in physical chemistry laboratory sessions.	1 2 3 4 5	R —
25. I would find that the physical chemistry laboratory is hot and stuffy.	1 2 3 4 5	R —
26. It would take me a long time to get to know everybody by his/her first name in this physical chemistry laboratory class.	1 2 3 4 5	R —
27. In my laboratory sessions, the teacher would decide the best way for me to carry out the physical chemistry laboratory experiments.	1 2 3 4 5	R —
28. What I do in physical chemistry laboratory sessions would help me to understand the theory covered in regular science classes.	1 2 3 4 5	—
29. The teacher would outline safety precautions to me before my physical chemistry laboratory sessions commence.	1 2 3 4 5	—
30. The physical chemistry laboratory would be an attractive place for me to work in.	1 2 3 4 5	—
31. I would work cooperatively in physical chemistry laboratory sessions.	1 2 3 4 5	—
32. I would decide the best way to proceed during physical chemistry laboratory experiments.	1 2 3 4 5	—
33. My physical chemistry laboratory work and regular science class work would be unrelated.	1 2 3 4 5	R —
34. My physical chemistry laboratory class would be run under clearer rules than my other classes.	1 2 3 4 5	—
35. My physical chemistry laboratory would have enough room for individual or group work.	1 2 3 4 5	—

For Teacher's Use Only: SC...........OE...........I...........RC.......... ME...............

Appendix G: The Attitude to Physical Chemistry Class English Version

Directions

The ten statements below are about your physical chemistry laboratory lesson that you have studied in this class. Please share your opinion of these statements. There are no "Right" or "Wrong" answers.

Please circle:

If you do not agree with the statement.

If you are not sure.

If you agree with the statement.

	Disagree	Not sure	Agree
1. I look forward to studying physical chemistry laboratory lesson.	1	2	3
2. Physical chemistry laboratory lesson is fun.	1	2	3
3. I am pleased with the activities we do in physical chemistry laboratory class.	1	2	3
4. The most interesting thing at school is physical chemistry laboratory class.	1	2	3
5. I want to study more about the world we live in.	1	2	3
6. It is important to find out about new things.	1	2	3
7. I am pleased with physical chemistry laboratory lesson in this class.	1	2	3
8. I like to talk to my friends about what we do in this class.	1	2	3
9. We should study more physical chemistry laboratory lesson each week.	1	2	3
10. After physical chemistry laboratory class, I feel satisfied.	1	2	3

Appendix H: Cognitive Test English Version

1. Which one of the following choices is represented to the meaning of a chemical reaction?

   a. An exothermic reaction which gives out a heat to a surrounding.

   b. A reaction which carries out in an open vessel at constant pressure, and a heat change is represented by ΔH.

   c. A reaction which carries out in a sealed container at constant volume, and a heat change is represented by ΔU.

   d. A reaction which involves the solubility of solids in a liquid or involved the liquids, and an internal energy change is represented by ΔH and ΔU. (correct)

2. Which couple of substance has the heat of neutralization equal to HCl acid neutralized NaOH base if the couple has a concentration and a volume as same as the HCl acid and the NaOH base.

   a. H_2SO_4 acid and KOH base.(correct)

   b. HCl acid and NH_4OH base.

   c. H_2SO_4 acid and NH_4OH base.

   d. CH_3COOH acid and KOH base.

3. The temperature of 50 ml warm water is 37.92°C, the temperature of 50 ml cold water is 20.91°C, and the temperature of mixture between warm and cold water is 29.11°C. What is the heat capacity of a calorimeter? (use $Q = ms\Delta t$ or $Q = C\Delta T$ for calculating)

   a. 46.0 J/K   b. 36.0 J/K

   c. 26.0 J/K   d. 16.0 J/K (correct)

4. When sulfuric acid splits on our clothes, why do we use a detergent to neutralize it instead of using the concentration of NaOH base or the dilution of CH_3COOH solution?

   a. Detergent is available.

   b. The cost of detergent is cheap.

   c. Detergent does not destroy our clothes? (correct)

   d. The chemical property of detergent is not good enough to neutralize sulfuric acid.

5. Which one of the following equations is represented to the meaning of the heat of solution?

   a. $C(s) + 2S(s) \rightarrow CS_2(s)$, $\Delta H = 25.4$ kcal

   b. $HCl(g) + aq \rightarrow HCl(aq)$, $\Delta H = -17.96$ kcal (correct)

   c. $1/2H_2(g) + 1/2I_2(g) \rightarrow HI(g)$, $\Delta H = 6.2$ kcal

   d. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$, $\Delta H = -135$ kcal

6. Which one of the following equations is the meaning of liquid's viscosity?

   a. The concentration of a liquid.

   b. The shape of a liquid molecule.

   c. The closing of liquid molecules.

   d. The resistance of flowing of a liquid molecule. (correct)

7. When is liquid' viscosity higher?

   a. The odor of a liquid is less.

   b. The color of a liquid is strong.

   c. The volume of a liquid is higher.

   d. The temperature of a liquid is lower. (correct)

8 With the equation $\eta = \frac{F/A}{v/L}$, when η, F (in Newton, N), A (in meter, m), v (in meter per second, m/s) and L (in square meter, m^2) are the viscosity, force, area, speed and thick of a whole liquid layer, respectively, which one of the following choices is a viscosity unit?

   a. $N\ s^2$. b. $N\ m^2$.

   c. $N\ s/m^2$. (correct) d. $N\ s^2/m^2$.

9. Which one of the following choices is the meaning of a density?

   a. A weight of a substance multiplies to a volume of the substance.

   b. A weight of a substance sums to a volume of the substance.

   c. A weight of a substance per a volume of water.

   d. A weight of a substance per one volume of the substance. (correct)

10. When the Archimedes' principle is used to determine a specific gravity, a substance has a volume as same as water. Which one of the following choices is the meaning of the specific gravity?

   a. The ratio between a substance's weight in an air and a water's weight replaced. (correct)

b. The ratio between a substance's weight in water and a water's weight replaced.

c. The ratio between a water's weight replaced and a substance's weight in water.

d. The ratio between a water's weight replaced and a substance's weight in an air.

11. Which one of the following choices is the glass's density of a cubic glass which has 75 cubic centimeters of a volume and 200 grams of a weight?

a. 4.6 g/ml b. 3.6 g/ml

c. 2.6 g/ml (correct) d. 1.6 g/ml

12. Why is specific gravity of liquid important?

a. It can be built an airport.

b. It can be classified a liquid.

c. It can be built an hourglass.

d. It can be indicated the impurity of a liquid. (correct)

13. Which one of the following choices is the statement of the Avogadro's law?

a. If two solids have a same volume, they will have a same mole number.

b. If two gases have a same volume, they will have a same molecule number. (correct)

c. If two substances have a same volume, they will have a same mole number.

d. If two liquids have a same volume, they will have a same molecule number.

14. Which one of the following substances is used to determine the molar volume of gas?

a. N_2 (correct) b. H_2O

c. Na_2O d. NaOH

15. What is the hydrogen electrode?

a. The hydrogen electrode consists of the piece of the platinum metal coated with the black powders of the platinum metal, and dips into one molar of the H^+ solution. One atmosphere of H_2 gas continuously bubbled through on a solution over the black powders of the platinum metal.

b. The hydrogen electrode has been arbitrarily assigned to zero volts at all temperatures, if one molar of the H^+ ion and one atm of the gas are satisfied.

c. The hydrogen electrode can act as an anode or a cathode, depending on the kind of a half cell is connected. (correct)

d. The hydrogen electrode acts as a cathode when the reaction of ½ H_2 (g,1 atm) $\rightarrow$ H^+(1 M) + e^- takes place

16. As with the electrochemical series, the couple of Cu^+/Cu^{2+} is situated above the couple of I^-/I_2. When the KI solution is added to the $CuSO_4$ solution, iodine and copper (I) iodide substances are formed as follow: $Cu^{+2} + 2I^- \rightarrow 1/2I_2(s) + CuI(s)$. What is the equilibrium constant of this equation?

a. $K = 1/[Cu^{2+}][I^-]^2$ (correct)

b. $K = \{[Cu^{2+}][I^-]\}/[Cu^+]$

c. $K = [Cu^{2+}][I^-]$

d. $K = [I][CuI(s)]$

17. Why is liquid's viscosity solved from experiment to differ from reference values?

a. Error of human while reading a temperature.

b. Apparatuses are covered with moisture.

c. An apparatus is leak.(correct)

d. Wrong timing is done.

18. Which one of the apparatus diagrams is set up for an electrochemical cell?

a. Two half cells, a salt bridge, a wire, two electrodes and a electrolyte solution. (correct)

b. Two half cell, a salt bridge, a wire, a liquid and a carbon.

c. Two half cells, a salt bridge, a wire and a liquid.

d. Two half cells, a salt bridge, a wire and a battery.

19. Which one of the following choices is a condition that real gases obeys the Boyle's law?

a. A constant temperature and a high pressure.

b. A constant temperature and a few volume.

c. A constant temperature and a low pressure. (correct)

d. A constant temperature and a lot of volume.

20. Which of the following sets is used to obtain molar volume of the oxygen gas instead of using a water bottle that is connected with two glass tubes?

a. A thick test tube.

b. A height beaker.

c. A plastic bottle.

d. Any bottle that gas can replace water in a bottle (correct).

Appendix I: Practical Test English Version

The gas constant

The object:

To determine a gas constant (R) by using pressure (P), temperature (T) and volume (V) relations.

The theory:

When the Boyle's law, Charl's law and Avogadro's law are combined, the equation of an ideal gas is obtained as PV = nRT. This equation is called the equation of state of the ideal gas. Where the gas constant is abbreviated as R, one mole of a gas has 22.414 liters at a standard temperature and standard pressure. When P = 1 atm, V = 22.414 liters, n = 1 mol, T = 273.15 K are used on the PV = nRT equation, R is 0.082057 L atm K^{-1} mol^{-1}. In an SI unit, whilst a pressure is in the N m^{-2} unit and a volume is in the m^3 unit, the R constant is 8.314 N m K^{-1} mol^{-1} or 8.314 J K^{-1} mol^{-1}.

The PV = nRT equation is available for real gases if they have a low pressure and/or a high temperature. The hydrogen gas is generated from a combination of the Mg and HCl, and is collected by replacing with water. The hydrogen gas is prepared by a reaction of the Mg and the HCl as follows:

$$Mg(s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g) \qquad (1)$$

The hydrogen gas is collected by replacing of water. As seen in the equation (1) one mole of the Mg reacts with two moles of the HCl to produce one mole of the $MgCl_2$ and one mole of the H_2. If a reaction begins with two moles of the Mg and five moles of the HCl, the mole number of the Mg and HCl are reduced in the reaction to 1 : 2 ratio, respectively. When the reaction is completed, the amount of the HCl has left. The Mg is called the amount of finite substance. The amount of the finite substances is used to determine a weight or the mole number of a product. If a substance is weighed accurately, the product is gained as same as the weight of the substance is reduced. Therefore, a dry and high molecular mass of the substance is selected for this experiment. In this experiment, the Mg is used as the finite substance. The weight of the Mg is calculated to determine the mole number of the H_2. Also, an excess of the HCl is used.

The hydrogen gas can be collected by displacing with water in a bottle, and a volume of the gas can be determined from a displaced volume of water. A pressure of the gas is obtained by using the Dalton's law of partial pressures, a vapor pressure of water, and an atmospheric pressure. The Dalton's law states that the pressure of a mixture of the gases in a container is equal to a sum of the pressures that each gas would exert as it is presented alone:

$$P_{total} = \Sigma_i P_i \quad \text{or} \quad P_{atm} = P_{O_2} + P_{water\ vapor}$$

The procedure:

1. The equipment is set as shown in Figure 1. Make sure that every apparatus is dry.
2. Full of water is filled in a burette, and the burette is turned to reverse in a beaker which fills with a half of water. A bubble should be on the top of burette.
3. Observe water at the top line of a burette.
4. Add 100 ml of 3 M of the HCl solution into a flask.
5. 0.03 grams of the Mg metal are weighed and added into a glass vial which is hold with a thread. The glass vial is placed into a flask, and then close the flask with a rubber stopper. (Caution: not to spill the Mg metal before an experiment is taken place.)

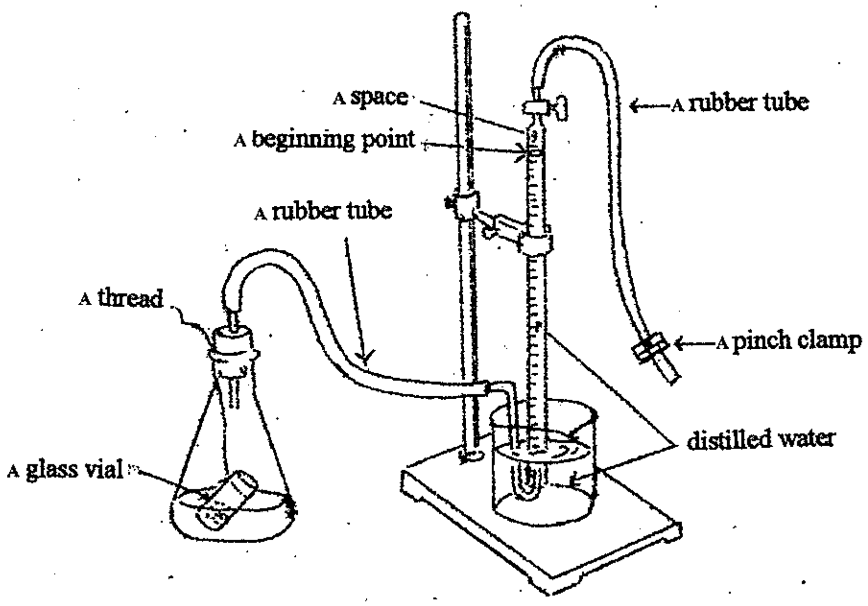

Figure 1. The apparatus for determining a volume of the hydrogen gas by displacing water.

Source: (Naresuan University, science faculty, chemistry department, n.d., p. 28).

6. Record the volume of water in a burette. (measuring skill and recording skill)

The volume of water is.........................ml

(1 marks for measuring skill and 1 mark for recording skill).

7. Stir a flask to start a reaction of the HCl and Mg metal. Observe the changes of a reaction. (observing skill)

The changes are...(1 marks)

8. Record the volume of water in a burette and measure the height of water in the burette beginning from the surface layer of water in a beaker. (measuring skill, recording skill and manipulating skill).

The volume of water in the burette is........................ml.

The height of left water is............................centimeter.

(1 mark for measuring skill, 1 mark for recording skill and 1 mark for manipulating skill).

9. Measure the temperature of water in a beaker. Make sure that it is as same as the temperature of a gas in a burette. (measuring skill and manipulating skill).

The temperature of water in the beaker is......................°C

(1/2 mark for measuring skill and 1/2 mark for manipulating skill).

10. What hypothesis was an experiment designed to a test? (hypothesis formulating skill)

....

(2 marks.)

11. Summarise your results. (conclusion skill)

....(2 marks)

Table 1 is shown as follows:

Table 1

The Vapor Pressure of Water at Different Temperatures

Temperature (°C)	Pressure (Pa)	Temperature (°C)	Pressure (Pa)	Temperature (°C)	Pressure (Pa)
24	2983.30	25	3167.15	26	3360.86
27	3564.84	28	3779.49	29	4005.33
30	4242.78	31	4492.22	32	4754.59
33	5030.03	34	5319.20	35	5622.77

Source (Naresuan University, science faculty, chemistry department, n.d., p. 29)

11. Determine the gas constant in this experiment by using the PV = nRT equation. The n is a mole number of the hydrogen gas. The P is a pressure of the hydrogen gas in a Pascal unit. The V is the volume of the hydrogen gas in a meter cube unit. An atmospheric pressure is equal the pressure of the hydrogen gas that sums with the vapor pressure of water and with the pressure from the height of water in

a burette. One-centimeter height of water has 98.088 Pa. Compare a gas constant with a reference. (interpreting skill and calculating skill)

....

....

(2 marks for interpreting skill and 1 mark for calculating skill)

12. Design an apparatus to determine the oxygen gas constant. The $KClO_3$ substance and MnO_2 catalyst are used as reactants. They are burned in a test tube. The oxygen gas is collected by replacing with water. (the ability to design experiments)

....(1 mark)

Appendix J: Student Actual Form of the CLEI Thai Version

แบบสอบถามเกี่ยวกับสิ่งแวดล้อมในรูปแบบที่เป็นจริง

คำชี้แจง

แบบสอบถามนี้เป็นข้อความที่เกี่ยวกับการปฏิบัติการในห้องเรียนเคมีเชิงฟิสิกส์ นักเรียนจะถูกถามการปฏิบัติการที่เกิดขึ้นจริง

แบบสอบถามนี้ไม่มีคำตอบที่ถูกหรือผิด แต่ต้องการให้นักเรียนแสดงความคิดเห็นเท่านั้น ขอให้นักเรียนอ่านและพิจารณาว่าข้อความต่อไปนี้บรรยายถึงห้องปฏิบัติการเคมีเชิงฟิสิกส์ที่เป็นจริงอย่างไร โดยทำเครื่องหมาย วงกลมรอบ ๆ ตัวเลขต่อไปนี้

ตัวเลข 1 หมายถึง การปฏิบัติการที่เกิดขึ้น เกือบจะไม่เคย

ตัวเลข 2 หมายถึง การปฏิบัติการที่เกิดขึ้น นาน ๆ ครั้ง

ตัวเลข 3 หมายถึง การปฏิบัติการที่เกิดขึ้น บางครั้ง

ตัวเลข 4 หมายถึง การปฏิบัติการที่เกิดขึ้น บ่อยครั้ง

ตัวเลข 5 หมายถึง การปฏิบัติการที่เกิดขึ้น บ่อยครั้งมาก

ถ้าท่านต้องการเปลี่ยนคำตอบ ให้กากบาทข้อที่ไม่ต้องการทิ้งและวงกลมรอบตัวเลขอื่นที่ต้องการ บางข้อความในแบบสอบถามนี้จะคล้ายคลึงกับข้อความในข้ออื่น ซึ่งนักเรียนไม่ต้องสงสัย ขอให้แสดงความเห็นทุก ๆ ข้อ

ตัวอย่าง สมมุติว่านักเรียนอ่านข้อความว่า " ฉันเลือกเพื่อนเป็นคู่ในการทดลองปฏิบัติการ " นักเรียนต้องตัดสินใจว่าจะเลือกเพื่อนเป็นคู่ในการทดลองปฏิบัติการ "เกือบจะไม่เคย", "นาน ๆ

ครั้ง",   "บางครั้ง",   "บ่อยครั้ง"   หรือ   "บ่อยครั้งมาก"   ถ้านักเรียนเลือกบ่อยครั้งมาก นักเรียนควรวงกลมรอบเลข 5 ลงในกระดาษคำตอบ

โปรดอย่าลืมเขียนชื่อและรายละเอียดลงด้านบนสุดของด้านหลังแผ่นนี้

ชื่อ________________________ มหาวิทยาลัยราชภัฏ______________ชั้น_________

พึงระลึกว่านักเรียนกำลังอยู่ในห้องเรียนตามที่เป็นจริง	เกือบไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	บ่อยครั้งมาก	สำหรับครู
1. ฉันเป็นเพื่อนที่ดีกับนักเรียนคนอื่นในห้องปฏิบัติการ.	1	2	3	4	5	__
2. ฉันมีโอกาสทดลองเคมีเชิงฟิสิกส์ ที่ฉันสนใจในห้องปฏิบัติการ.	1	2	3	4	5	__
3. โดยทั่ว ๆ ไป การเรียนเคมีในห้องเรียนของฉัน ไม่สัมพันธ์กับการทดลองในห้องปฏิบัติการ.	1	2	3	4	5	R __
4. ห้องปฏิบัติการของฉันมีกฎเกณฑ์อย่างชัดเจน ที่ช่วยแนะนำในการทดลอง.	1	2	3	4	5	__
5. ฉันพบว่าห้องปฏิบัติการมีคนหนาแน่น ขณะฉันทำการทดลอง.	1	2	3	4	5	R __
6. ฉันมีโอกาสน้อยที่จะรู้จักนักเรียนคนอื่นในห้องปฏิบัติการ.	1	2	3	4	5	R __
7. ฉันต้องออกแบบการทดลองเองเพื่อแก้ปัญหาด้วยตัวเอง.	1	2	3	4	5	__
8. การทดลองในห้องปฏิบัติการไม่สัมพันธ์กับหัวข้อวิชาเคมีเชิงฟิสิกส์ที่ฉันเรียน.	1	2	3	4	5	R __
9. ห้องปฏิบัติการของฉันค่อนข้างไม่มีพิธีรีตอง และมีกฎเกณฑ์น้อย	1	2	3	4	5	R __
10. เครื่องมือและวัสดุที่จำเป็นในการทดลองมีพร้อมที่จะให้ใช้ได้.	1	2	3	4	5	__
11. เพื่อนนักเรียนในห้องปฏิบัติการช่วยเหลือฉัน.	1	2	3	4	5	__
12. ขณะที่ทำการทดลอง เพื่อนคนอื่นเก็บข้อมูลได้ไม่เหมือนกับข้อมูลของฉันในการแก้ปัญหาเดียวกัน	1	2	3	4	5	__
13. โดยทั่ว ๆ ไป บทเรียนวิชาเคมีเชิงฟิสิกส์ จะสอดคล้องกับการทดลองในห้องปฏิบัติการ.	1	2	3	4	5	__
14. ฉันต้องปฏิบัติตามกฎที่ตั้งไว้ในห้องปฏิบัติการ.	1	2	3	4	5	__
15. ฉันรู้สึกอายห้องปฏิบัติการนี้.	1	2	3	4	5	R __

พึงระลึกว่านักเรียนกำลังอยู่ในห้องเรียนตามที่เป็นจริง	เกือบไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	บ่อยครั้งมาก	สำหรับครู
16. ฉันรู้จักนักเรียนในห้องปฏิบัติการเป็นอย่างดี.	1	2	3	4	5	__
17. ฉันได้รับอนุญาติให้ทำแบบฝึกหัดปฏิบัติการล่วงหน้าและทำการทดลองด้วยตัวเองได้.	1	2	3	4	5	__
18. ฉันนำเนื้อหาจากทฤษฎีมาใช้ในระหว่างทดลอง.	1	2	3	4	5	__
19. ฉันเห็นคุณค่าของความปลอดภัยในห้องปฏิบัติการ.	1	2	3	4	5	__
20. เครื่องมือที่ฉันใช้ในห้องปฏิบัติการจัดไว้ไม่เป็นระบบ.	1	2	3	4	5	R __
21. ฉันขอความช่วยเหลือจากนักเรียนคนอื่น ๆ ในระหว่างทดลองได้.	1	2	3	4	5	__
22. ระหว่างการทดลอง ฉันทำการทดลองที่ไม่เหมือนกับนักเรียนบางคน	1	2	3	4	5	__
23. หัวข้อในบทเรียนเคมีเชิงฟิสิกส์ 1 แตกต่างจากหัวข้อปฏิบัติการที่ฉันทดลอง	1	2	3	4	5	R __
24. มีกฎตายตัว 2-3 กฎที่ฉันต้องปฏิบัติตามในห้องปฏิบัติการ.	1	2	3	4	5	R __
25. ฉันพบว่าห้องปฏิบัติการร้อนและระบายอากาศไม่ดี.	1	2	3	4	5	R __
26. ฉันใช้เวลานานมาก กว่าฉันจะจำชื่อของเพื่อนทุก ๆ คนในห้องปฏิบัติการได้.	1	2	3	4	5	R __
27. ครูได้หาวิธีที่ดีที่สุดให้ฉันทดลองในระหว่างมีการปฏิบัติการทดลอง.	1	2	3	4	5	R __
28. การทดลองในห้องปฏิบัติการทำให้ฉันเข้าใจเนื้อหาทฤษฎีที่เรียนในห้องเรียน.	1	2	3	4	5	__
29. ครูได้บอกฉันควรระวังด้านความปลอดภัยก่อนปฏิบัติการทดลอง.	1	2	3	4	5	__
30. ห้องปฏิบัติการเป็นสถานที่ดึงดูดให้ฉันชอบทำงาน.	1	2	3	4	5	__
31. ฉันทำงานร่วมกับคนอื่นในห้องปฏิบัติการ.	1	2	3	4	5	__
32. ฉันได้หาวิธีทดลองที่ดีสุดในการทดลองในห้องปฏิบัติการ	1	2	3	4	5	__
33. การทดลองไม่สัมพันธ์กับเนื้อหาที่เรียนในห้องเรียน.	1	2	3	4	5	R __
34. ห้องปฏิบัติการของฉันมีกฎเกณฑ์ที่ชัดเจนกว่าห้องเรียนอื่น ๆ.	1	2	3	4	5	__
35. ห้องปฏิบัติการของฉันมีสถานที่เพียงพอกับการทดลองของนักเรียนเป็นกลุ่มหรือรายบุคคล.	1	2	3	4	5	__

Appendix K: Student Preferred Form of the CLEI Thai Version

แบบสอบถามเกี่ยวกับสิ่งแวดล้อมในรูปแบบที่ชอบ

คำชี้แจง

แบบสอบถามนี้เป็นข้อความที่เกี่ยวกับการปฏิบัติการเคมีเชิงฟิสิกส์ในห้องเรียน
นักเรียนจะตอบคำถามของการปฏิบัติการที่นักเรียนชอบ

แบบสอบถามนี้ไม่มีคำตอบที่ถูกหรือผิด
แต่แบบสอบถามนี้ต้องการให้นักเรียนแสดงความคิดเห็นเท่านั้น
ขอให้นักเรียนอ่านและพิจารณาว่า
ข้อความต่อไปนี้บรรยายถึงห้องปฏิบัติการที่นักเรียนชอบอย่างไร
โดยทำเครื่องหมายวงกลมรอบ ๆ ตัวเลขต่อไปนี้

ตัวเลข	1	หมายถึง	การปฏิบัติการที่ท่านชอบ	เกือบไม่เคยเกิด
ตัวเลข	2	หมายถึง	การปฏิบัติการที่ท่านชอบ	เกิดนาน ๆ ครั้ง
ตัวเลข	3	หมายถึง	การปฏิบัติการที่ท่านชอบ	เกิดบางครั้ง
ตัวเลข	4	หมายถึง	การปฏิบัติการที่ท่านชอบ	เกิดบ่อยครั้ง
ตัวเลข	5	หมายถึง	การปฏิบัติการที่ท่านชอบ	เกิดบ่อยครั้งมาก

ถ้านักเรียนต้องการเปลี่ยนคำตอบ ให้กากบาทข้อที่ไม่ต้องการทิ้ง
และวงกลมรอบตัวเลขอื่นที่ต้องการ
บางข้อความในแบบสอบถามนี้จะคล้ายคลึงกับข้อความในข้ออื่น ซึ่งนักเรียนไม่ต้องสงสัย
ขอให้แสดงความเห็นทุก ข้อ

ตัวอย่าง สมมุติว่านักเรียนอ่านข้อความว่า

"ฉันควรเลือกเพื่อนเป็นคู่ในการทดลองปฏิบัติการ"

นักเรียนควรตัดสินใจว่าควรจะเลือกเพื่อนเป็นคู่ในการทดลองปฏิบัติการ "เกือบไม่เคยเกิด", "เกิดนาน ๆ ครั้ง" , "เกิดบางครั้ง" , "เกิดบ่อยครั้ง" หรือ "เกิดบ่อยครั้งมาก"

ถ้านักเรียนเลือกบ่อยครั้งมาก ท่านควรวงกลมรอบเลข 5 ลงในกระดาษคำตอบ

ชื่อ__________________________มหาวิทยาลัยราชภัฏ________________ชั้น________

พึงระลึกว่านักเรียนกำลังอยู่ในห้องเรียนที่ชอบ	เกือบไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	บ่อยครั้งมาก	สำหรับครู
1. ฉันควรเป็นเพื่อนที่ดีกับนักเรียนคนอื่นในห้องปฏิบัติการ.	1	2	3	4	5	__
2. ฉันควรมีโอกาสทดลองเคมีเชิงฟิสิกส์ที่ฉันสนใจในห้องปฏิบัติการ.	1	2	3	4	5	__
3. โดยทั่ว ๆ ไปการเรียนเคมีในห้องเรียน ควรไม่สัมพันธ์กับการทดลองในห้องปฏิบัติการ.	1	2	3	4	5	R __
4. ห้องปฏิบัติการของฉันควรมีกฎเกณฑ์อย่างชัดเจน ที่ช่วยแนะนำในการทดลอง.	1	2	3	4	5	__
5. ฉันควรพบว่าห้องปฏิบัติการมีคนหนาแน่น ขณะฉันทำการทดลอง.	1	2	3	4	5	R __
6. ฉันควรมีโอกาสน้อยที่จะรู้จักนักเรียนคนอื่นในห้องปฏิบัติการ.	1	2	3	4	5	R __
7. ฉันควรต้องออกแบบการทดลองเพื่อแก้ปัญหาด้วยตัวเอง.	1	2	3	4	5	__
8. การทดลองในห้องปฏิบัติการไม่ควรสัมพันธ์กับหัวข้อวิชาเคมีเชิงฟิสิกส์ ที่ฉันเรียน.	1	2	3	4	5	R __
9. ห้องปฏิบัติการของฉันควรจะค่อนข้างไม่มีพิธีรีตอง และมีกฎเกณฑ์น้อย	1	2	3	4	5	R __
10. เครื่องมือและวัสดุที่จำเป็นในการทดลองควรมีพร้อมที่จะให้ใช้ได้.	1	2	3	4	5	__
11. เพื่อนนักเรียนในห้องปฏิบัติการควรช่วยเหลือฉัน.	1	2	3	4	5	__
12. ขณะที่ทำการทดลอง เพื่อนคนอื่นควรเก็บข้อมูลได้ไม่เหมือนกับข้อมูลของฉันในการแก้ปัญหาเดียวกัน	1	2	3	4	5	__
13. โดยทั่ว ๆ ไป บทเรียนวิชาเคมีเชิงฟิสิกส์ ควรจะสอดคล้องกับการทดลองในห้องปฏิบัติการ.	1	2	3	4	5	__
14. ฉันควรต้องปฏิบัติตามกฎที่ตั้งไว้ในห้องปฏิบัติการ.	1	2	3	4	5	__
15. ฉันควรรู้สึกอายห้องปฏิบัติการนี้.	1	2	3	4	5	R __

พึงระลึกว่านักเรียนกำลังอยู่ในห้องเรียนที่ชอบมากกว่า	เกือบไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	บ่อยครั้งมาก	สำหรับครู
16. ฉันควรจะรู้จักนักเรียนในห้องปฏิบัติการเป็นอย่างดี.	1	2	3	4	5	_
17. ฉันควรจะได้รับอนุญาตให้ทำแบบฝึกหัดปฏิบัติการล่วงหน้าและทำการทดลองด้วยตัวเองได้.	1	2	3	4	5	_
18. ฉันควรจะนำเนื้อหาจากทฤษฎีมาใช้ในระหว่างทดลองในห้องปฏิบัติการ.	1	2	3	4	5	_
19. ฉันควรเห็นคุณค่าของความปลอดภัยในห้องปฏิบัติการ.	1	2	3	4	5	_
20. เครื่องมือที่ฉันใช้ในห้องปฏิบัติการไม่ควรจัดไว้เป็นระบบ.	1	2	3	4	5	R _
21. ฉันควรจะขอความช่วยเหลือจากนักเรียนคนอื่น ๆ ในระหว่างทดลองได้.	1	2	3	4	5	_
22. ระหว่างทดลอง ฉันควรจะทดลองไม่เหมือนกับนักเรียนบางคน .	1	2	3	4	5	_
23. หัวข้อในบทเรียนเคมีเชิงฟิสิกส์ 1 ควรจะแตกต่างจากหัวข้อปฏิบัติการที่ฉันทดลอง	1	2	3	4	5	R _
24. มีกฎตายตัว 2-3 กฎที่ฉันควรต้องปฏิบัติตามในห้องปฏิบัติการ.	1	2	3	4	5	R _
25. ฉันควรพบว่าห้องปฏิบัติการร้อนและระบายอากาศไม่ดี.	1	2	3	4	5	R _
26. ฉันควรใช้เวลานานมาก กว่าฉันจะจำชื่อของเพื่อนทุก ๆ คนในห้องปฏิบัติการได้.	1	2	3	4	5	R _
27. ครูควรหาวิธีที่ดีที่สุดให้ฉันทดลองในระหว่างมีการปฏิบัติการทดลอง.	1	2	3	4	5	R _
28. การทดลองในห้องปฏิบัติการควรทำให้ฉันเข้าใจเนื้อหาทฤษฎีที่เรียนในห้องเรียน.	1	2	3	4	5	_
29. ครูควรบอกฉันให้ระวังด้านความปลอดภัยก่อนปฏิบัติการทดลอง.	1	2	3	4	5	_
30. ห้องปฏิบัติการควรเป็นสถานที่ดึงดูดให้ฉันชอบทำงาน.	1	2	3	4	5	_
31. ฉันควรทำงานร่วมกับคนอื่นในห้องปฏิบัติการ.	1	2	3	4	5	_
32. ฉันควรหาวิธีทดลองที่ดีสุดในการทดลองในห้องปฏิบัติการ	1	2	3	4	5	_
33. การทดลองควรไม่สัมพันธ์กับเนื้อหาที่เรียนในห้องเรียน.	1	2	3	4	5	R _
34. ห้องปฏิบัติการของฉันควรมีกฎเกณฑ์ที่ชัดเจนกว่าห้องเรียนอื่น ๆ.	1	2	3	4	5	_
35. ห้องปฏิบัติการของฉันควรมีสถานที่เพียงพอกับการทดลองของนักเรียนเป็นกลุ่มหรือรายบุคคล.	1	2	3	4	5	_

Appendix L: Student Actual Form of the QTI Thai Version

แบบสอบถามปฏิสัมพันธ์ของครูในรูปแบบที่เป็นจริง

คำชี้แจง

แบบสอบถามนี้ถามนักเรียนให้บรรยายพฤติกรรมครูของนักเรียน

แบบสอบถามนี้ไม่ใช่ข้อทดสอบ แบบสอบถามนี้ต้องการให้ท่านแสดงความคิดเห็น แบบสอบถามนี้มี 48 ประโยคที่เกี่ยวกับครู ให้นักเรียนวงกลมรอบ ๆ ตัวเลขในประโยคที่ครูปฏิบัติต่อนักเรียน ตัวอย่างเช่น

	ไม่เคย	นานๆ ครั้ง	บางครั้ง	บ่อยครั้ง	เป็นประจำ
ครูคนนี้พูดได้อย่างชัดเจน	0	1	2	3	4

ถ้านักเรียนคิดว่าครูของนักเรียนพูดได้อย่างชัดเจนเสมอ ๆ ให้นักเรียนวงกลมรอบหมายเลข 4 ถ้าท่านคิดว่าครูของท่านไม่เคยพูดชัดเจน ให้นักเรียนวงกลมรอบ ๆ หมายเลข 0 นักเรียนสามารถเลือกหมายเลข 1, 2 และ 3 ก็ได้ ถ้าท่านต้องการเปลี่ยนคำตอบ ให้กากบาททิ้งและวงกลมรอบตัวเลขใหม่ โปรดตอบทุกข้อ ขอขอบคุณในความร่วมมือของนักเรียน

โปรดอย่าลืมเขียนชื่อและรายละเอียดลงด้านบนสุดของด้านหลังแผ่นนี้

ชื่อ____________________ มหาวิทยาลัยราชภัฏ______________ ชั้น__________

	ไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	เป็นประจำ	สำหรับครู
1. ครูอธิบายเนื้อหาอย่างกระตือรือร้น	0	1	2	3	4	
2. ครูให้ความไว้วางใจพวกเรา	0	1	2	3	4	
3. ดูเหมือนครูจะไม่มีความแน่ใจ	0	1	2	3	4	
4. ครูจะมีอารมณ์โกรธอย่างไม่คาดฝัน	0	1	2	3	4	
5. ครูอธิบายเนื้อหาอย่างชัดเจน	0	1	2	3	4	
6. ถ้าพวกเราไม่เห็นด้วยกับครู พวกเราสามารถบอกได้	0	1	2	3	4	
7. ครูมีความลังเล	0	1	2	3	4	
8. ครูมีอารมณ์โกรธอย่างรวดเร็ว	0	1	2	3	4	
9. ครูเอาใจใส่พวกเรา	0	1	2	3	4	
10. ครูเต็มใจที่จะอธิบายซ้ำ	0	1	2	3	4	
11. ท่าทางของครูเหมือนกับครูไม่รู้ที่จะทำอะไร	0	1	2	3	4	
12. เมื่อพวกเราฝ่าฝืนกฎ ครูจะแก้ไขให้ถูกต้องอย่างรวดเร็ว	0	1	2	3	4	
13. ครูรู้ทุกสิ่งทุกอย่างที่เกิดขึ้นในห้องเรียน	0	1	2	3	4	
14. ถ้าพวกเรามีอะไรจะพูด ครูจะฟังพวกเรา	0	1	2	3	4	
15. ครูอนุญาตให้พวกเราวางเงื่อนไข	0	1	2	3	4	
16. ครูไม่มีความอดทน	0	1	2	3	4	
17. ครูเป็นผู้นำที่ดี	0	1	2	3	4	
18. ครูรับรู้เมื่อพวกเราไม่เข้าใจ	0	1	2	3	4	
19. ครูไม่มั่นใจที่จะทำอะไร เมื่อพวกเราแกล้งทำให้เสียเวลา	0	1	2	3	4	
20. เป็นการง่ายที่จะมีข้อโต้แย้งกับครู	0	1	2	3	4	
21. ครูมีความเชื่อมั่นในตัวเอง	0	1	2	3	4	
22. ครูมีความอดทน	0	1	2	3	4	
23. เป็นการง่ายที่จะทำให้ครูมีความไม่มั่นใจ	0	1	2	3	4	
24. ครูพูดเชิงเยาะเย้ย	0	1	2	3	4	

	ไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	เป็นประจำ	สำหรับครู
25. ครูได้ช่วยเหลืองานของพวกเรา	0	1	2	3	4	
26. พวกเราสามารถตัดสินใจบางสิ่งบางอย่างได้ในห้องเรียน	0	1	2	3	4	
27. ครูคิดว่าพวกเราหลอกลวง	0	1	2	3	4	
28. ครูเข้มงวด	0	1	2	3	4	
29. ครูมีความเป็นมิตร	0	1	2	3	4	
30. พวกเรามีอิทธิพลกับครู	0	1	2	3	4	
31. ครูคิดว่าพวกเราไม่รู้อะไร	0	1	2	3	4	
32. พวกเราต้องเงียบในห้องเรียน	0	1	2	3	4	
33. ครูเป็นบุคคลที่พวกเราพึ่งพาได้	0	1	2	3	4	
34. ครูอนุญาติให้พวกเราตัดสินใจกันเองว่าเมื่อไรจะทำงานในห้องเรียน	0	1	2	3	4	
35. ครูได้ดูถูกพวกเรา	0	1	2	3	4	
36. ข้อสอบของครูยาก	0	1	2	3	4	
37. ครูมีอารมณ์ขัน	0	1	2	3	4	
38. ครูอนุญาติให้พวกเราหลบออกไปได้นาน ๆ	0	1	2	3	4	
39. ครูคิดว่าพวกเราไม่สามารถทำอะไรได้ผลดี	0	1	2	3	4	
40. มาตรฐานของครูสูงมาก	0	1	2	3	4	
41. ครูเป็นคนตลก	0	1	2	3	4	
42. ครูให้เรามีเวลาว่างมาก ๆ ในห้องเรียน	0	1	2	3	4	
43. ดูเหมือนครูจะไม่พอใจ	0	1	2	3	4	
44. เมื่อครูให้คะแนน ครูจะเข้มงวด	0	1	2	3	4	
45. ห้องเรียนของครูให้ความสบายใจ	0	1	2	3	4	
46. ครูมีการผ่อนผันให้กับพวกเรา	0	1	2	3	4	
47. ครูเป็นคนขี้สงสัย	0	1	2	3	4	
48. พวกเรากลัวครู	0	1	2	3	4	

Appendix M: Student Preferred Form of the QTI Thai Version

แบบสอบถามปฏิสัมพันธ์ของครูในรูปแบบที่เป็นอุดมคติ

คำชี้แจง

แบบสอบถามนี้ถามนักเรียนให้บรรยายพฤติกรรมครูในอุดมคติของนักเรียน

ให้นักเรียนคิดถึงครูในอุดมคติ ขณะตอบคำถาม

แบบสอบถามนี้มี 48 ประโยคที่เกี่ยวกับครูในอุดมคติ

ให้นักเรียนวงกลมรอบตัวเลขที่เป็นคำตอบของนักเรียน ตัวอย่างเช่น

	ไม่เคย				เป็นประจำ
ครูควรพูดได้อย่างชัดเจน	0	1	2	3	4

ถ้านักเรียนคิดว่าครูในอุดมคติควรพูดได้อย่างชัดเจนเสมอ ๆ

ให้นักเรียนวงกลมรอบหมายเลข 4 ถ้านักเรียนคิดว่าครูในอุดมคติไม่เคยพูดชัดเจน

ให้ท่านวงกลมรอบหมายเลข 0 นักเรียนสามารถเลือกหมายเลข 1, 2 และ 3 ก็ได้ถ้าต้องการ

ถ้านักเรียนต้องการเปลี่ยนคำตอบ ให้กากบาททิ้ง และวงกลมรอบเลขใหม่

ขอขอบคุณในความร่วมมือของท่าน

โปรดเขียนชื่อนักเรียนและรายละเอียดที่ด้านบนสุดของด้านหลังแผ่นนี้

ชื่อ____________________มหาวิทยาลัยราชภัฏ______________ชั้น__________

	ไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	เป็นประจำ	สำหรับครู
1. ครูควรอธิบายเนื้อหาอย่างกระดือรือร้น	0	1	2	3	4	
2. ครูควรให้ความไว้วางใจพวกเรา	0	1	2	3	4	
3. ครูควรไม่มีความแน่ใจ	0	1	2	3	4	
4. ครูควรมีอารมณ์โกรธอย่างไม่คาดฝัน	0	1	2	3	4	
5. ครูควรอธิบายเนื้อหาอย่างชัดเจน	0	1	2	3	4	
6. ถ้าพวกเราไม่เห็นด้วยกับครู พวกเราควรบอกได้	0	1	2	3	4	
7. ครูควรมีความลังเล	0	1	2	3	4	
8. ครูควรมีอารมณ์โกรธอย่างรวดเร็ว	0	1	2	3	4	
9. ครูควรเอาใจใส่พวกเรา	0	1	2	3	4	
10. ครูควรเต็มใจที่จะอธิบายซ้ำ	0	1	2	3	4	
11. ท่าทางของครูเหมือนกับครูควรจะไม่รู้ที่จะทำอะไร	0	1	2	3	4	
12. เมื่อพวกเราฝ่าฝืนกฎ ครูควรแก้ไขให้ถูกต้องอย่างเร็ว	0	1	2	3	4	
13. ครูควรจะรู้ทุกสิ่งทุกอย่างที่เกิดขึ้นในห้องเรียน	0	1	2	3	4	
14. ถ้าพวกเรามีอะไรจะพูด ครูควรจะฟังพวกเรา	0	1	2	3	4	
15. ครูควรจะอนุญาติให้พวกเราวางเงื่อนไข	0	1	2	3	4	
16. ครูควรไม่มีความอดทน	0	1	2	3	4	
17. ครูควรจะเป็นผู้นำที่ดี	0	1	2	3	4	
18. ครูควรจะรับรู้เมื่อพวกเราไม่เข้าใจ	0	1	2	3	4	
19. ครูควรไม่มั่นใจที่จะทำอะไร เมื่อพวกเราแกล้งทำให้เสียเวลา	0	1	2	3	4	
20. ควรเป็นการง่ายที่จะมีข้อโต้แย้งกับครู	0	1	2	3	4	

	ไม่เคย	นาน ๆ ครั้ง	บางครั้ง	บ่อยครั้ง	เป็นประจำ	สำหรับครู
21. ครูควรจะได้ช่วยเหลืองานของพวกเรา	0	1	2	3	4	
22. พวกเราควรจะสามารถตัดสินใจบางสิ่งบางอย่างได้ในห้องเรียน	0	1	2	3	4	
23. ครูควรคิดว่าพวกเราหลอกลวง	0	1	2	3	4	
24. ครูควรเข้มงวด	0	1	2	3	4	
25. ครูควรมีความเป็นมิตร	0	1	2	3	4	
26. พวกเราควรมีอิทธิพลกับครู	0	1	2	3	4	
27. ครูควรคิดว่าพวกเราไม่รู้อะไร	0	1	2	3	4	
28. พวกเราควรจะต้องเงียบในห้องเรียน	0	1	2	3	4	
29. ครูควรเป็นบุคคลที่พวกเราพึ่งพาได้	0	1	2	3	4	
30. ครูควรอนุญาติให้พวกเราตัดสินใจกันเองว่าเมื่อไรเราควรจะทำงานในห้องเรียน	0	1	2	3	4	
31. ครูควรดูถูกพวกเรา	0	1	2	3	4	
32. ข้อสอบของครูควรยาก	0	1	2	3	4	
33. ครูควรมีอารมณ์ขัน	0	1	2	3	4	
34. ครูควรจะอนุญาติให้พวกเราหลบออกไปได้นาน ๆ	0	1	2	3	4	
35. ครูควรคิดว่าพวกเราไม่สามารถทำอะไรได้ดี	0	1	2	3	4	
40. มาตรฐานของครูควรสูงมาก	0	1	2	3	4	
41. ครูควรตลก	0	1	2	3	4	
42. ครูควรให้เรามีเวลาว่างมาก ๆ ในห้องเรียน	0	1	2	3	4	
43. ครูควรไม่พอใจ	0	1	2	3	4	
44. เมื่อครูให้คะแนน ครูควรเข้มงวด	0	1	2	3	4	
45. ห้องเรียนของครูควรจะให้ความสบายใจ	0	1	2	3	4	
46. ครูควรจะมีการผ่อนผันให้กับพวกเรา	0	1	2	3	4	
47. ครูควรจะเป็นคนขี้สงสัย	0	1	2	3	4	
48. พวกเราควรกลัวครู	0	1	2	3	4	

Appendix N: The Attitude to Physical Chemistry Class Thai Version

ทัศนคติต่อวิชาปฏิบัติการเคมีเชิงฟิสิกส์

คำชี้แจง

ข้อ 1-10 ข้างล่างนี้ คือ ข้อความที่เกี่ยวกับบทเรียนวิชาปฏิบัติการเคมีเชิงฟิสิกส์ นักเรียนจะตอบคำถาม เกี่ยวกับความคิดเห็นที่มีต่อข้อความเหล่านี้ คำตอบที่ได้จะไม่มีผิดหรือถูก ความคิดเห็นของนักเรียนเป็นสิ่งที่ต้องการ

ให้นักเรียนวงกลมรอบหมายเลขในแต่ละข้อความ ต่อไปนี้

1 ถ้านักเรียนไม่เห็นด้วยกับข้อความนี้

2 ถ้านักเรียนไม่แน่ใจ

3 ถ้านักเรียนเห็นด้วยกับข้อความนี้

	ไม่เห็นด้วย	ไม่แน่ใจ	เห็นด้วย
1. ฉันตั้งตาคอยที่จะเรียนวิชาปฏิบัติการเคมีเชิงฟิสิกส์	1	2	3
2. บทเรียนวิชาปฏิบัติการเคมีเชิงฟิสิกส์สนุก	1	2	3
3. ฉันพอใจกับกิจกรรมในวิชาปฏิบัติการเคมีเชิงฟิสิกส์	1	2	3
4. ไม่ว่าฉันจะทำอะไรในวิชาปฏิบัติการเคมีเชิงฟิสิกส์ เป็นสิ่งที่น่าสนใจที่สุดในโรงเรียน	1	2	3
5. ฉันต้องการค้นหาข้อมูลเกี่ยวกับโลกที่ฉันอาศัย อยู่เพิ่มขึ้น	1	2	3
6. การค้นพบสิ่งใหม่ ๆ เป็นสิ่งที่สำคัญ	1	2	3
7. ฉันพอใจกับบทเรียนในวิชาปฏิบัติการเคมีเชิงฟิสิกส์ในชั้นเรียน	1	2	3
8. ฉันชอบคุยกับเพื่อนว่าเราจะทำอะไรบ้างในวิชาปฏิบัติการ เคมีเชิงฟิสิกส์	1	2	3
9. เราน่าจะเรียนวิชาปฏิบัติการเคมีเชิงฟิสิกส์ เพิ่ม ขึ้นในแต่ละสัปดาห์	1	2	3
10. ฉันรู้สึกพอใจหลังจากเรียนวิชาปฏิบัติการเคมีเชิง ฟิสิกส์	1	2	3

Appendix O: Cognitive Test Thai Version

ข้อสอบวิชาปฏิบัติการเคมีเชิงฟิสิกส์ 1

ชื่อ.............................มหาวิทยาลัยราชภัฏ.......................วิชาเอก.....................

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จงวงกลมรอบข้อที่นักศึกษาคิดว่าถูกที่สุด

1. เมื่อทำกรด $H_2 SO_4$ หกที่เสื้อผ้า

   เพราะเหตุใดถึงใช้สารดีเทอร์เจนทำปฏิกิริยาสะเทินกับกรด แทนที่จะใช้สาร

   ละลาย NaOH ที่เข้มข้น หรือสารละลายแอมโมเนีย หรือกรด CH_3COOH เจือจาง

   .ก ดีเทอร์เจนหาง่าย ข. ดีเทอร์เจนมีราคาถูก

   ค. ดีเทอร์เจนมีสมบัติไม่แรง ง. ดีเทอร์เจนไม่ทำให้เสื้อผ้าเสีย (ถูก)

2. สารคู่ใดในข้อต่อไปนี้ มีความร้อนของการสะเทินเท่ากับ HCl เกิดปฏิกิริยาการสะเทินกับ

   NaOH เมื่อความเข้มข้นและปริมาตรของสารทั้ง 2 คู่เท่ากัน

   .ก $H_2 SO_4$ สะเทินกับ KOH (ถูก) ข. CH_3COOH สะเทินกับ KOH

   ค. $H_2 SO_4$ สะเทินกับ NH_4OH ง. HCl สะเทินกับ NH_4OH

3. ความหมายของปฏิกิริยาเคมีคือ

   ก. เป็นปฏิกิริยาคายความร้อนแสดงได้ด้วย ΔH ข.

   เป็นการเปลี่ยนแปลงพลังงานความร้อนแสดงได้ด้วย

   ΔH ซึ่งเกิดในภาชนะเปิด ณ

   ความดันคงตัว

   ค. เป็นการเปลี่ยนแปลงความร้อนแสดงได้ ง.

   เป็นการเปลี่ยนแปลงความร้อนและการเปลี่ยนแปลง

   ด้วย ΔU ซึ่งเกิดในภาชนะปิด ณ ปริมาตร พลังงานภายใน แสดงได้ด้วย ΔH และ

   ΔU และ

คงตัว

เกี่ยวข้องกับของแข็งละลายในของเหลวหรือเกี่ยว

ข้องกับของเหลว (ถูก)

4. กำหนดให้อุณหภูมิของน้ำอุ่น ซึ่งมีปริมาณ 50.0 ml เท่ากับ 37.92°C, อุณหภูมิของน้ำเย็น ซึ่งมีปริมาณ 50.0 ml เท่ากับ 20.91°C

และอุณหภูมิหลังจากที่นำน้ำอุ่นและน้ำเย็นมาผสมกันเท่ากับ 29.11°C

จงคำนวณหาความจุความร้อนของแคลอรีมิเตอร์ (C) กำหนดค่าความร้อนจำเพาะของน้ำ (s) = 4.18 J/K-g (ข้อแนะนำใช้สูตร $Q = ms\Delta T$ หรือ $Q=C\Delta T$

เมื่อความร้อนที่สูญเสียให้กับแคลอรีมิเตอร์

มีค่าเท่ากับความจุความร้อนของแคลอรีมิเตอร์คูณกับอุณหภูมิของแคลอรีมิเตอร์ที่เปลี่ยนแปลง)

ก. 16.0 J/K (ถูก) ข. 26.0 J/K

ค. 36.0 J/K ง. 46.0 J/K

5. ข้อใดเป็นความหมายของความหนืดของของเหลว.

ก. ความข้นเหนียวของของเหลว ข. รูปร่างโมเลกุลของของเหลว

ค. โมเลกุลของของเหลวอยู่ชิดกัน ง. ความต้านทานการไหลของของเหลว

(ถูก)

6.

สาเหตุที่ค่าความหนืดที่หาได้จากการทดลองในห้องปฏิบัติการแตกต่างจากค่าความหนืดที่ยอมรับโดยทั่วไป น่าจะเป็นเพราะสาเหตุใด **ที่มีโอกาสคลาดเคลื่อนมากที่สุด**

.ก เครื่องมือมีรูรั่ว (ถูก) ข. เครื่องมือไม่แห้งสนิท

ค. วัดอุณหภูมิในขณะทำการทดลอง ง.

จับเวลาการไหลของของเหลวผิดขณะทำการทดลอง

ผิด

7. จากสมการความหนืด $\eta = \frac{F/A}{v/L}$ เมื่อ η คือ ความหนืด F

คือแรงในหน่วยนิวตันต่อหน่วยเมตรยกกำลังสอง A คือพื้นผิวในหน่วยเมตร v

คือความเร็วในหน่วยเมตรต่อวินาที และ L

คือความหนาของชั้นของไหลทั้งหมดในหน่วยเมตรยกกำลังสอง ดังนั้น

ความหนืดจะมีหน่วยเป็นอะไร.

.ก นิวตันคูณกับวินาทียกกำลังสอง(NS^2) ข. นิวตันคูณกับเมตรยกกำลังสอง(N

m^2)

ค. นิวตันคูณกับวินาที และหารด้วยเมตร ง.

นิวตันคูณกับวินาทียกกำลังสองและหารด้วยเมตร

ยกกำลังสอง (NS/m^2) (ถูก) ยกกำลังสอง (NS^2/m^2)

8. เพราะเหตุใดความหนืดของของเหลวจึงมีค่ามากขึ้น ?

.ก ปริมาตรของของเหลวมากขึ้น ข. อุณหภูมิของของเหลวต่ำลง (ถูก)

ค. สีของของเหลวเข้มขึ้น ง.. กลิ่นของของเหลวน้อยลง

9. ข้อใดเป็นความหมายของความหนาแน่น

.ก น้ำหนักของสารต่อปริมาตรน้ำ ข. น้ำหนักของสารต่อ 1

หน่วยปริมาตรสาร (ถูก)

ค. น้ำหนักของสารรวมกับปริมาตรของสาร ง.

น้ำหนักของสารคูณกับปริมาตรของสาร

10. แก้วชิ้นหนึ่งมีปริมาตร 75 ml มีมวล 0.2 kg จะมีความหนาแน่นเท่าใด ?

ก. 1.6 g/ml ข. 2.6 g/ml (ถูก)

ค. 3.6 g/ml ง. 4.6 g/ml

11. ทำไมค่าความถ่วงจำเพาะของของเหลวมีความสำคัญกับของเหลว

ก. ใช้สร้างอากาศยาน ข. ใช้สร้างนาฬิกาทราย

ค. ใช้แบ่งประเภทของของเหลว ง. ใช้บอกความบริสุทธิ์ของของเหลว

(ถูก)

12. เมื่อสารที่จะหาความถ่วงจำเพาะมีปริมาตรเท่ากับน้ำแล้ว

จะได้ความหมายของความถ่วงจำเพาะของสารใด

ว่า น้ำหนักของสารนั้นหารด้วยน้ำหนักของน้ำที่มีปริมาตรเท่ากับสารนั้น

และถ้านำหลักของอาร์คีมีดีส

มาใช้ จะได้ความหมายของความถ่วงจำเพาะ ดังนี้

ก. อัตราส่วนระหว่างน้ำหนักของสารที่ชั่งใน ข.

อัตราส่วนระหว่างน้ำหนักของสารที่ชั่งในน้ำต่อน้ำ

อากาศต่อน้ำหนักของน้ำที่ถูกแทนที่ (ถูก) หนักของน้ำที่ถูกแทนที่

ค. อัตราส่วนระหว่างน้ำหนักของน้ำที่ถูก ง.

อัตราส่วนระหว่างน้ำหนักของน้ำที่ถูกแทนที่ต่อ

แทนที่ต่อน้ำหนักของสารที่ชั่งในน้ำ น้ำหนักของสารที่ชั่งในอากาศ

13. ข้อใดคือกฎของอาโวกาโดร

ก. แก๊สที่มีปริมาตรเท่ากันจะมีจำนวน ข.

สารที่มีปริมาตรเท่ากันจะมีจำนวนโมลเท่ากัน

โมเลกุลเท่ากัน (ถูก)

ค. ของเหลวที่มีปริมาตรเท่ากัน จะมี ง. ของแข็งที่มีปริมาตรเท่ากัน

จะมีจำนวนโมลเท่ากัน

จำนวนโมเลกุลเท่ากัน

13. จากการทดลองหาปริมาตรต่อโมลของแก๊ส O_2 นั้น

สามารถทดลองหาปริมาตรต่อโมลของสารใดได้เช่น

เดียวกัน ดังข้อต่อไปนี้

ก. N_2 (ถูก) ข. KI

ค. NaOH ง. Na_2O

15. จากตารางอนุกรมแรงเคลื่อนไฟฟ้า ค่าศักย์ไฟฟ้ารีดักชันของ Cu^{+}/Cu^{2+} จะอยู่เหนือกว่า $I^{-}/1/2I_2$

เมื่อเติมสารละลาย KI ลงในสารละลาย $CuSO_4$ จะเกิดของแข็งไอโอดีน และทองแดง (I) ไอโอไดด์ขึ้น ดัง

สมการ $Cu^{2+} + 2I^{-} \rightarrow 1/2I_2(s) + CuI(s)$ ดังนั้น ค่าคงตัวสมดุล (K) ของปฏิกิริยาที่เกิดขึ้นคือข้อ

ใด ?

ก. $K = [Cu^{2+}][I^{-}]$

ข. $K = \frac{[Cu^{2+}][I^{-}]}{[Cu^{+}]}$

ค. $K = [I][CuI(s)]$

ง. $K = \frac{1}{[Cu^{2+}][I^{-}]^2}$ (ถูก)

16. ข้อใดเป็นส่วนประกอบที่สมบูรณ์ของเซลล์ไฟฟ้าเคมี

ก. ครึ่งเซลล์ 2 ครึ่งเซลล์, สะพานเกลือ, ลวดตัวนำ, แผ่น

ลวดตัวนำ, แผ่นพรุน

ข. ครึ่งเซลล์ 2 ครึ่งเซลล์, สะพานเกลือ, พรุน, ขั้วคาร์บอน

ค. ครึ่งเซลล์ 2 ครึ่งเซลล์, สะพานเกลือ, ลวดตัวนำ, ขั้ว

ลวดตัวนำ, โวลต์มิเตอร์หรือแบตเตอรี

โวลต์มิเตอร์

สารละลายอิเล็กโทรไลต์

ง. ครึ่งเซลล์ 2 ครึ่งเซลล์, สะพานเกลือ, ไฟฟ้า 2 ขั้ว, สารละลายอิเล็กโทรไลต์ , หรือแบตเตอรี (ถูก)

17. ข้อใดคือลักษณะของขั้วไฟฟ้าไฮโดรเจนมาตรฐาน

ก. เป็นขั้วแคโทดเมื่อเกิดปฏิกิริยา

$\frac{1}{2} H_2(g, 1\ atm) \rightarrow H^{+}(1\ M) + e^{-}$

ข. เป็นขั้วแอโนดหรือขั้วแคโทดก็ได้ ขึ้นกับครึ่งปฏิกิริยา

ค. เป็นขั้วที่มีค่าศักย์ไฟฟ้าเป็นศูนย์ ณ

ง. มีขั้วไฟฟ้าไฮโดรเจนจุ่ม (ถูก)

เป็นขั้วที่ประกอบด้วยแพลทินัมจุ่มลงในสารละลาย

อุณหภูมิ 25°C โดยสารละลายกรดมีความ กรดเข้มข้น 0.5 M และมีแก๊ส H_2 ณ

ความดัน 1 bar

เข้มข้น 0.5 M และความดันแก๊สเป็น 1 atm ผ่านในสารละลาย

18. ในการทดลองหาปริมาตรต่อโมลของแก๊ส O_2 เราใช้ขวดที่บรรจุน้ำและต่อกับหลอดแก้ว

เพื่อให้แก๊สมา

แทนที่น้ำ เราสามารถใช้ภาชนะอะไรแทนขวดนี้ได้อย่างเหมาะสม

ก. บีกเกอร์ทรงสูง ข. ขวดพลาสติก

ค. หลอดทดสอบอย่างหนา ง.

ขวดอะไรก็ได้ที่แก๊สสามารถแทนที่น้ำ (ถูก)

19. สมการใดต่อไปนี้แสดงถึงความหมายของความร้อนของสารละลาย?

ก. $C(s) + 2S(s) \rightarrow CS_2(s)$, $\Delta H = 25.4$ kcal

ข. $HCl(g) + aq \rightarrow HCl(aq)$, $\Delta H = -17.96$ kcal (ถูก)

ค. $1/2H_2(g) + 1/2I_2(g) \rightarrow HI(g)$, $\Delta H = 6.2$ kcal

ง. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$, $\Delta H = -135$ kcal

20. ข้อความใดต่อไปนี้ แสดงสถานะว่าแก๊สจริงเป็นไปตามกฎของบอยล์

ก. อุณหภูมิคงตัวและความดันสูง ข. อุณหภูมิคงตัวและปริมาตรน้อย

ค. อุณหภูมิคงตัวและความดันต่ำ (ถูก) ง. อุณหภูมิคงตัวและปริมาตรมาก

Appendix P: Practical Test Thai Version

แบบปฏิบัติการหาค่าคงตัวของแก๊ส

วัตถุประสงค์

เพื่อหาค่าคงตัวของแก๊สโดยอาศัยความสัมพันธ์ ความดันปริมาตร และอุณหภูมิ

หลักการ

จากกฎของบอยล์ กฎของชาร์ล และกฎของอาโวกาโดร สามารถเขียนความสัมพันธ์ระหว่างความดัน (P) ปริมาตร (V) และจำนวนโมล (n) ของแก๊สอุดมคติได้ ดังนี้

$$PV = nRT \quad (1)$$

สมการที่ (1) เรียกว่าสมการสถานะของแก๊สอุดมคติ ค่า R เรียกว่าค่าคงตัวของแก๊ส แก๊ส 1 โมลที่อุณหภูมิและความดันมาตรฐานจะมีปริมาตร 22.414 ลิตร เมื่อแทนค่า P = 1 atm, V = 22.414 L , n = 1 mol , T = 273.15 K ลงในสมการที่ 1 จะได้ R = 0.082057 L atm K^{-1} mol^{-1} ในระบบ SI ความดันมีหน่วยเป็น N m^{-2} และปริมาตรมีหน่วยเป็น m^3 จะได้ R= 8.314 N m $K^{-1}mol^{-1}$ = 8.314 J K^{-1} mol^{-1}

จากสมการที่ 1 อาจใช้กับแก๊สจริงก็ได้ ในกรณีที่แก๊สนั้นมีความดันต่ำและหรืออุณหภูมิสูง ในการทดลองนี้จะเตรียมแก๊สไฮโดรเจน และเก็บแก๊สโดยการแทนที่น้ำ แก๊สไฮโดรเจนเตรียมได้จากปฏิกิริยาระหว่างโลหะ Mg กับกรด HCl ดังสมการ

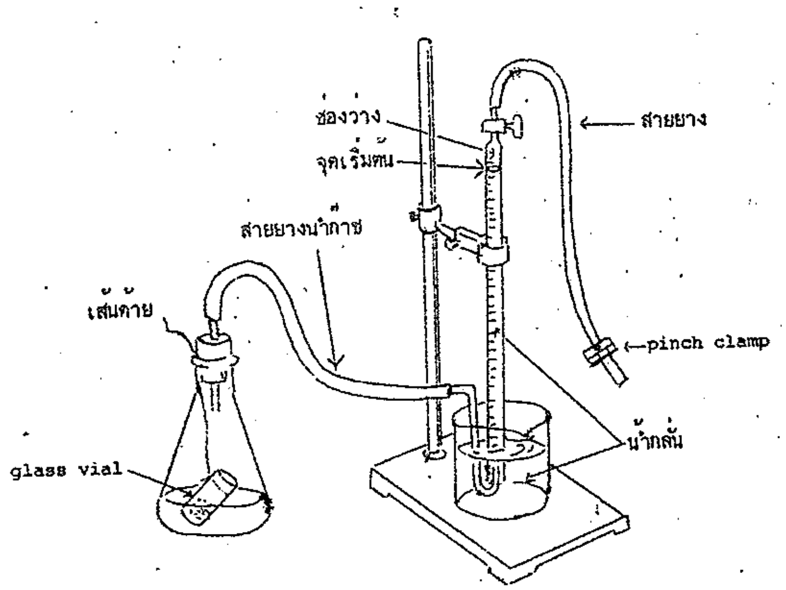
$$Mg\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2(g) \quad (2)$$

จากสมการที่ 2 จะเห็นว่า Mg 1 โมล ทำปฏิกิริยาพอดีกับ HCl 2 โมล เกิด $MgCl_2$ 1 โมล และ H_2 1 โมล ถ้าเริ่มต้นด้วย Mg จำนวน 2 โมล และ HCl จำนวน 5 โมล ปฏิกิริยาจะเกิดขึ้นโดย Mg 1 โมลจะทำปฏิกิริยาพอดีกับ HCl 2 โมล ดังนั้น Mg และ HCl ก็จะลดลงด้วยอัตราส่วนของจำนวนโมลเป็น 1: 2 จน Mg หมดไป และเหลือ HCl 1 โมล ปฏิกิริยาจะสิ้นสุดลง จะเห็นว่า Mg เป็นสารที่ทำให้ปฏิกิริยาหยุดลง เราเรียกสารที่มีปริมาณจำกัด จนทำให้ปฏิกิริยาสิ้นสุดนี้ว่า " สารกำหนดปริมาณ "

จำนวนโมลของสารกำหนดปริมาณมีประโยชน์ในการคำนวณหาน้ำหนัก หรือจำนวนโมลของผลผลิตที่เกิดจากปฏิกิริยา และเนื่องจากน้ำหนักหรือจำนวนโมลของสารกำหนดปริมาณนี้ได้จากการชั่ง ถ้าชั่งถูกต้อง น้ำหนักที่ใช้ในการคำนวณปริมาณผลผลิตที่เกิดก็จะถูกต้องด้วย ดังนั้น จึงนิยมเลือกใช้สารกำหนดปริมาณที่เป็นสารไม่ดูดความชื้น และเป็นสารที่มีมวลโมเลกุลหรือมวลอะตอมสูง ซึ่งในการทดลองนี้เลือกใช้สารกำหนดปริมาณเป็น Mg จำนวนโมลของแก๊สไฮโดรเจนที่เกิดขึ้น สามารถคำนวณได้จากน้ำหนักของ Mg ที่ใช้ โดยใช้ HCl มากเกินพอในการทำปฏิกิริยา

ความดันของแก๊สไฮโดรเจนที่เก็บโดยการแทนที่น้ำ ได้จากการหักค่าความดันไอน้ำอิ่มตัว (ดังในตารางที่ 1) และความดันอันเนื่องจากความสูงของน้ำที่ค้างอยู่ในหลอดที่เก็บแก๊ส (ความสูงของน้ำ 1 ซม. จะมีความดัน 98.088 Pa) ออกจากความดันบรรยากาศ ณ อุณหภูมิของแก๊สนั้น

วิธีทดลอง จัดเครื่องมือดังแสดงในรูปที่ 1 เครื่องมือทุกชิ้นต้องทำความสะอาดและทำให้แห้ง



รูปที่ 1 เครื่องมือที่ใช้หาปริมาตรแก๊สไฮโดรเจนโดยการแทนที่น้ำ

ที่มา (มหาวิทยาลัยนเรศวร คณะวิทยาศาสตร์ ภาควิชาเคมี, ม.ป.ป., หน้า 28)

1. บรรจุน้ำลงในบิวเรตให้เต็ม จับบิวเรตกลับข้าง ปล่อยให้ปลายที่ไม่มีจุกปิดอยู่ต่ำกว่าระดับน้ำในบีกเกอร์ และปลายที่มีจุกปิดอยู่ข้างบน ควรมีฟองอากาศเหลือบ้างในปลายด้านบน
2. สังเกตปริมาตรน้ำให้อยู่ที่ขีดบนสุด
3. ตวงสารละลายกรดไฮโดรคลอริกเข้มข้น 3 M จำนวน 100 ml ใส่ในคนโท
4. ชั่งโลหะ Mg หนัก 0.03 กรัม แล้วใส่ลงในขวดแก้วเล็ก ๆ (glass vial) ผูกด้วยเส้นด้ายยาว 8 นิ้ว ค่อย ๆ หย่อนหลอดแก้ววางในคนโท พยายามอย่าให้โลหะ Mg หก หย่อนเส้นด้ายที่เหลือลงไปในคนโท ให้ปลายที่เหลืออยู่ตรงที่ปิดจุกยาง
5. จดปริมาตรของน้ำที่อยู่ในบิวเรต (ทักษะการวัด และทักษะการบันทึกข้อมูล)

   ปริมาตรของน้ำ = …………..ลบ.ซม

   (ทักษะการวัด 1 คะแนน และทักษะการบันทึกข้อมูล 1 คะแนน (2 คะแนน)

6. ค่อย ๆ เอียงคนโท เพื่อให้สารละลายกรดเกลือทำปฏิกิริยากับโลหะ Mg เขย่าคนโท

สังเกตการเปลี่ยนแปลง (ทักษะการสังเกต)

มีการเปลี่ยนแปลง

ดังนี้..

(1 คะแนน)

7. จดปริมาตรน้ำในบิวเรต และวัดความสูงของน้ำที่เหลือในบิวเรต

จากระดับน้ำที่อยู่ในบีกเกอร์เป็นเซนติเมตร (ทักษะการวัด และทักษะการใช้เครื่องมือ)

ปริมาตรน้ำที่เหลือในบิวเรต = ...ลบ.ซม

ความสูงของน้ำที่เหลือในบิวเรต จากระดับน้ำที่อยู่ในบีกเกอร์ = ...ซม.

ทักษะการวัด 1 คะแนน และทักษะการใช้เครื่องมือ 1 คะแนน (รวม 2 คะแนน)

8. วัดอุณหภูมิของน้ำในบีกเกอร์ ซึ่งถือว่าเป็นอุณหภูมิของแก๊สที่อยู่ในบิวเรต

(ทักษะการวัดและทักษะการใช้เครื่องมือ)

อุณหภูมิของน้ำในบีกเกอร์ = ...องศา

ทักษะการวัด ½ คะแนน และทักษะการใช้เครื่องมือ ½ คะแนน (รวม 1 คะแนน)

9. จงบอกสมมุติฐานที่เกี่ยวข้องกับการทดลองนี้ (ทักษะการตั้งสมมุติฐาน)

1...

....

2...

....

(2 คะแนน)

10. จงสรุปผลที่ได้ทั้งหมด (ทักษะการลงความเห็นจากข้อมูล)

....

....

....

....(2 คะแนน)

11. จงแสดงวิธีการหาค่าคงตัวของแก๊สที่ได้จากการทดลองนี้ โดยใช้ข้อมูลในตารางที่ 1 และใช้สูตร PV=nRT เมื่อ n คือจำนวนโมลของแก๊สไฮโดรเจนที่เกิดขึ้น P คือความดันของแก๊สไฮโดรเจนมีหน่วยเป็นพาสคัล (Pa) V คือปริมาตรของแก๊สไฮโดรเจนมีหน่วยเป็นลบ.เมตร ซึ่งมีค่าเท่ากับปริมาตรของน้ำที่ถูกแทนที่ R ที่ได้มีหน่วยเป็น J $deg^{-1}mol^{-1}$ และกำหนดให้ความดันบรรยากาศ=ความดันของแก๊ส H_2 + ความดันของไอน้ำอิ่มตัวที่อุณหภูมิของแก๊สขณะนั้น + ความดันเนื่องจากความสูงของน้ำเป็นเซนติเมตรในบิวเรต โดยที่ความสูงของน้ำ 1 cm จะมีความดัน 98.088 Pa (ทักษะการตีความหมายจากข้อมูล และทักษะการคำนวณ)

....

....

....

....

....ทักษะการตีความหมายจากข้อมูล 2 คะแนน และทักษะการคำนวณ 1 คะแนน (รวม 3 คะแนน)

ตารางที่ 1 แสดงค่าความดันไอน้ำอิ่มตัวที่อุณหภูมิต่าง ๆ

อุณหภูมิ (°C)	ความดัน (Pa)	อุณหภูมิ (°C)	ความดัน (Pa)	อุณหภูมิ (°C)	ความดัน (Pa)
24	2983.30	25	3167.15	26	3360.86
27	3564.84	28	3779.49	29	4005.33
30	4242.78	31	4492.22	32	4754.59
33	5030.03	34	5319.20	35	5622.77

ที่มา (มหาวิทยาลัยนเรศวร คณะวิทยาศาสตร์ ภาควิชาเคมี, ม.ป.ป., หน้า 29)

13. จงเขียนเครื่องมือวิธีการทดลอง เพื่อหาค่าคงตัวของแก๊สอื่น ๆ เช่นแก๊สอ๊อกซิเจนบ้าง โดยใช้สาร $KClO_3$ กับ MnO_2 เผาในหลอดทดสอบทนไฟ และเก็บแก๊สอ๊อกซิเจนโดยการแทนที่น้ำ (ทักษะการออกแบบการทดลอง)

....

....

....

....

....

(2 คะแนน)

Appendix Q: Translation Back of Student Actual Form of the CLEI

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked the frequency of each practice that really takes place in your class.

There are no "right" or "wrong" answer. The questionnaire wants you to express your opinion.

Read and think about how well the following statements describe what this laboratory class is really like for you. Circle around the number that corresponds to your response.

1	the practice takes place	Almost Never
2	the practice takes place	Rarely/Not often
3	the practice takes place	Sometimes
4	the practice takes place	Often
5	the practice takes place	Very Often

If you want to change your answer, cross it out and circle a new number. Some statements in this questionnaire are quite similar to other statements. Do not worry about this. Be sure to answer every statement.

Practice Example. Suppose that you read the statement, "I choose my partners for laboratory experiments" You would decide whether you thought that you really choose your partners **Almost Never, Seldom, Sometimes, Often or Very Often**. For example, if you choose "Very Often", you would circle the number 5 on your Answer Sheet.

Do not forget to write your name and other details on the top of the back side of this page.

This page is an appendix to a book entitled *Assessing the Climate of Science Laboratory Classes* by Barry J. Fraser, Geoffrey J. Gidding and Campbell J. McRobbie and published by the Key Center for School Science and Mathematics at Curtin University of technology, Perth, Australia.

1. I am friendly with other students in the laboratory class.
2. I have the chance to work at my own interests in science in the laboratory class.
3. What I do in my regular science classes is not related to my laboratory work.
4. There are clear rules of the laboratory class to guide my experiments.
5. I find that the laboratory is crowded when I am performing experiments.
6. In the laboratory class. I have little possibility to get to know other students.
7. I am demanded to design my own experiments to solve a given problem in the laboratory class.
8. The laboratory work is not related to the science topics that I am studying.
9. My laboratory class is somewhat informal and few rules are required from me.
10. The equipment and materials that I need for my experiments are in the condition needed for use.
11. Other students in the laboratory class help me.
12. In my laboratory class, other students get different data from mine for the same problem.
13. My science class work is combined into lab experiments.
14. I need to follow certain rules in the laboratory.
15. I feel ashamed of the appearance of the laboratory.
16. I know students in the laboratory class well.
17. I am allowed to go further on the regular science laboratory and do some experiments of my own.
18. I use the theory from my science class during my experiments.
19. I am acknowledged to do things safely in the laboratory.
20. The laboratory equipment which I use is not arranged in good order.
21. I am able to rely on other students for help during laboratory classes.
22. In my laboratory classes. My experiments are different from the experiments of other students.
23. The topics in my science class work and in the laboratory are quite different.
24. There are few fixed rules that I have to follow in the laboratory.
25. I find that the laboratory is hot and badly ventilated.
26. It takes me a long time to know everybody in the laboratory class by his/her first name.
27. In my laboratory classes, the teacher chooses the best way for me to get the laboratory experiments done.

28. The experiments in the laboratory classes help me to understand the theory I studied in my science classes.
29. The teacher explains the points of safety before I start my experiments.
30. The laboratory is pleasing for me to work in.
31. I work with others in the laboratory classes.
32. I decide the best way to continue the laboratory experiments.
33. My laboratory experiments are not related to my science class.
34. My laboratory class has clearer rules than my other classes.
35. My laboratory has enough space for individual or group work.

Appendix R: Translation Back of Student Preferred Form of the CLEI

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked the frequency of each practice that would like to takes place in your class.

There are no "right" or "wrong" answer. The questionnaire wants you to express your opinion.

Read and think about how well the following statements describe what this laboratory class that you would like. Circle the number that corresponds to your response.

1	if you would like the practice to takes place	Almost Never
2	if you would like the practice to takes place	Rarely/Not often
3	if you would like the practice to takes place	Sometimes
4	if you would like the practice to takes place	Often
5	if you would like the practice to takes place	Very Often

If you want to change your answer, cross it out and circle a new number. Some statements in this questionnaire are quite similar to other statements. Do not worry about this. Be sure to answer every statement.

Practice Example. Suppose that you read the statement, "I would choose my partners for laboratory experiments" You would decide whether you thought that you would like to choose your partners **Almost Never, Seldom, Sometimes, Often or Very Often**. For example, if you choose "Very Often", you would circle the number 5 on your Answer Sheet.

Do not forget to write your name and other details on the top of the back side of this page.

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1. I would be friendly with other students in the laboratory class.
2. I would have the chance to work at my own interests in science in the laboratory class.
3. What I do in my regular science classes would not be related to my laboratory work.
4. There would be clear rules of the laboratory class to guide my experiments.
5. I would find that the laboratory would be crowded when I am performing experiments.
6. In the laboratory class. I would have little possibility to get to know other students.
7. I would be demanded to design my own experiments to solve a given problem in the laboratory class.
8. The laboratory work would not be related to the science topics that I am studying.
9. My laboratory class would be somewhat informal and few rules would be required from me.
10. The equipment and materials that I need for my experiments would be in the condition needed for use.
11. Other students in the laboratory class would help me.
12. In my laboratory class, other students would get different data from mine for the same problem.
13. My science class work would be combined into laboratory experiments.
14. I would need to follow certain rules in the laboratory.
15. I would feel ashamed of the appearance of the laboratory.
16. I would know students in the laboratory class well.
17. I would be allowed to go further on the regular science laboratory and would do some experiments of my own.
18. I would use the theory from my science class during my experiments.
19. I would be acknowledged to do things safely in the laboratory.
20. The laboratory equipment which I use would not be arranged in good order.
21. I would be able to rely on other students for help during laboratory classes.
22. In my laboratory classes, my experiments would be different from the experiments of other students.
23. The topics in my science class work and in the laboratory would be quite different.

24. There would be few fixed rules that I would have to follow in the laboratory.
25. I would find that the laboratory is hot and badly ventilated.
26. It would take me a long time to know everybody in the laboratory class by his/her first name.
27. In my laboratory classes, the teacher would choose the best way for me to get the laboratory experiments done.
28. The experiments in the laboratory classes would help me to understand the theory I studied in my science classes.
29. The teacher would explain the points of safety before I start my experiments.
30. The laboratory would be pleasing for me to work in.
31. I would work with others in the laboratory classes.
32. I would decide the best way to continue the laboratory experiments.
33. My laboratory experiments would be unrelated to my science class.
34. My laboratory class would have clearer rules than my other classes.
35. My laboratory would have enough space for individual or group work.

Appendix S: Translation Back of Student Questionnaire of the QTI

Directions

This questionnaire asks to describe your teacher's behaviour.

This is NOT a test.

This questionnaires wants you to express your opinion.

The questionnaire has 48 items about your teacher and his interaction. For each statement, circle the number that corresponds to your response. For example :

	Never				Always
The teacher expresses himself/herself clearly.	0	1	2	3	4

If you think that your teacher always expresses himself/herself clearly, circle the number 4. If you think your teacher never expresses himself/herself clearly, circle the number 0. You can choose the number 1, 2 and 3. If you want to change your answer, cross it out and circle the new number.

Please answer all questions.

Thank you for your co-operation.

1. The teacher talks about his /her subject with enthusiasm.
2. The teacher trusts us.
3. The teacher appears to be uncertain.
4. The teacher becomes angry without expecting.
5. The teacher explains his/her subject clearly.
6. If we do not agree with the teacher, we can discuss about it.
7. The teacher shows signs of uncertainty.
8. The teacher becomes angry quickly.
9. The teacher gives thought and care to us.
10. The teacher is willing to explain his/her subjects again.
11. The teacher does as if he/she does not know what to do.
12. The teacher is too quick to correct us when we fail to obey a rule.
13. The teacher knows what goes in the classroom.
14. If we have something to say, the teacher will listen.
15. The teacher allows us to have responsibility.
16. The teacher is quick-tempered.
17. The teacher is a good leader.
18. The teacher is conscious when we do not understand.
19. The teacher is not sure what to do when we make silly jokes.
20. It is easy to disagree/argue with the teacher.
21. The teacher does with the feeling of confidence.
22. The teacher is patient.
23. It is easy to make the teacher seem uncertain.
24. The teacher makes foolish/mocking comments.
25. The teacher helps us with our work.
26. In the teacher's class, we can decide something.
27. The teacher thinks that we are dishonest.
28. The teacher is severe.
29. The teacher is friendly.
30. We can use our power on the teacher.
31. The teacher thinks that we do not know anything.
32. We must be silent in the teacher's class.
33. We can depend on the teacher.
34. The teacher allows us to decide when we will make experiments in class.

35. The teacher suppresses us by authority.
36. The teacher's tests are difficult.
37. The teacher has a sense of amusement.
38. The teacher allows us to avoid the penalty with a lot in class.
39. The teacher thinks that we cannot do things well.
40. The standards of the teacher are very high.
41. The teacher can accept a joke.
42. The teacher gives us much free time in class.
43. The teacher does not seem to be pleased.
44. The teacher is strict when he/she marks papers.
45. The teacher's class is agreeable.
46. The teacher is not severe/strict.
47. The teacher is suspicious.
48. We are afraid of the teacher.

Appendix T: Translation Back of Ideal Teacher of the QTI

Directions

This questionnaire asks for your opinion of an ideal teacher's behaviour.
Think about your ideal teacher and keep this ideal teacher as you respond to the following statements.

The questionnaire has 48 items about the ideal teacher. For each statement, circle the number that corresponds to your response. For example :

	Never				Always
The teacher expresses himself/herself clearly.	0	1	2	3	4

If you think that your teacher always expresses himself/herself clearly, circle the number 4. If you think your teacher never expresses himself/herself clearly, circle the number 0. You can choose the number 1, 2 and 3. If you want to change your answer, cross it out and circle the new number.

Thank you for your co-operation.

Please write your name and other details at the top of the back side of this page so that we can give you a report of the results.

1. The teacher would talk about his /her subject with enthusiasm.
2. The teacher would trust us.
3. The teacher would appear to be uncertain.
4. The teacher would become angry without expecting.
5. The teacher would explain his/her subject clearly.
6. If we did not agree with the teacher, we would discuss about it.
7. The teacher would show signs of uncertainty.
8. The teacher would become angry quickly.
9. The teacher would give thought and care to us.
10. The teacher would be willing to explain his/her subjects again.
11. The teacher would do as if he/she did not know what to do.
12. The teacher would be too quick to correct us when we failed to obey a rule.
13. The teacher would know what goes in the classroom.
14. If we had something to say, the teacher would listen.
15. The teacher would allow us to have responsibility.
16. The teacher would be quick-tempered.
17. The teacher would be a good leader.
18. The teacher would be conscious when we did not understand.
19. The teacher would not be sure what to do when we made silly jokes.
20. It would be easy to disagree/argue with the teacher.
21. The teacher would do with the feeling of confidence.
22. The teacher would be patient.
23. It would be easy to make the teacher seem uncertain.
24. The teacher would make foolish/mocking comments.
25. The teacher would help us with our work.
26. In the teacher's class, we would decide something.
27. The teacher would think that we are dishonest.
28. The teacher would be severe.
29. The teacher would be friendly.
30. We would use our power on the teacher.
31. The teacher would think that we did not know anything.
32. We would have to be silent in the teacher's class.
33. We would depend on the teacher.

34. The teacher would allow us to decide when we would make experiments in class.
35. The teacher would suppress us by authority.
36. The teacher's tests would be difficult.
37. The teacher would have a sense of amusement.
38. The teacher would allow us to avoid the penalty with a lot in class.
39. The teacher would think that we could not do things well.
40. The standards of the teacher would be very high.
41. The teacher would accept a joke.
42. The teacher would give us much free time in class.
43. The teacher would not seem to be pleased.
44. The teacher would be strict when he/she marked papers.
45. The teacher's class would be agreeable.
46. The teacher would not be severe/strict.
47. The teacher would be suspicious.
48. We would be afraid of the teacher.

Appendix U: Translation Back of Attitude to Science Lessons

Directions

The ten statements below are about your science lessons that you have studied in this class. Please share your opinion of these statements. There are no "Right" or "Wrong" answers.

Please circle:

1	If you do not agree with the statement.
2	If you are not sure.
3	If you agree with the statement.

	Disagree	Not sure	Agree
1. I look forward to studying science lessons.	1	2	3
2. Science lessons are fun.	1	2	3
3. I am pleased with the activities we do in science class.	1	2	3
4. The most interesting thing at school is science class.	1	2	3
5. I want to study more about the world we live in.	1	2	3
6. It is important to find out about new things.	1	2	3
7. I am pleased with science lessons in this class.	1	2	3
8. I like to talk to my friends about what we do in this class.	1	2	3
9. We should study more science lessons each week.	1	2	3
10. After science class, I feel satisfied.	1	2	3

Appendix V: Copy of Inclusions in First Mailout: Consent to Collect Data.

(letterhead here)
Principal
School Name
Postal Address
Postal Suburb
State, Post Code

Date

Dear Principal (Name)

We ask you to permit research data conducted by Professor Darrell Fisher, Professor David Treagust and Assistant professor Sunan Wititsiri from the National Key Centre for School Science and Mathematics, Curtin University of Technology. The key Centre aims to improve the quality of school science and mathematics.

This study examines student' outcomes and perception of physical chemistry learning by combining quantitative and qualitative methods within the same study in physical chemistry classrooms in Thailand. It is expected to encourage science teachers to assess the environment of physical chemistry laboratory classrooms at the university level, and so improve the quality of their teaching and professional life.

A number of 198 students from co-educational Rajabhat Universities will be participated in this research study in early semester. They will be asked to respond the Chemistry Laboratory Environment Inventory (CLEI) and the Questionnaire on Teacher Interaction (QTI). The questionnaires were completed about 30 minutes, and the Attitude Scale, the cognitive test and the practical test completed about 60 minutes. In the end of the semester, these 198 students are then reduced to 100 students and they will be asked to respond the actual environment of questionnaires, the Attitude Scale, the cognitive test and the practical test.

We are anonymous Individual schools, teachers and students, and identify numbers used for all the data analyses. You can contact us by phone number on 056-219100 or fax number on 056-221554.

Thank you to consider our request.

Yours sincerely

Professor Darrell Fisher, Professor David Treagust and Assistant professor Sunan Wititsiri

To parents of student:

Professor Darrell Fisher, Professor David Treagust and Assistant professor Sunan Wititsiri from the National Key Centre for School Science and Mathematics, Curtin University of Technology are investigating a study to examine students' perceptions in physical chemistry laboratory classrooms and their outcomes.

A number of 198 students from four Rajabhat Universities will be participating in this study. This study involves your child answering four questionnaires and some students are asked questions in qualitative data collection. Researcher and supervisor will be anonymous all students names.

If you agree to your child's participation in this study, please sign the slip below and return it to me. Thank you for your kind cooperation.

Yours faithfully

---(Principal)

....

I hereby permit for my child ---(Name)
to answer questionnaires related to the learning environment in a physical chemistry laboratory classroom.

---(Signature)----------------------(Date)

Appendix W: Letter of Consent to Interview Students

Dear Parents

I am a doctoral student at the Science and Mathematics Education Centre at Curtin University of Technology. This letter informs you about interview and story written to your child's science laboratory class. The reasons for interviews and story written are to collect data about classroom environments and teacher-student interactions in the physical chemistry laboratory class. I have permission from the principal and child's teacher to qualitative data collecting for my research study. I will ask some students about their perceptions' learning environments and motivate students to write short stories about their teacher behaviours. This uses ten minutes of time. These asking and story written cause students reflect learning environments and teacher behaviours in a classroom. The information collected will not be contributed to assessment and grading. Some students are selected to this qualitative part.

If you have any questions regarding in my research please contact me on 05-0505738.

Yours faithfully.

Sunan Witisiri

Doctoral student