Science and Mathematics Education Centre

Students' Learning Environment and Attitudes Toward Science in Light of the Teach Less, Learn More Initiative

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DECLARATION

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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ABSTRACT

In light of the 'Teach Less Learn More' (TLLM) initiative, the thrust of which is to teach in such a way as to guide and facilitate students to seek out information on their own accord and inculcate in them the skills and habits of life-long learning, thus equipping them to be enterprising players of the knowledge-based economy of the 21st century, greater emphasis was placed on inquiry-based learning in science in the revised science curriculum in Singapore in 2008.

As inquiry-based learning rests on the bedrock of the theory of constructivism, this research exercise was carried out to determine if there were differences between students' preferred and the actual constructivist learning environment in the classrooms using both the Preferred and Actual Forms of the Constructivist Learning Environment Survey (CLES). The students' perceptions of their teachers' interpersonal behaviour were also mapped using the Questionnaire on Teacher Interaction (QTI) (Elementary). An attempt was made to determine if there were any associations between the constructivist learning environment and students' attitude to science lessons, in terms of their enjoyment of science lessons. In addition, the associations, if any, between teachers' interpersonal behaviour and students' enjoyment of science lessons, were also examined. Information regarding the different programmes designed by schools to bring about greater engaged learning and to what extent the landscape of assessment had changed in view of the TLLM initiative was gathered using an investigator-designed survey form.

Findings indicated that generally, there was a disparity between what the students would like to have and the existing level of constructivist classroom learning environment. The disparity was most significant in the scale of 'Shared Control'. Regarding students' perception of their teachers' inter-personal behaviour, students perceived their teachers to display strong

leadership in class, characterized by a helpful, friendly and understanding disposition but strict and stringent in giving students responsibility and freedom.

No association was found between the constructivist learning environment and students' enjoyment of science lessons. However, teachers' behaviours like strong leadership, helpfulness, friendliness and understanding were positively correlated to the students' enjoyment of their science lessons.

Many schools had designed interesting activities to engage their students. However, assessment was still generally summative in nature. Though some schools tried to incorporate different types of alternative assessments, the general feeling was that different modes of alternative assessments seemed wanting at this point in time, with the age-old science practical test being the main form of performance-based assessment in all the schools surveyed.

Findings arising from research of this nature provide teachers with information about the environment in which their students are immersed in every day for many hours. Being thus informed, teachers can take steps to rectify what is lacking and the outcome will be a classroom environment that is conducive and supportive of engaged learning.

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GLOSSARY

Ability-Driven Education	The educational reform from 1997 to the present.
Constructivist Learning Environment Survey (CLES)	A questionnaire to assist teachers or researchers in their assessment of the degree to which a particular classroom's environment is consistent with a constructivist epistemology.
Curriculum Planning and Development Division (CPDD)	A division in the Ministry of Education responsible for the planning and development of the curriculum.
Curriculum 'white-space'	20% freed-up time in the curriculum for schools to implement customized school-based programmes to bring about more engaged learning.
Efficiency-Driven Education	The educational reform from 1979 to 1996.
K-W-L graphic organizer	A graphic organizer for eliciting prior knowledge.
PETALS framework	An operational tool of TLLM, encompassing five key dimensions of engaged learning.
Questionnaire on Teacher Interaction (QTI)	An instrument for obtaining and mapping the interaction pattern between teachers and students in the classroom from an interpersonal perspective.
Survival-Driven Education	The educational reform from 1959 to 1978.
Teach Less Learn More (TLLM)	An initiative in education, mooted in 2004, to foster innovation in the curriculum and teaching practices to bring about quality and choice in learning.
Thinking Schools Learning Nation (TSLN)	A vision mooted in 1997 as a formula to enable Singaporeans to compete and stay ahead in the global economy.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The pivotal role that education has played in transforming Singapore from a post-colonial society plagued with problems of national cohesion and economic survival to a politically and economically stable country is evident in the numerous educational reforms and fine-tunings that took place through the five decades, from 1959, the year Singapore attained self-government from her colonial master, right to the present. These changes, 'when viewed against the larger mosaic of the vision of Singapore leaders, are all of a piece, propelled by the logic of survival in a resource-scarce and stamp-size republic and a passion for ensuring that Singapore has a place in the community of nations' (Yip, Eng, & Yap, 1997, p. 29). Despite modifications and changes, the ideological objective of educating a child to 'bring out his greatest potential so that he will grow up into a good man and useful citizen' (Lee, 1979 cited in Yip, Eng & Yap, 1997, p. 16) has remained unchanged.

1.2 DEVELOPMENT OF EDUCATION IN SINGAPORE (1959 -PRESENT)

The development of education from 1959 right up to the present is a continuum which can be arbitrarily divided into different phases – Survival-Driven Education (1959 – 1978), Efficiency-Driven Education (1979 – 1996) and Ability-Driven Education (1997 – present). Though not officially labeled, what is happening today is discernibly a distinct phase and it can be named Innovation-Driven Education (Ho, 2006).

1.2.1 Survival-Driven Education (1959 – 1978)

The educational reform during the period from 1959 to 1978 has been referred to as the 'Survival-Driven Education' phase because the government had to provide mass education in response to the pressing need for national cohesion and economic survival.

Following self-government in 1959, the Government inherited the problems of national cohesion and economic survival. The British had left behind a diverse education system with schools using different languages (English, Malay, Chinese and Tamil) as their medium of instruction to teach vastly different curricular contents. As part of its nation-building effort and to unify standards, the Ministry of Education (or MOE, for short) brought schools under the umbrella of a national system with a common curriculum, whilst allowing schools to retain their different languages as their medium of instruction (Ho, 2006).

On the economic front, unemployment and under-employment were high as the largely entrepot economy of Singapore failed to meet the demands for jobs from the thousands of school leavers entering the job market each year. As Singapore's economic future lay in industrializing the economy, the government placed great emphasis on the learning of science, mathematics, technical studies and for the less able, vocational studies, to generate a workforce which was better educated and equipped to meet the needs of an economy which was rapidly industrializing and modernizing (Sharpe & Gopinathan, 1997).

A Five-Year Plan in education, based on the White Paper of 1956, was introduced to realize the socio-economic and political goals of the nation. The main features of this Plan were:

i) equal treatment for the four streams of education: Malay, Chinese, Tamil and English;

ii) the establishment of Malay as the national language of the new State; and

iii) emphasis on the study of Mathematics, Science and Technical subjects (Yip et al., 1997, p. 7)

This assiduous and vigorous educational reform not only created the educational infrastructure needed for the transformation of the economy, it also paved the way for the evolution of a national education system in the years to come.

Though much had been achieved economically since 1959, the year 1965 witnessed a watershed event in the history of Singapore – the separation of Singapore from Malaysia. With political independence, arose, amongst political and social problems, the economic problem of survival as a nation. 'Conventional wisdom in economics in the 1960s held that every industrialized nation, especially a small one, needed a hinterland to succeed' (Rastin, 2003, p. 3). With no hinterland and neighbours to trade with, Singapore needed to look for other opportunities and shift the emphasis from import substitution to export-oriented industries. The entire socio-economic infrastructure had to be made conducive to attract foreign investments, especially that of multi-national corporations. The Government's initial effort, up to 1965, of quantitative expansion of education with the purpose of realizing a universal primary education took on a slightly different form, with greater emphasis on and better streamlining of technical education and diversification of curriculum to make schooling economically relevant; all this to provide a manpower base for industrialization in the face of Singapore's transformation from statehood to nationhood. The 1970s were regarded as the breakthrough decade for the training thrust as 'the more systematic and unified training, coupled with a more relevant curriculum, has meant much wider occupational opportunity with commensurate benefits in terms of income and status. It has meant for Singapore a wider or more skilled pool of labour to sustain economic growth' (Gopinathan, 1997, p. 40).

Just as the educational reform after self-government but prior to independence was termed ‘quantitative expansion’, the post-independent educational reform (from 1965 – 1978) was termed ‘qualitative consolidation’ (Yip et al., 1997).

1.2.2 Efficiency-Driven Education (1979 – 1996)

With industrial and non-industrial infrastructure in place, Singapore attracted investments from major multinationals. Singapore’s economic growth strategy then shifted from low-technology industries to technology-based higher value-added industries which include precision engineering, computer peripherals, software manufacturing and financial services (Gopinathan, 1997).

By the late 1970s, certain ‘structural defects’ of the education system began to manifest themselves. A Ministry of Education Study Team, led by Dr Goh Keng Swee, then Deputy Prime Minister and Minister of Defence, identified the weaknesses, one of which was the ‘concomitant low literacy levels in the country, coupled with the problem of high education wastage in the system’ (Yip et al., 1997, p.15). Educational wastage was in the form of the system’s inability to meet the array of pedagogical and social needs of a single diversified cohort of students.

In response to the report of the committee, the New Education System (NES) was introduced in February 1979, thus kick-starting the era of Efficiency-Driven Education in 1979. The reforms implemented affected three broad areas of the Singapore education system, namely:

(i) the structure;
(ii) the curriculum; and
(iii) the organization and procedures within the Ministry of Education
(Yip et al., 1997, p. 17)

The problem of educational wastage was addressed through ability-based streaming and changes made to the curriculum to cater to the different ability groups.

In general, the reforms addressed the intrinsic issues of education and its process and aimed at producing a workforce imbued with the capacity to initiate, create and innovate.

For two decades since her independence, Singapore had enjoyed high rate of economic growth until 1985 when the Singapore economy was hard-hit by the global recession. A crucial report put up by the Economic Committee 'emphasized the need not only to educate each individual to his maximum potential, but also to develop a creative, thinking and innovative Singapore society, complete with flexible skills at every level of the economy' (Yip et al., 1997, p. 24) and included important recommendations which served as a future thrust in educational policy in the 1990s. As a consequence, the MOE, in 1986, announced that future educational policies would be guided by the following three principles:

(i) education policy must keep pace with the economy and society;
(ii) basic languages, science, mathematics and humanities will be stressed to encourage logical thinking and life-long learning; and
(iii) creativity in schools must be boosted through a 'bottom-up' approach whereby the initiative must come from principals and teachers instead of from the Ministry (Tan, 1986 cited in Yip, 1997, p. 25).

1.2.3 Ability-Driven Education (1997 – present)

Since the mid 1990s, the school leaver had been envisioned to be an individual who was not only literate and numerate but also IT enabled. It was hoped that she/he would be a loyal and committed citizen of Singapore, possessing the capacity to create and innovate, possessing the spirit of risk-taking with the passion for life-long learning and be a good team player at work. Mr Lee Yock Suan, a former Minister for Education, once said, "We will… have to shift the emphasis of the education system, beginning with our primary schools, away from the mastery of content towards the acquisition of thinking and learning skills that could last students through life. The Education Ministry is looking at ways to achieve this." (Lee, 1995 cited in Ho & Gopinathan, 1999, p. 114).

At the threshold of the new millennium was the rapid information and technological advancement which was opening up frontiers and breaking down geographical barriers such that the world became more integrated and the world economy was slowly becoming more borderless. The rapid obsolescence of existing knowledge and the advent of a borderless knowledge-based economy in the twenty-first century led to the transition of the Efficiency-Driven Education, characterized by being 'highly centralized, standardized, hierarchical, competitive and efficient' (Sharpe & Gopinathan, 2002, p. 154), to the Ability-Driven Education, characterized by quality and choices in learning wherein the curriculum had been enriched to foster innovation, creativity, informed decision-making and problem-solving. Basic literacy included computer literacy and working with information as a resource commodity (Yip et al., 1997). It was a move to prepare students for a rapidly-evolving and challenging future, a future inundated with frequent and often unsettling changes that demanded more than just academic abilities but a tenacity among the young and an entrepreneurial spirit that embraced risk-taking, creativity and imagination (Lui, 2007).

This new movement in educational reforms was encapsulated in the speech entitled 'Shaping Our Future: Thinking Schools, Learning Nation' made by the then Prime Minister, Mr Goh Chok Tong, in June 1997 at the opening of the seventh International Thinking Conference. In his speech, PM Goh explained that 'Thinking Schools, Learning Nation' (or TSLN) is 'a vision for a total learning environment, including students, teachers, parents, workers, companies, community organizations, and government'. It is 'not a slogan for the Ministry of Education but a formula to enable Singapore to compete and stay ahead' (Goh, 1997). He went on to elaborate that:

> The concept of THINKING SCHOOLS is central to this vision. THINKING SCHOOLS must be crucibles for questioning and searching, within and outside the classroom, to forge this passion for learning among our young and develop future generations of thinking and committed citizens, capable of making good decisions to keep Singapore vibrant and successful in future. Our Ministry of Education is undertaking a fundamental review of its curriculum and assessment system to see how we can better develop the creative thinking skills and learning skills required for the future. It is studying how to cut back on the amount of content knowledge that students are required to learn, and to encourage teachers and students to spend more time on projects that can help develop these skills.
>
> (Goh, 1997)

The concept of “Learning Nation’ encompasses the individual’s mindset of viewing continual retraining and life-long learning as a matter of necessity. ‘Every individual, regardless of status, must be mobilized to think actively about how he can do better in his job and improve the organization’ (Goh, 1997).

The landmark speech on TSLN, given by the then PM Goh, set the stage for more reforms that were to follow in education. Another milestone reform following the TSLN vision was the initiative of Teach Less Learn More (or TLLM). It was initiated by the Prime Minister, Mr Lee Hsien Loong, during his inaugural National Day Rally in 2004. During his speech, he mentioned that:

> Our school system has gone through many improvements over the years… But beyond what we have got, I think we cannot just do more of the same because if you just do more of the same, you are just going to get incremental improvements. You need a qualitative change, a quantum leap to get different sort of education, different sort of results. And that’s why we have been moving to a more flexible and more diverse

> education system… In fact, I think we should cut down on some of this syllabus. It would mean less pressure on the kids, a bit less rote learning, more space for them to explore and discover their talents and also more space for the teachers to think, to reflect, to find ways to bring out the best in their students and to deliver quality results. We've got to teach less to our students so that they will learn more. Grades are important – don't forget to pass your exams – but grades are not the only thing in life and there are other things in life which we want to learn in school.
>
> (Lee, 2004)

Following PM Lee's National Day Rally speech in 2004, during the annual MOE Work Plan Seminar, plans to build on the initiative of TLLM were rolled out and made known to educationists and school leaders. The basic objective of education as spelt out by the then Prime Minister Lee Kuan Yew in 1979 still remained the guiding principle even though the goal had been elaborated to read:

> We want to nurture young Singaporeans with minds that keep enquiring and a desire to use their energies to create a better society. We want to help every child find his own talents, and grow and emerge from school confident of his abilities. And we want our young to have the toughness, the 'adversity quotient', to face up to life's demands and inevitable setbacks, and be willing to work hard to achieve their dreams.
>
> (Shanmugaratnam, 2004)

The means to achieve this lofty end involves a reduced emphasis on examinations so as to focus on holistic education, giving students more choices in their studies so that they can shape and enjoy their learning and giving support to teachers to bring about quality and innovative practices in the classrooms and schools. Mr Tharman Shanmugaratnam, the then Minister for Education, further explained that innovations should originate from the grassroots level, that is, the classrooms or the schools, rather than be pushed down from the top, so that there would be enthusiasm and a sense of ownership. The role of the MOE would be that of providing top-down support for bottom-up initiatives. The central roles that teachers and school leaders play in this initiative have been described as ‘beyond filling a vessel with knowledge but lighting a fire in our young’ (Shanmugaratnam, 2004).

Thus with the two thrusts, that of providing greater support for initiatives originating from schools and giving learners greater flexibility and choice, it is hoped that there will be new peaks of excellence, in fact, ‘a mountain range, not a pinnacle’ (Lee, 2005) in the educational landscape of Singapore.

1.3 OVERVIEW OF TLLM

The TLLM initiative signifies a new milestone in the area of teaching and learning in Singapore. It is a movement towards a quality-focused education system as reflected in the speech of Mr Tharman Shanmugaratnam, the then Minister for Education, during the Work Plan Seminar in 2005 in Singapore:

> We have embarked on a new phase in education in recent years. We are shifting focus from quantity to quality and from efficiency to choice in learning. We have made many refinements in recent years, but they boil down to this basic shift in focus – from an efficiency-driven system to one focused on quality and choice in learning… The improvements in quality as we go forward will have to come from innovations on the ground – new teaching practices, new curricular responding to a school’s unique needs, and new options and chances given to students. Quality will be driven by teachers and leaders in schools, with ideas bubbling up through the system rather than being pushed down from the top.
>
> (Shanmugaratnam, 2005)

The ‘top-down support for ground-up initiative’ approach is pictorially represented in Figure 1.1.

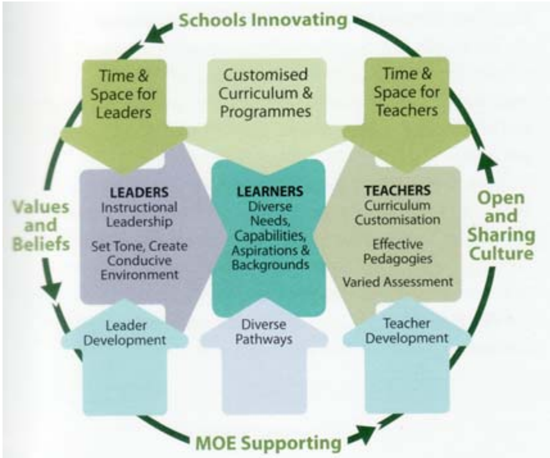

Figure 1.1. The TLLM framework.

[Source: Ministry of Education, 2007, p.7]

During the Work Plan Seminar in 2007 in Singapore, Mr Tharman Shanmugaratnam listed a three-pronged approach which will be implemented to drive the ‘top-down support for ground-up initiative’. They are:

(i) A reduction in curriculum content to free up some curriculum time called the ‘white space’ to design and implement more engaging teaching approaches or school-based programmes so that students ‘move beyond a cut-and-dried approach to knowledge’ (Shanmugaratnam, 2007).

(ii) An increase in the recruitment of teachers and para-education professionals so as to provide support in teaching and administrative workload respectively, thus enabling teachers to channel more of their time and energy to improving their teaching and interacting with their students.

(iii) Forging a two-way relationship between officers at the MOE headquarters and schools such that HQ officers lend their expertise in school-based initiatives and teachers from schools develop and share their own expertise at MOE. Gone are the days when teachers in schools would wait passively for directives to be cascaded to them by the HQ specialists.

The differentiation in the teaching and curriculum serves to create more paths and build more bridges to nurture and recognize students with different abilities and interests. It is a move away from ‘cutting tall poppies down to size’, as the Australians put it, because ‘we need all the tall poppies we can get, whether in the sports, and arts, or in Math and Literature’ (Shanmugaratnam, 2006). In this way, ‘every child will be given a first rate education’ (Shanmugaratnam, 2007) in accordance with what the Prime Minister, Mr Lee Hsien Loong, mentioned:

> Whichever school you go to, whatever your home background, we will help you develop your talents to the full. The ladders are steep, but we will provide you many ladders to success and help you climb up as high as you can.
>
> (Lee, 2007)

1.4 PETALS FRAMEWORK OF TLLM

To embark on the journey of TLLM, the Curriculum Planning and Development Division (CPDD) of the Ministry of Education identified five key dimensions of engaged learning. These five dimensions are encapsulated in the acronym, PETALS – Use of **P**edagogies, **E**xperience of Learning, **T**one of Environment, **A**ssessment and **L**earning Content. Similar to the morphology of many flowers whose petals converge at the centre, these five dimensions converge at a centre too. Occupying the centre of the framework is **S**tudent-centredness which is premised on the teacher’s role as the key architect to plan the students’ classroom experiences. A pictorial representation of the PETALS framework is shown in Figure 1.2.

Figure 1.2. The PETALS™ framework.

[Source: Ministry of Education, 2007, p.10]

1.4.1 Use of Pedagogies

Students come to school not as blank slates (*tabula rasa*) but as individuals with experiences stored in their memories and behavioural patterns that will be built on as they mature. These unique individuals are also at different levels of conceptual readiness to learn new things and display different 'learning styles', a construct with a proliferation of definitions, 'ranging from definitional statements to elaborate categorization of learning style elements' (Henson & Borthwick, 1984, p. 6). Nevertheless, its phenomenological definition is 'distinct behaviours which serve as indicators of how a person learns from and adapts to his environment. It also gives clues as to how a person's mind operates' (Gregorc, 1979, p. 234).

Educators attempt to ascertain what learning has taken place and what level of readiness there is for new learning not by crawling inside the minds of their young charges and looking around but by developing constructs about the minds of their students based on what can be seen and heard (Joyce, Weil & Calhoun, 2004). Very often, these observations lead to the revelation of the differing needs and levels of readiness manifested in the diverse student population.

Faced with a group of learners with unique and differing needs in the context of educational activities in the classrooms, it is pertinent that the teacher realizes that she cannot assume that a ‘one size fits all’ instructional approach can bring about effective teaching and learning for ‘the same fire that melts the butter hardens the egg’ (MacKinnon, 1978 cited in Smith & Renzulli, 1984, p. 44). Instead, she/he should respect this wide range of characteristics that make students unique and make informed decisions about the areas or units of study within which style differences can be incorporated (Smith & Renzulli, 1984). To do this, teachers need to employ a repertoire of teaching models which are ‘strategies based on the theories (and often the research) of educators, psychologists, philosophers, and others who question how individuals learn’ (Ellis, 1979, p. 275). Examples of models of teaching include inductive thinking, concept attainment, scientific inquiry, group investigation, role playing and direct instruction. Knowledge of how students perceive and process information or how the environment affects one’s learning ability enables teachers to plan activities or create an environment which promotes learning (Rayner & Riding, 1997). In fact, exposing students to different models of teaching increases students’ repertoire of learning strategies (Joyce et al., 2004) as researchers have determined that students are able to ‘style-flex’, that is, they are able to ‘use learning strategies other than their primary learning style when the subject matter demanded them to do so’ (Williamson & Watson, 2006, p. 349). This meta-cognitive skill of knowing how one learns and monitoring one’s own learning is a characteristic feature of effective learners. ‘Style-flex’ is feasible on the condition that ‘the instruction provided is of sufficiently high quality, in terms of such dimensions as task clarity, feedback and opportunities for practice, to facilitate learning’ (Doyle & Rutherford, 1984, p. 22).

Other than taking different learning styles into consideration, the teacher, too, needs to be mindful of the different stages of cognitive development their students are at. Thus, teachers who are sensitive to their students' differing levels of readiness to learn new concepts will plan activities in accordance with their students' conceptual level.

The role that students' prior knowledge plays in learning cannot be underestimated in constructivist teaching and learning. Knowledge is not merely transmitted from the teachers to students but is reconstructed in the minds of the students as they respond to the information using their prior knowledge (Joyce et al., 2004). Thus, teachers should adopt instructional strategies that build on students' existing knowledge so as to facilitate students' connection of new information to existing knowledge for meaningful reconstruction and retention of new knowledge.

By attending to their own actions, teachers will focus on what they can control. 'Effective teachers have diverse repertoires and are not restricted to a few pet practices' (Arends, 2004, p. 23). The acquisition, practice and utilization of an array of instructional strategies enable the teachers to 'read' and 'flex' regarding the teaching situation, giving them a sense of efficacy in the classroom (Hyman & Rosoff, 1984).

1.4.2 Experience of Learning

Teaching and learning take place in and out of the classrooms. Instructional settings can be 'dynamic settings that launch dreams and delight minds, or arid places that diminish hope and deplete energy' (Intrator, 2004, p. 21). A meaningful experience of learning takes place when the students' cognitive ability is stretched to enable them to acquire a deep understanding of what they learn, new knowledge is connected to prior knowledge to facilitate meaning construction, new knowledge acquired is applied in new contexts and students assume control of and become responsible for their own learning (MOE, 2007).

The types of thinking students engage in and the quality of learning that occurs are greatly influenced by the nature of the tasks that teachers assigned to students (Mergendoller, Marchman, Mitman, & Packer, 1988). Challenging tasks encourage student engagement, both cognitively and affectively, thus leading to greater depth of understanding. However, though challenging the tasks must be, the level of difficulty should not be way beyond the conceptual development of the students. Instead, tasks should be designed and structured within the students' zone of proximal development, defined as 'the distance between the actual development level as determined by independent problem solving and the level of potential development as determined by problem-solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978 cited in Henderson, 1986, p. 408). Tasks of appropriate cognitive demand minimize frustration but maximize potential development, thus infusing in students a sense of self-efficacy which is an impetus to greater motivation to become engaged learners seeking meaning and understanding in their journey of learning.

Since teaching and learning are two sides of the same coin, learning for meaning and understanding is understandably coupled with teaching for meaning and understanding. The instructional strategies in many learning situations are influenced by the constructivist learning theory which has 'at its centre the importance of meaning as constructed by individual in their attempt to make sense of the world' (Driver & Oldham, 1986, p.106). Many educators are aware that students are more likely to make meaning and gain understanding when new information is linked to prior knowledge, facts are related to 'big ideas', essential questions are explored and new learning is applied in new contexts (McTighe, Seif, & Wiggins, 2004). Accompanying this constructivist approach is the change in the role of teachers; from being transmitters of knowledge to facilitators of student learning and concept development, taking into account the student's existing ideas (Bell & Gilbert, 1996). Through constructivist teaching and learning, the spirit of inquiry and problem-solving is fostered in many instructional settings.

The assigning of academic tasks pitched appropriately at students' current skill levels to bring about development of new skills, and the changing role of teachers as facilitators of student learning, are directed towards the goal of nurturing students to become self-regulated learners who are meta-cognitively, motivationally and behaviourally active participants in their own learning process (Zimmerman, 1986). Meta-cognitively, they are aware of personal learning strategies, state of knowledge, their learning progress and requirements of the situations. They also monitor and evaluate their thinking capacities and limitations through reflections (Wilson & Johnson, 2000). Motivationally, students perceive themselves as competent, self-efficacious and autonomous. Behaviourally, students select structure and create an environment that optimizes their learning.

With research showing that maximum learning and better student performance are the outcomes of engaged and self-regulated learning (Marks, 2000; McCombs, 1986; Skinner & Belmont, 1993; Zimmerman, 2002), it is thus pertinent that curriculum and instructional approaches are designed to provide opportunities for students to experience intellectual and social vigour in their learning experience.

1.4.3 Tone of Environment

The tone of environment refers to the quality of learning environment that supports learning. The learning environment is 'the overall climate and structure of the classroom that influence how students respond to and remain engaged in learning tasks; the context in which teaching acts are carried out' (Arends, 2001, p. 476). Regardless of the methods of instruction, the teacher is certainly the central figure in any instructional setting. How the teacher behaves in a learning environment determines how students feel; whether they are comfortable, happy, motivated, anxious or disengaged. In fact, the important role a teacher plays in determining the psychosocial aspects of the learning environment is summed up in the following statement:

> I've come to a frightening conclusion that I am the decisive element in the classroom. It's my personal approach that creates. It's my daily mood that makes the weather. As a teacher, I have a tremendous power to make a child's life miserable or joyous. I can be a tool of torture or an instrument of inspiration. I can humiliate or humour, hurt or heal. In all situations, it is my response that decides whether a crisis will be escalated or de-escalated and a child humanized or dehumanized.
>
> (Ginott, 1971, p. 13)

Thus, it can be seen that other than the physical environment, the emotional and psychological aspects of the environment play a significant role in the learning of an individual. Abraham Maslow, one of America's foremost mid-twentieth century psychologist, posited that human beings have a hierarchy of needs that they strive to satisfy. As such, the basic physiological needs of students for security, sense of belonging and being loved and respected have to be met before the higher growth needs such as self-understanding, living up to one's potential and self-actualization can be fulfilled. The implication for instruction in the classroom is that the environment must be such that it exudes an atmosphere of acceptance, care and warmth in which mistakes are forgiven and success celebrated in the process of learning.

A conducive classroom social environment encompasses four broad dimensions; teacher support, interaction, mutual respect and students' task-related beliefs (Anderson, Stevens, Prawat, & Nickerson, 1998; Ryan & Patrick, 2001).

1.4.3.1 Teacher Support

Teacher support refers to 'the extent which students believe teachers value and establish personal relationships with them' (Ryan & Patrick, 2001, p. 440). This dimension is generally characterized by friendliness, understanding, concern, dedication and dependability. When students perceive their teacher as supportive, they possess the confidence and assurance that their differing opinions or ways of approaching certain tasks are respected and accommodated instead of belittled. This leads to a positive academic self-concept and efficacy which in turn may bring about increased self-regulated learning.

1.4.3.2 Interaction

Researchers into constructivism believe that not only is knowledge personally constructed, but it is also socially mediated (Prawat, 1993; Taylor, 1993 as cited in Treagust, Duit, & Fraser, 1996). In other words, the process of an individual's construction of meaning is embedded in the social setting of which the individual is a part. As such, interaction amongst students is a critical component of student-centred instructional approaches. Students who work with their peers as a cooperative unit not only develop their social skills but also have a greater array of resources to tap and are exposed to differing perspectives and opinions than if they were working individually. In fact, the interaction amongst classmates is found to support self-regulated or 'co-regulated' learning (McCashin & Good, 1996 cited in Ryan & Patrick, 2001).

1.4.3.3 Mutual Respect

In a mutually respectful environment, be it between teachers and students or amongst students, social skills of cooperation and team spirit can be taught and honed and the students grow as an entity in their learning environment, a microcosm of the working world that will be encountered by the students in the near future. The psychological feelings of safety and comfort reduce the anxiety about making mistakes and as a consequence, according to resource allocation theory, the individual is able to channel working memory from task-irrelevant thoughts to more productive ones to meet the demands of the tasks (Ellis & Ashbrook, 1987 cited in Ryan & Patrick, 2001). Thus, a classroom in which mutual respect prevails promotes students' self-regulated learning and academic efficacy.

1.4.3.4 Students' Task-related Beliefs

Task-related beliefs encompass beliefs about self-competence in academic domains, beliefs about control over success and failure and beliefs about the intrinsic value of performing such tasks in an independent manner (Anderson et al., 1998). In order to bring about positive task-related beliefs in students, teachers need to subscribe to the instrumental-incremental theory of intelligence, whereby intelligence is regarded as consisting of a repertory of skills and knowledge which can be increased, as opposed to the view that intelligence is an 'entity' and therefore is a stable, global trait (Marshall & Weinstein, 1984). Teachers will convey to students, both verbally and through instructional strategies, that each student has the ability to improve regardless of current status or rank, that different paces and modes of learning of different individuals are expected and accepted and peer coaching is encouraged. To create a stable and predictable learning environment, teachers structure information; explicitly linking ideas from specific to general or vice versa, from the unknown to the familiar and providing information on procedural details and expected appropriate student behaviour. Opportunities are created for students to exercise choice of tasks, monitor their own task performance and be accountable for task completion, thus developing in them an internal locus of control (Anderson et al., 1998).

1.4.4 Assessment

Assessment, defined as 'the process of obtaining information that is used to make educational decisions about students, to give feedback to the student about his or her progress, strengths, and weaknesses, to judge instructional effectiveness and curricular adequacy, and to inform policy' (American Federation of Teachers, 1990, p. 30) is an integral part of the learning process. Arends (2001) asserts that assessment can be a form of timely feedback used to engage and support students in their learning if it fulfills the following:-

(i) it is in congruence with instructional objectives;
(ii) it measures a broad spectrum of the cognitive domains ranging from the recall of factual information to understanding, analysis and creative application of principles; and
(iii) it measures what it claims to measure (validity) and produces dependable, consistent scores for persons who take it more than once over a period of time (reliability).

The thrust of the TLLM initiative, being to encourage teachers to refrain from spoon-feeding students with information but to teach in such a way as to guide and facilitate them to seek out information in their learning, thus inculcating in them the skills and habits for life-long learning, implies a reform in the way teaching and learning are carried out in the instructional settings in and outside the classrooms. Since sound educational practice requires teaching, learning and assessment to be aligned, any change in teaching and learning will inevitably require a change in assessment.

The current assessment system encompasses two domains of assessments; summative and formative. In summative assessment, the teacher forms a judgmental notion of student learning and progress gleaned from disparate areas (Bell & Cowie, 2001). These assessments are recorded as marks or grades for ranking and selection purposes. Formative assessments are designed to help the students' progress as such assessments provide the teachers and learners with feedback; information about whether the learning objectives are attained and areas of weakness, strength and potential (Lloyd-Jones & Bray, 1986).

The implementation of the TLLM initiative is the impetus for the increased importance accorded to performance-based formative assessment. This is of no surprise since the ultimate goal of the TLLM initiative is to bring about engaged and self-regulated learning. As opposed to tests, particularly multiple-choice tests, whose focus is outward rather than inward, on material rather than on personal constructions and which answers the overarching question, 'Do you know this material?', performance tasks in formative assessment invite students to exhibit what they have learned and internalized through application and it answers the overarching question, ‘What do you know?’ (Brooks & Brooks, 1993). Performance tasks are challenging, authentic and multi-disciplinary, requiring students to collaborate with peers, teachers, family members and others in the community outside school, resulting in students shifting from pure memorization of facts to active multi-faceted learning which in turn leads to higher-order thinking in students, transforming them into problem-solvers over time (National Research Council, 1996).

With performance-based assessment, teachers play a greater role in assessment when they design performance assessment programmes and craft standardized scoring procedures; the latter task may be carried out jointly with the students. Involving students in the crafting of assessment criteria or informing them in advance of such assessment rubrics takes the guesswork out of evaluation. Students will pitch their performance to the expectations, and hence experience greater success in their performance tasks, a motivational drive for engaged learning.

The element of reflection inherent in formative assessment requires students to reflect on their learning process, become more aware of how they learn, expand their repertoire of learning strategies and evaluate the effectiveness of strategies used. Given this personal involvement in their learning, students become more motivated and take responsibility for their own learning (Davies & Wavering, 1999).

Given the complexity of understanding an individual’s performance or success, it is nearly impossible to use a single tool to do the job of fairly assessing student performance. As such, the National Centre for Research on Evaluation, Standards and Student Testing advocates that an assessment made up of multiple assessments (including norm-referenced, criterion-referenced assessments, alternative assessments and classroom assessments) can produce ‘comprehensive, credible, dependable information upon which important decisions can be made about students…' (Critical Issue, 1997).

In addition to being multi-dimensional, assessment, being an integral part of the learning experience, must 'respond to the changing needs of society, to new branches of knowledge, to changing perceptions of its role and to refinements in its techniques' (Lloyd-Jones & Bray, 1986, p. 13). Only then will assessment lead to improved instruction and learning and as a consequence, produce not merely doers and followers but thinkers and innovators who are able to meet the challenges of the global and knowledge-based economy of the 21st century.

1.4.5 Learning Content

Learning content refers to what students learn. This comprises knowledge, skills and values (or attitudes) which are aligned with the attainment of educational goals. Being a vital component of curriculum, it is pertinent that the learning content be designed to challenge and refine students' thinking, leading to educational engagement defined as 'the psychological investment required to comprehend and master knowledge and skills explicitly taught in school' (Wehlage, Rutter, Smith, Lesko, & Fernandez, 1989, p. 177).

The initiative of TLLM encapsulates the idea that 'less is more'. 'Less' refers to less mindless coverage of curriculum and acquisition of superficial knowledge, 'more' refers to greater mastery of fewer topics, greater complexity of understanding and more thoughtfulness (Wehlage et al., 1989).

In order to mitigate the obsessive coverage of curriculum, a process that leads to the fragmentation of knowledge, the inhibition to gaining greater competence and undermining whatever interest that subject matter might hold for students, learning content should be one of authentic learning which is characterized by the application of relevant knowledge and skills to solve real problems. Such learning involves 'finding and focusing on a problem;

identifying relevant information, categorizing, critically analyzing, and synthesizing that information; and effectively communicating the results' (Renzulli, Gentry, & Reis, 2004, p. 74). At this juncture, it is worthwhile to distinguish problem-solving from doing exercises. The latter requires students to solve problems by recalling, analyzing and applying techniques or skills in sequential steps to obtain a solution or different solutions; while in real life problem-solving are activities in which the means of solving are not immediately known or obvious and may require the discovery of new information or the manipulation and realignment of prior knowledge into a new configuration (Chin, 1993).

The moving force behind authentic learning is authentic instruction which encompasses the five standards: higher-order thinking, depth of knowledge, connectedness to the world beyond the classroom, substantive conversation and social support for student achievement (Newmann & Wehlage, 1993). It can be inferred from the characteristics of authentic learning and the five standards of authentic instruction that authentic learning and instruction rest on the bedrock of constructivism. To ensure that the idea of authentic learning and instruction takes off successfully in schools, it is pertinent that constructivism becomes a culture – a set of beliefs, norms, and practices that constitute the fabric of school life, rather than isolated instructional strategies grafted on to otherwise traditional teaching techniques for it is this culture of constructivism that affects students' relationship with their peers and teachers, their interaction with the subject matter, their patterns of communication and even the notion of 'what learning is good for' (Windschitl, 1999).

1.5 PRIMARY SCIENCE EDUCATION IN SINGAPORE

1.5.1 Goals of Science Education in Singapore

Primary science education in Singapore serves to equip the pupils with the skills and processes needed to acquire knowledge about the natural world, as reflected in the following:

> The study of science is an attempt to understand the natural world. As such, science may be broadly thought of as comprising a body of knowledge about the natural world; and the skills and processes by which this knowledge is acquired, synthesized, evaluated and applied. Science Education, on the other hand, refers to the training necessary for learners to acquire this body of knowledge and the set of skills.
>
> (CPDD, 2001, p. 1)

In Singapore, primary science is formally introduced at primary three instead of primary one to allow students more time for the acquisition and mastery of English Language, Mother Tongue and Mathematics during their first two years of formal education. The two main general goals of science education in Singapore are:

(i) to inculcate scientific literacy for all, so that people can make informed choices in their personal lives and approach challenges in the workplace in a systematic and logical way; and

(ii) to produce, in the various scientific disciplines, competent professionals who can carry out research and development work at the highest level (Low & Yeo, 2003).

1.5.2 Science Curriculum Framework

The Science Curriculum Framework is derived from the Policy Framework for the Teaching and Learning of Science. It encapsulates the thrust of science education in Singapore to prepare students to be sufficiently adept as effective citizens, able to function in and contribute to an increasingly technologically-driven world. Figure 1.3 is a pictorial depiction of the framework.

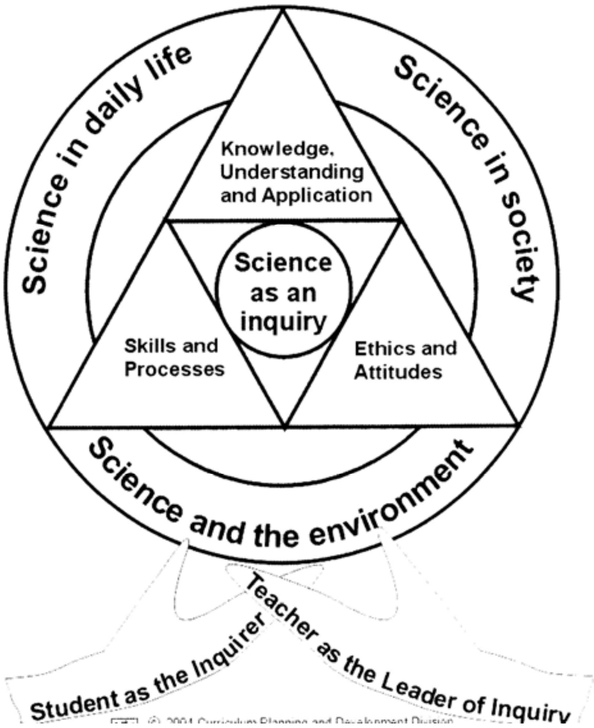

Figure 1.3. The science curriculum framework.
[Source: CPDD, 2008, p.1]

Central to the framework is the inculcation of the spirit of scientific inquiry which is ‘a systematic and investigative performance ability which incorporates unrestrained inductive thinking capabilities after a person has acquired a broad and critical knowledge of the particular matter through formal learning processes’ (Kyle, 1980). As such, with reference to the framework, the conduct of inquiry is founded on three domains of (a) knowledge, understanding and application, (b) skills and processes and (c) ethics and attitudes. It is grounded in knowledge, issues and questions that pertain to the roles of science in daily life, society and the environment. It is evident that the curriculum not only emphasizes science literacy but also scientific literacy so that in the long run, there will emerge a scientifically literate society where people are able to make informed choices and approach challenges in a systematic and logical way (Lee, Lee, Chin, & Yap, 2003).

The ethics and attitudes embodied in the curriculum framework seek to nurture the student's scientific mental attitudes like curiosity, creativity, integrity, objectivity, open-mindedness, perseverance and responsibility (CPDD, 2008). With their spirit of curiosity encouraged, students will most likely enjoy science and value it as an important tool in their exploration of their natural and physical world. There is the transformation of the learners from being consumers of knowledge to being producer-consumers (Fish & Goldmark, 1966). The roles that teachers play as leaders of inquiry are that of facilitators and role models of the inquiry process in a learning environment that encourages and challenges students to develop their sense of inquiry.

1.5.3 Syllabus Framework

The primary science syllabus comprises the knowledge, skills and attitudes that all pupils should acquire and a component of freed up curriculum time known as the 'white space' as a result of a 20% reduction in curriculum content. This is to enable teachers to adopt more engaging teaching and learning pedagogies and/or to implement customized school-based programmes which meet the aims of the syllabus.

Table 1.1 presents an overview of the primary science syllabus.

Table 1.1
Overview of the Science Syllabus

Themes	Syllabus Requirement * Lower Block (Primary 3 and 4)	 ** Upper Block (Primary 5 and 6)	White Space
Diversity	• Diversity of living and non-living things (General characteristics and classification) • Diversity of materials		The freed up curriculum time is to enable teachers to use more engaging teaching and learning approaches, and/or to implement customised school-based programmes as long as the aims of the syllabus are met. This enables teachers to make learning more meaningful and enjoyable for their students.
Cycles	• Cycles in plants and animals (Life cycles) • Cycles in matter and water (Matter)	• Cycles in plants and animals (Reproduction) • Cycles in matter and water (Water)	
Systems	• Plant system (Plant parts and functions) • Human system (Digestive system)	• Plant system (Respiratory and circulatory systems) • Human system (Respiratory and circulatory systems) • Cell system • Electrical system	
Interactions	• Interaction of forces (Magnets)	• Interaction of forces (Frictional force, gravitational force, force in springs) • Interaction within the environment	
Energy	• Energy forms and uses (Light and heat)	• Energy forms and uses (Photosynthesis) • Energy conversion	

[Source: CPDD, 2008, p.10]

The knowledge content of the syllabus is organized into five themes, namely, 'Diversity', 'Cycles', 'Systems', 'Interactions' and 'Energy'. Structuring the curriculum around 'big ideas' and broad concepts is a critical dimension of constructivist pedagogy because 'students are most engaged when problems and ideas are presented holistically rather than in separate, isolated parts' (Brooks & Brooks, 1993, p. 46). This phenomenon can be clearly illustrated in the example of assembling a model aircraft. The package contains precise written directions in sequential order. However, one cannot help but refer every now and then to the picture of the aircraft on the box in the process of assembling it because one needs to see the 'whole' before being able to make sense of the parts. The topics under each theme are not to be viewed as compartmentalized blocks of knowledge. On the contrary, they are related in one way or another and students are to be taught and made aware of their inter-connectedness with topics under each different theme. For example, under the theme of 'Energy' is the topic 'Photosynthesis'. Under the themes of 'Cycles' and 'Interactions' is, respectively, the topic 'Life cycle in plants' and 'Interaction within the environment' which includes concepts of food chains and food webs. Students should be able to see that concepts in these three topics, though under three different themes, are inter-related in that photosynthesis is the food generating process to provide plants with energy to carry out life processes like reproduction and it is also this ability to make food that plants are termed 'food producers' and they play an important role in the ecological food relationships.

This body of concepts subsumed under the five themes and the acquisition of skills and processes like observing, analyzing, evaluating, creative problem-solving and decision-making, just to name a few, enable students to inquire things and phenomena around them. This provides a broad-based understanding of the environment and serves as a foundation for students' further study of science.

Another feature inherent in the syllabus is the spiral approach characterized by the revisiting of concepts, skills and processes at different levels and with increasing depth. This spiral approach recognizes students' cognitive readiness and fulfills the psychological consistency of expected outcomes in the domains of inquiry by 'not demanding a behaviour or activity which the student's developmental, intellectual, and/or personality characteristics do not allow him or her to perform' (Welch, Klopfer, Aikenhead, & Robinson, 1981, p. 42). With this approach, students are able to gradually attain mastery of concepts, skills and processes by building upon their existing concepts and skills.

The curriculum 'white space' makes possible, to a certain extent, an in-depth study of a given topic, leading from superficial exposure to a rich and complex understanding. It is a move away from the addiction to curriculum coverage which 'fosters the delusion that human beings are able to master everything worth knowing' (Newmann, 1988, p. 346). The alternative to coverage is depth and depth has been summarized as 'less is more' (Sizer, 1984, cited in Newmann, 1988, p. 347). 'Less' in this context does not mean less knowledge or information but less mastery of information that provides only a superficial acquaintance with a topic. Less coverage with depth is more likely to result in lasting retention and transfer of knowledge, cultivation of thoughtfulness to cope reasonably well with the virtual galaxy of material worth knowing, following the knowledge explosion of this century (Newmann, 1988). Indeed, Sizer's concept of 'less is more' is congruent to the initiative of TLLM in the educational landscape of Singapore.

1.6 RATIONALE OF THE STUDY

When the idea of TLLM was mooted, the PETALS framework was conceptualised by the CPDD. Encapsulated in the PETALS framework were five dimensions of engaged learning, all of which were guided by the concepts of constructivism, learning environment and assessments.

The teaching and learning of science in primary schools experienced a paradigm shift when the PETALS framework was put into operation. The primary science syllabus was revised and implemented in 2008, resulting in the then Primary 3 and 4 cohort of students being the pioneer cohort of the revised syllabus. Amongst the changes is a content reduction in the curriculum such that there is a 20% freed-up time called the curriculum ‘white space’ during which schools are able to implement their customized school-based programmes to bring about more engaged learning in pupils (MOE, 2006).

The development of the curriculum is based on the ‘Understanding by Design’ model of Grant Wiggins and Jay McTighe and the pedagogy emphasized is that of inquiry-based learning, a strategy that encapsulates the spirit of scientific investigation and the development of knowledge about the natural world (Flick & Lederman, 2004). As inquiry-based learning lies on the bedrock of constructivism, educators work towards creating a constructivist science learning environment in the classrooms. The tone of the classroom environment with respect to interactions between teachers and students became an important aspect of teaching and learning.

Schools are reassessing the number of school-based tests and examinations and experimenting with different approaches to assessing how pupils are progressing (MOE, 2005). Clearly, there is a growing belief in alternative assessments as instruments to provide an insight into pupils’ ongoing reflective practices and integrative thinking other than providing feedback on content mastery (Davies & Wavering, 1999).

The exciting changing landscape in the teaching and learning of science, impacted by the TLLM initiative, became an intriguing area into which a research study could be made and as such, this research was carried out.

1.7 AIM OF THE STUDY

The objective of the research is to investigate the impact that TLLM has on science education in Singapore with respect to the level of prevalence of the constructivist science learning environment and its association with students’ attitude towards science lessons and the students’ perception of their science teachers' interpersonal behaviour. In addition, the study also aims to gain an insight into the different customised school-based programmes and the different modes of alternative assessments designed by different schools to bring about greater engaged learning in students.

1.8 RESEARCH QUESTIONS

The aim of the study leads to the following research questions:

(i) Are the CLES (Actual and Preferred), QTI and Attitude Scale valid and reliable instruments for use in Singapore?

(ii) Are there significant differences between the actual and preferred levels of constructivism in the classroom as perceived by eleven-year-olds?

(iii) Are there any significant associations between the constructivist learning environment and the attitude of students to science lessons?

(iv) What are the students' perceptions of the classroom learning environment as portrayed by their science teachers' interpersonal behaviour?

(v) What are some of the customised programmes being used by teachers to bring about engaged learning in pupils?

(vi) What forms of summative and formative assessments have been implemented in schools as a consequence of the TLLM initiative?

1.9 OVERVIEW OF METHODOLOGY

With the modification of curriculum designs and autonomy given to schools through the 20% 'white-space' and greater emphasis on inquiry-based teaching and learning, an approach founded on the principle of constructivism, the classroom psychosocial learning environment perceived by eleven-year-olds and their attitude towards science are investigated through the administration of the Preferred and Actual Forms of the *Constructivist Learning Environment Survey* (CLES). The CLES 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 for teachers to reflect on their epistemological assumptions and reshape their pedagogy (Taylor, Dawson, & Fraser, 1995; Taylor, Fraser, & Fisher, 1997 cited in Fraser, 1998, p. 534). The *Questionnaire on Teacher Interaction* (QTI), a modified 48-item questionnaire which has its origin in the 1980s in The Netherlands (Wubbels, Creton, Levy, & Hooymayers, 1985 cited in Fisher, Rickards, & Fraser, 1996, p. 30) and a survey entitled *Attitude to Science Lessons* were also used. Using the class mean as the unit of analysis, the results were analyzed quantitatively. Furthermore, the administration of another questionnaire to the head of the science department of various schools and the qualitative analysis of the responses was designed to shed some light on the customized school-based programmes and alternative assessments designed by different schools in light of the TLLM initiative.

1.10 CHAPTER SUMMARY

The educational landscape of Singapore has been transformed over a time span of five decades, from 1959, the year Singapore attained self-government from her colonial master, right to the present, an era inundated with rapid advancement in science and technology and characterized by a global and knowledge-based economy. In general, the TLLM initiative serves to nurture students into future generations of citizens who are creative, and innovative, imbued with the spirit of risk-taking and the passion for life-long learning. To aid schools on this exciting journey of TLLM, the PETALS Framework which encapsulates the five key dimensions of engaged learning was drawn up by the CPDD of MOE and cascaded to schools to serve as a guide. In the realm of science education whose curriculum has undergone revision in order to move in tandem with the TLLM initiative, the objective of inculcating in students the spirit of scientific inquiry has been accorded with greater and renewed importance. Scientific literacy is recognized to be of equal importance as science literacy.

This research study which adopts a quantitative as well as a qualitative approach to investigate students' perception of their psychosocial learning environment and their attitude towards science and the different customized school-based programmes and assessments should, to a certain extent, shed some light on the impact TLLM has on the teaching and learning of science in primary schools.

Following this chapter, in Chapter 2, is the literature review of constructs associated with this research study. They are, namely, classroom learning environment, constructivism, inquiry-based learning and attitudes toward science. The instruments and methods used in the collection and analysis of data are described in detail in Chapter 3, together with a discussion on the ethical consideration involved in data collection. The results obtained from the analysis of the data are discussed in Chapter 4. The implications and limitations of this research study, and suggestions for further research constitute the final points of discussion found in Chapter 5, the concluding chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This research study revolved around inquiry-based learning in science, with constructivism as its underlying principle. As such, some basic ideas of inquiry-based learning and constructivism are discussed and some issues concerning the constructivist classroom learning environment examined. Tied to this study was the examination of students' attitude towards science. Thus, the concepts of scientific attitude and attitude towards science are also reviewed in this chapter.

2.2 CLASSROOM LEARNING ENVIRONMENT

It is an undeniable fact that students spend a vast amount of time in class. As such, they have a stake in what happens to them in class and the perceptions of their experiences in the classrooms are of great significance. An evaluation of the educational process is not complete without the assessment of the learning environment in which students immerse themselves for many hours of their lives.

2.2.1 Historical Perspectives on Classroom Environment Research

The study of learning environment dates back to the 1930s, pioneered by Lewin and Murray and their followers such as Pace and Stern (Fraser, 1998). Lewin's early but seminal work on field theory recognized that human behaviour was determined by the interaction of the environment and personal characteristics of the individual, the essence of which was encapsulated in the familiar Lewinian formula, B=f(P,E).

Following Lewin's approach, Murray proposed a needs-press model to represent analogously the person and the environment. 'Personal needs refer to motivational personality characteristics representing tendencies to move in the direction of certain goals, while environmental press provides an external situational counterpart which supports or frustrates the expression of internalized personality needs' (Fraser, 1986, p. 6). The needs-press theory was then popularized and elucidated by Pace and Stern (Stern, 1958, 1970 cited in Fraser, 1986, p. 6).

Building on the ideas of Lewin, Murray and their followers were Herbert Walberg and Rudolf Moos who began their seminal independent research programmes forty years ago. Walberg developed the widely-used *Learning Environment Inventory* (LEI) as part of researching and evaluating the activities of Harvard Project Physics. Rudolf Moos conducted programmes of research on various social environments like university residences, hospital wards, community-based treatment settings, juvenile and adult correctional facilities, military companies, families, social and therapeutic groups and work milieus. Through his work, he found that the individual dimensions that characterized the diverse psychosocial environments could be broadly categorized into three dimensions, namely 'Relationship Dimension', 'Personal Development Dimensions' and 'System Maintenance and System Change Dimensions'. The 'Relationship Dimension' encompasses the identification of the nature and intensity of personal relationships within the environment and the assessment of people's involvement in the environment and the extent of help and support they provide for one another. The 'Personal Development Dimensions' assess basic directions along which personal growth and self-enhancement tend to occur and 'System Maintenance and System Change Dimensions' concern the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change (Moos, 1974, 1975, 1976, 1979). Any instrument assessing human environments should preferably cover each of the three basic dimensions. Moos, during the process of developing the first of his social climate scales, developed the *Classroom Environment Scale (CES).*

The pioneering work of Walberg and Moos on perceptions of classroom environment was a font from which numerous major research programmes on classroom learning environment spring forth (Fraser, 1998) and it was the same pioneering work which served as a model for the development of a range of instruments over the next two decades or so (McRobbie, Fisher, & Wong, 1998).

2.2.2 Approaches to Studying Classroom Environments

There are three common approaches to studying classroom environment. The 'objective' method of direct observation by an external detached observer in systematic coding of classroom communication and events according to some category scheme has been termed 'alpha press' by Murray. As opposed to the 'objective' method is the 'subjective' approach whereby learning environment is assessed based on the students' and teachers' perceptions of the learning environment. Murray used the term 'beta press' to describe the environment as observed by these milieu inhabitants. The third approach involves the application of the techniques of naturalistic inquiry, ethnography, case study or interpretive research (Fraser, 1998).

2.2.3 Advantages of Using Perceptual Measures

There are several advantages in using perceptual measures to study classroom learning environment as compared to using the method of classroom observation.

2.2.3.1 Cost

It is more economical to adopt the paper-and-pencil perceptual measures than classroom observation techniques as the latter involves the expense of trained observers (Fraser & Walberg, 1991).

2.2.3.2 Coverage

Perceptual measures are based on the experience of students and teachers over a span of many lessons while observational data are usually restricted to a very small number of lessons. Furthermore, perceptual measures involve the pooled judgement of all students in a class as opposed to observation techniques which typically involve only a single observer (Fraser & Walberg, 1991).

2.2.3.3 Ownership

Gathering perception of students and teachers has the advantage of characterizing the class through the eyes of the actual participants, capturing data which an appointed observer could miss or consider unimportant (Fraser, 1986). Because students have encountered many different learning environment and spent sufficient time in class to form accurate impressions, they are in a better capacity than a detached observer in making good judgments about classroom environment. As such, a more accurate portrayal of the classroom environment is available.

2.2.3.4 Perceptions versus Real Situations

As students' behaviour is determined more by their perceptions than the real situation, it is thus more important to obtain perceptual measures than vivid descriptions of the classrooms.

2.2.3.5 Perceptions versus Observed Variables

Perceptual measures of classroom environment have been found to account for more variance in student learning outcomes than that accounted for by observed variables.

2.2.3.6 Low and High Inference Measures

Perceptual measures of classroom environment tend to focus on high inference variables which measure psychological significance that classroom events have for students and teachers, requiring them to make a judgement about the meaning of classroom events (e.g. the degree of teacher friendliness) while classroom observation tends to focus on low inference variables which tap specific explicit phenomena (e.g. the number of student questions) (Rosenshine, 1970).

2.2.4 Instruments for Assessing Classroom Environment

Nine historically important and contemporary instruments, namely, the *Learning Environment Inventory* (LEI), *Classroom Environment Scale* (CES), *Individualized Classroom Environment Questionnaire* (ICEQ), *My Class Inventory* (MCI), *College and University Classroom Environment Inventory* (CUCEI), *Questionnaire on Teacher Interaction* (QTI), *Science Laboratory Environment Inventory* (SLEI), *Constructivist Learning Environment Survey* (CLES) and *What Is Happening In This Class* (WIHIC) questionnaire, are briefly described in the following paragraphs.

2.2.4.1 Learning Environment Inventory (LEI)

Development and validation of a preliminary version began in the late 1960s in conjunction with the research and evaluation of Harvard Project Physics (Fraser, Anderson, & Walberg, 1982). The final version contains 15 scales each with seven items describing typical school classes. Respondents express their degree of agreement or disagreement with each item using four responses alternatives of ‘Strongly Disagree’, ‘Disagree’, ‘Agree’ and ‘Strongly Agree’. Some items require reverse scoring.

2.2.4.2 Classroom Environment Scales (CES)

Developed by Rudolf Moos from a comprehensive programme of research involving perceptual measures of various human environment including psychiatric hospitals, prisons, university residences and work milieus, the final version of the CES contains nine 10-item scales with True-False response format in each scale (Moos, 1974, 1979).

2.2.4.3 Individualized Classroom Environment Questionnaire (ICEQ)

Assessing dimensions which distinguish individualized classrooms from conventional ones, the final published version of the ICEQ is a 50-item questionnaire, with ten items under each of the five scales. Each item is responded on a five-point scale with responses like ‘Almost Never’, ‘Seldom’, ‘Sometimes’, ‘Often’ and ‘Very Often’. Reverse scoring is required for many items (Fraser, 1998).

2.2.4.4 My Class Inventory (MCI)

Simplified from the LEI, the final version of MCI is suitable for use at the primary school level and user-friendly, especially for those who have reading difficulties with other instruments as the MCI contains only 38 items which are simply worded with either a two-point (Yes-No) or three point (‘Seldom’, ‘Sometimes’ and ‘Most of the time’) response format (Fraser et al., 1982).

2.2.4.5 College and University Classroom Environment Inventory (CUCEI)

The CUCEI was developed for use in small classes (about 30 students) at tertiary institutions like colleges and universities. The final form of the CUCEI has seven scales, each containing seven items with four responses (‘Strongly Agree’, ‘Agree’, ‘Disagree’, ‘Strongly Disagree’). Reverse scoring has to be carried out for approximately half of the items (Fraser & Treagust, 1986).

2.2.4.6 Questionnaire on Teacher Interaction (QTI)

Originating in The Netherlands, the QTI focuses on the nature and quality of interpersonal relationships between teachers and students and assesses perceptions of eight behaviour aspects. An economical 48-item version has been developed with each item having a five-point response scale ranging from 'Never' to 'Always' (Fraser, 1998). Being an instrument of choice in this research, the QTI is elaborated in Section 2.2.6.

2.2.4.7 Science Laboratory Environment Inventory (SLEI)

As the name implies, the SLEI was developed to assess the environment of science laboratory classes at the senior high school or higher education levels. It has five scales, each with seven items and the five responses alternatives are 'Almost Never', 'Seldom', 'Sometimes', 'Often' and 'Very Often' (Fraser, Giddings, & McRobbie, 1995).

2.2.4.8 Constructivist Learning Environment (CLES)

The CLES was developed to enable teachers and researchers to assess the degree of constructivist epistemology inherent in each classroom environment so that teachers can reflect and reshape their teaching practices (Taylor, Fraser, & Fisher, 1997). The CLES is described in greater details in Section 2.2.5 as it was an instrument used in this research.

2.2.4.9 What Is Happening In This Class (WIHIC)

WIHIC is the product of combining modified versions of the most salient scales of a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns like equity and constructivism (Fraser, McRobbie, & Fisher, 1996). The final form contains seven scales with eight items.

Table 2.1 shows an overview of the nine instruments previously described. Note that with the exception of the MCI, all the instruments have scales which can be classified under each of Moos's scheme of dimensions.

Table 2.1

Overview of Scales Contained in Nine Classroom Environment Instruments (LEI, CES, ICEQ, MCI, CUCEI, QTI, SLEI, CLES, WIHIC)

Instrument	Level	Items per scale	Scales classified according to Moos's scheme		
			Relationship dimensions	Personal development dimensions	System maintenance and change dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material environment Goal direction Disorganisation Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher support	Task orientation Competition	Order and organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College and University Classroom Environment Inventory (CUCEI)	Higher education	7	Personalisation Involvement Student cohesiveness Satisfaction	Task orientation	Innovation Individualisation
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8–10	Helpful/friendly Understanding Dissatisfied Admonishing		Leadership Student responsibility and freedom Uncertain Strict
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher education	7	Student cohesiveness	Open-Endedness Integration	Rule clarity Material environment
Construcitivist Learning Environment Survey (CLES)	Secondary	7	Personal relevance Uncertainty	Critical voice Shared control	Student negotiation
What Is Happening In This Classroom (WIHIC)	Secondary	8	Student cohesiveness Teacher support Involvement	Investigation Task orientation Cooperation	Equity

[Source: Fraser, 1998, p. 531]

2.2.5 The Constructivist Learning Environment Survey (CLES)

The CLES was developed to assist researchers in their assessment of the degree to which a particular classroom's environment is consistent with a constructivist epistemology. It is also a tool to help teachers reflect on their epistemological assumptions and reshape their teaching practice. Not only does the CLES extend the fields of learning environment research, it also brings about a confluence of research in constructivist teaching and learning approaches with research in learning environment (Taylor & Fraser, 1991). The following paragraphs detail the theoretical underpinnings and a description of the CLES with regard to the scales, format, forms and statistical robustness, namely, the internal consistency and discriminant validity.

2.2.5.1 Theoretical underpinnings of the CLES

The original version of the CLES was based largely on a psychosocial view of constructivist reform that focused on developing teaching approaches that facilitate students' conceptual development. The objective of the original CLES was to:

> provide teachers with an efficient means of learning more about their students' perceptions of the extent to which the classroom learning environment enabled them to reflect on their prior knowledge, develop as autonomous learners, and negotiate their understanding with other students. (Taylor, Fraser, & White, 1994, p. 3)

Though the original CLES was psychometrically sound, its theoretical framework supported only a weak programme of constructivist reform as the development of constructivist pedagogies for conceptual change was found to be easily assimilated in the traditional teacher-centred classroom environment, resulting in little success in the constructivist reform movement (Taylor et al., 1994).

Ongoing research programmes revealed that socio-cultural norms work in concert to counter the development of constructivist learning environment (Taylor, 1992, 1993 cited in Taylor, Dawson, & Fraser, 1995). The critical theory of the philosopher, Habermas, drew the attention of science educators to the science classroom as a socio-cultural site within which good meaning-making and ethical social interactions may be constrained and thus urged the emancipation of the individual from repressive cultural myths (Taylor et al., 1995).

Recognizing the constraints imposed by the socio-cultural context on the cognitive constructivist activity of the individual learner, a new version of the CLES was developed from the perspective of critical constructivism, a social epistemology that combines key elements of the radical constructivist theory of von Glasersfeld (1993) and the critical social theory of Habermas (1972) and which serves as a referent for the transformation of the socio-cultural reality of the science classroom environment (Taylor et al., 1995).

The critical constructivist learning environment is characterized by a major emphasis on facilitating students' involvement in activity negotiation with teachers and peers. The purpose of negotiation is to 'make learning relevant to students' out-of-school lives (i.e., *lifeworlds*), encourage students to assume control of their learning, and to engender a critical awareness of shared cultural values and beliefs (e.g., reproductive nature of schooling, objective nature of knowledge, externalized control of assessment) that restrain constructivist reform of teaching and learning (Taylor et al., 1995). These characteristics are reflected in the scales of the new version of the CLES.

2.2.5.2 Scales of the CLES

The revised CLES is composed of five scales which recognize that 'the cognitive constructivist activity of the individual learner occurs within, and is constructed by, a socio-cultural context (Kim, Fisher, & Fraser, 1999, p. 241). The five scales are Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation. The scales obtain measures of students' perceptions of the frequency of occurrence of the five key dimensions of a constructivist learning environment.

Personal Relevance

The Personal Relevance scale focuses on the relevance of school science to students' out-of-school experiences. When taking account of students' prior knowledge, teachers go beyond the pedagogical approach of getting students to recall accurately previously learned formulae, rules and laws. They utilize the rich tapestry of experiences that students bring with them from their out-of-school worlds to help them construct scientific knowledge.

Uncertainty

The objectivist perspective accords scientific knowledge a privileged status; it is an embodiment of universal Truths existing independently of human experience, static and unchanging over time. This objectivist myth of certainty is one of the major constraints to constructivist pedagogical reform (Taylor et al., 1995). The Uncertainty scale assesses the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory-dependent inquiry, involving human experience and values, evolving and culturally and socially determined.

Critical Voice

From the technical interest perspective of Habermas (1972), the curriculum is metaphorically regarded as 'a container of immutable knowledge' and 'a product that the teacher is obligated to deliver' (Taylor et al., 1994). Other than feeling accountable to external curriculum and assessment authorities for the coverage and delivery of the curriculum, teachers ought to demonstrate a willingness to be accountable to their students for their pedagogical actions by fostering students' critical attitudes towards the teaching and learning activities. The Critical Voice scale assesses the extent to which the classroom social climate has been established such that students feel empowered to question the pedagogical methods and activities and express their legitimate concerns about obstacles to their learning.

Shared Control

From a critical constructivist perspective, opportunities should be provided to students to enable them to develop into autonomous learners, empowered to exercise a degree of control over their learning and evaluating their conceptual development. The Shared Control scale measures the extent to which students are invited to share control with the teacher in the learning environment, manifested in the students articulating their own learning goals, designing and managing their learning activities and determining and applying assessment criteria.

Student Negotiation

Inherent in the scales of Personal Relevance, Shared Control and Critical Voice is the recognition of the importance of teacher-student negotiation. The importance of student-student negotiations in the learning environment is reflected in the Student Negotiation scale. The scale assesses the extent to which opportunities are provided for students to explain and justify to their peers their newly developing ideas, to listen attentively and reflect on the viability of others' ideas and subsequently perform a critical self-reflection on the viability of one's own ideas.

Since the inquiry-based teaching and learning stems from the theory of constructivism, it is deemed appropriate to use the CLES to study the degree of constructivism in the learning environment of the pupils' science lessons.

2.2.6 The Questionnaire on Teacher Interaction (QTI)

The instrument used to obtain the interaction pattern between teachers and students in the classroom learning environment in this research is the 48-item QTI modified for use in the primary schools. The development of the QTI and the validation of the version for use in primary schools are detailed in the following sections.

2.2.6.1 The Leary Model – A Precursor of the Model of Interpersonal Teacher Behaviour

In 1957, a model was developed by Leary to depict interpersonal behaviours graphically along two dimensions: influence and proximity. The Leary model was a product of extended, empirical research in clinical psychology and places personality at the heart of interpersonal behaviour for Leary believes that the way humans communicate is indicative of their personality (Wubbels, Créton, Levy, & Hooymayers, 1993). Figure 2.1 shows the two dimensional plane of Leary's model.

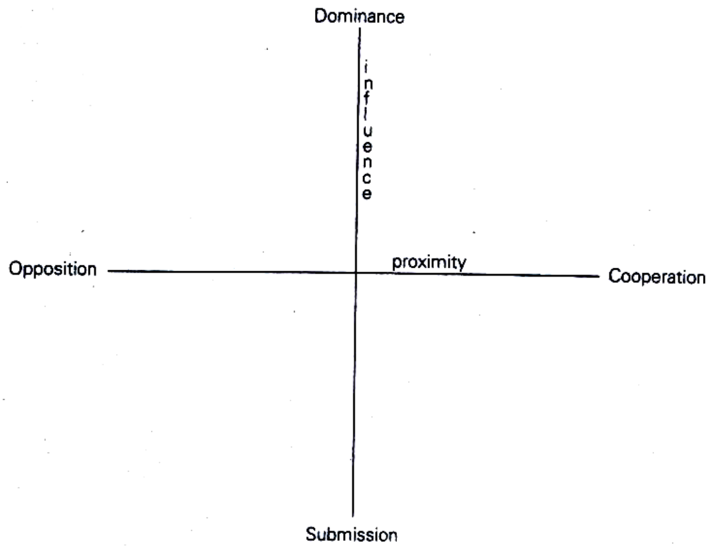

Figure 2.1. The coordinate system of the Leary Model.
[Source: Wubbels, Créton, Levy, & Hooymayers, 1993, p. 15]

The Influence dimension (Dominance-Submission) is a continuum of behaviours measuring the degree of dominance or control over the communication process. The Proximity dimension (Cooperation-Opposition) measures the degree of cooperation or closeness between those who are communicating. Leary called this continuum the 'Affection-Hostility' axis.

In the 1980s, researchers in The Netherlands extended the field of classroom learning environment research by investigating teacher behaviour in classrooms from a systems perspective, adapting a theory on communication processes developed by Watzalawick, Beavis and Jackson

(1967). The systems perspective on communication is based on the assumption that the behaviours of participants influence each other mutually, that is, communication processes develop in a circular manner for they do not only consist of behaviour but determine behaviour as well (Fisher, Fraser, & Cresswell, 1995). In the context of the classroom setting, the behaviour of the teacher is influenced by the behaviour of the students and in turn influences student behaviour.

2.2.6.2 Model of Interpersonal Teacher Behaviour

With the systems perspective in mind, Wubbels, Créton and Hooymayers (1985) adapted Leary's model to describe teacher interpersonal behaviour in classrooms. Teachers' behaviour is mapped within the axes of Influence dimension (Dominance-Submission) and Proximity dimension (Cooperation-Opposition) to form eight sectors as shown in Figure 2.2.

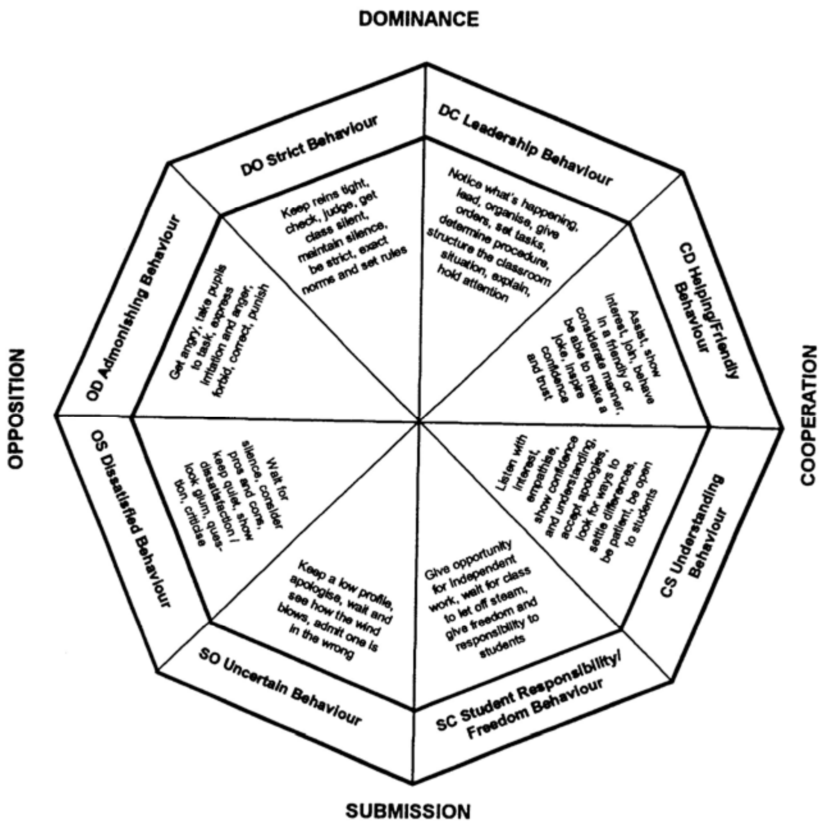

Figure 2.2. The model for Interpersonal Teacher Behaviour.

[Source: Wubbels, Créton, Levy, & Hooymayers, 1993, p. 16]

Each of the eight sectors describes a different behaviour aspect: Leadership, Helpful/Friendly, Understanding, Student Responsibility and Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviour. These eight sectors are labelled DC, CD, CS, SC, SO, OS, OD and DO in accordance with their circular placing in the model of interpersonal teacher behaviour. To clarify further what the eight sectors involve, descriptions of typical teacher behaviours belonging to each sector are provided in the inner segment of the circumplex model (See Figure 2.2).

2.2.6.3 Development of the QTI

While the model of Interpersonal Teacher Behaviour seemed to fit classroom situations, an instrument which could provide reliable data on interpersonal teacher behaviour was needed. Leary's evaluation instrument, the Interpersonal Checklist (ICL), which has been used extensively in clinical psychology and psycho-therapeutic contexts, was found unsuitable for describing or measuring teacher interpersonal behaviour in classrooms. An adaptation was made from the ICL and this gave rise to the Questionnaire on Teacher Interaction (QTI).

Since the QTI provides an insight into the interaction between teachers and students, the use of this instrument complemented the findings of the CLES in this research as it provided a more lucid picture of what the learning environment was like in the teaching and learning of science.

2.2.7 Important Developments with Learning Environment Instruments

Over the years, learning environment instruments have 'evolved' and different forms arose. Available for use are the Personal Form and Class Form, the Actual and Preferred Forms of scales and the Long and Short Forms of many different learning environment instruments.

2.2.7.1 Personal / Class Forms (Level of Analysis)

The ideas of 'alpha press' and 'beta press' were extended to include the idiosyncratic perceptions each individual has of the environment (private beta press) and the shared view that members have of their environment (consensual beta press). A difference could exist between private and consensual press and both differ from the detached view of a trained non-participant observer (alpha press) (Fraser & Walberg, 1991). It is important that researchers decide, when designing classroom environment studies, whether they are analyzing the perception scores obtained from individual students (private press) or the average of the environment scores of all the student within the class (consensual press) as 'perceptions of persons from different perspectives could lead to different interpretations of the environment' (Fraser, Fisher, & McRobbie, 1996).

This distinction came about in the latter half of the 1980s when the assumption that all students within a class would have similar learning environment experience was challenged. Interpretive studies using classroom learning environment instruments, classroom observations and interviews involving teachers and students revealed that even within a class, there existed discrete and differently-perceived learning environments (Tobin, 1987; Tobin & Gallagher, 1987; Tobin & Malone, 1989 cited in Fraser et al., 1996, p. 2). The implication is that using the traditional class form of learning environment instruments to study the differences in perceptions held by different groups of students within the same class (e.g. by gender or socio-economic status) can pose a problem since the class form elicited the students' perceptions of the class as a whole rather than the student's personal perception of his or her role in that classroom (Fraser & Tobin, 1991 cited in Fraser et al., 1996, p. 2).

The revelation of these studies and the influence of social constructivist epistemology at around that time served as an impetus for the development of a different form of learning environment instrument that asked students for their personal perception of their role in the classroom environment rather than their perception of the classroom environment as a whole. As a consequence, there arose two forms, the *Personal Form* and the *Class Form*.

The *Personal Forms* have been proven to be useful in studying the classroom learning environment at different 'grain sizes' (Fraser & Hoffman, 1995 cited in Fraser, et al., 1996, p. 15). At the smallest grain size are the perceptions of individual students and teachers and these environment scores can be aggregated to the class and even the system level. However, the aggregation of the environment scores of groups of students with varying perceptions of the learning environment will result in the obscurrence of differences between student or groups within the same classroom (Fraser, et al., 1996).

Depending on the scale, the Personal Form can be used to identify factors that personally influence students' learning since in the Personal Forms, students respond in terms of their perceptions of their personal involvement in the classroom (McRobbie, et al., 1998).

The role that social factors play in knowledge construction is recognized in recent approaches to teaching. Since responses to the *Personal Form* reflects, too, from a social perspective, the extent to which students perceive themselves as participants in the construction of knowledge in the context of the classroom, both with the class as a whole and with their closer working groups, the use of Personal Form enables teachers to characterize the classroom learning environment from the perspective of recent views of learning (McRobbie, et al., 1998).

2.2.7.2 Actual/Preferred Forms of Scales

Earlier research made use of classroom instruments to assess students and teacher perceptions of what their classroom learning environment was actually like. However, classroom environment instruments have been used in more recent studies to assess the perceptions of preferred classroom learning environment of students and teachers. This is made possible with the development of the preferred forms which are concerned with 'goals and values orientations and they measure perceptions of the environment ideally liked or preferred (Fraser & Fisher, 1983a, p. 116). In some instruments, item wording is identical for both actual and preferred forms, but directions for answering the two forms differ. In other instances, the wording of the items in the preferred form is formulated by adding the word 'would' to its corresponding item in the actual form. For example, the item 'The teacher asks me questions' in the actual form of the CLES is modified to 'The teacher would ask me questions' in the preferred form.

The availability of four different forms (Personal, Class, Actual and Preferred) enables the classroom environment scales to be used in an array of interesting research like investigations of differences between forms, person-environment fit studies of whether students' learning outcome is improved when in their preferred environment and improving classroom learning environment to make it more congruent with the preference of students and teachers.

2.2.7.3 Long/Short Forms of Classroom Learning Environment Instruments

Users of the original long forms of various classroom environment instruments preferred to have more economical and simple methods of assessing classroom environment. This situation gave rise to the development of the short forms of several widely applicable classroom environment instruments.

To develop the short forms, the long form of the instrument was administered to a large sample of students. Several item analyses were performed on the data obtained. The internal consistency of each scale (Cronbach alpha coefficient) was maximized by 'selecting items with large item-remainder correlations (i.e., correlations between item score and total score of the rest of the scale)' (Fraser, 1982b, p. 222). The discriminant validity (the mean correlation of a scale with the other scales in the same instrument) was enhanced by ‘including only those items whose correlations with its *a priori* assigned scale was smaller than its correlations with any other items in the battery’ (Fraser, 1982b, p. 222). Other than having to adhere to the statistical criteria, logical criteria like face validity and achieving a balanced polarity of items both within each scale and each instrument as a whole have to be taken into consideration. However, due to some scales in the long forms containing an imbalance of positively and negatively scored items, this imbalance is perpetuated in the short forms of these scales (Fraser, 1982b).

Though the short forms provide a highly economical assessment of classroom environment, it is worthy to mention at this juncture that the use of the long form is strongly recommended in research which uses the individual student as the unit of analysis, applications which involve the assessment of teachers’ classroom environment perceptions (e.g. comparing the teacher’s and aggregate students’ perceptions of the same classroom environments) or studies which compare the effects the choice of unit of analysis (e.g. individual student versus class mean) has on the magnitude of relationships between student outcomes and classroom environment characteristics (Fraser, 1982b).

2.2.8 Research Involving Classroom Environment Instruments

Classroom environment instruments have been used in different types of research, of which three will be highlighted below. They are (a) associations between student outcomes and classroom environment; (b) use of classroom environment dimensions as criterion variables; and (c) investigation of whether students achieve better when in their preferred environment. Other than being used in research, classroom environment instruments also serve the practical purpose of improving classroom climate, the procedures of which will also be discussed.

2.2.8.1 Associations Between Student Outcomes and Classroom Environment

Comprehensive reviews of prior research involving classroom environment can be found in books, guest-edited journals and numerous reviews. All these works point to the very strong tradition of investigating the associations between students' outcome in the cognitive, affective and psychomotor domains and their perceptions of psychosocial learning environment (Fraser & Fisher, 1983b; Fraser & O'Brien, 1985). Numerous research programmes in numerous countries have proven that students' perceptions of their classroom environment account for appreciable amounts of variance in learning outcomes, often beyond that attributable to background student characteristics like general ability or student entry characteristics like pre-test performance (Fraser & Fisher, 1983b; Fraser & Walberg, 1991).

It has been found that there is a positive relationship between perceptions of Influence and Proximity of the QTI and students' cognitive outcomes. The higher a teacher was perceived on the Influence dimension, the higher the learning outcomes of the students. Similar relationships had also been found for the Proximity dimension, that is, the more teachers were perceived as cooperative, the better was the students' performance in cognitive tests (Brekelmans, den Brok, van Tartwijk & Wubbels, 2005).

Studies which investigated the association between the teacher-student relationship and affective outcomes found that both the Influence and Proximity dimensions had a positive effect on the affective outcome, in terms of subject-specific motivation. The higher the perception on the Proximity dimension, the higher the motivation of the students (Brekelmans, et al., 2005).

The practical implication of this outcome-environment relationship is that student outcomes might be enhanced by making classroom environments conducive to learning.

2.2.8.2 Use of Environment Perceptions as Criterion Variables

The classroom environment dimensions have been utilized as dependent variables in (a) studies of curriculum evaluation, (b) investigations of differences between student and teacher perceptions of actual and preferred environment and (c) studies involving other independent variables (Fraser & Walberg, 1991). When used as a source of process criteria in curriculum evaluation, classroom environment instruments proved to be a useful tool as evidenced in the Australian Science Education Project (ASEP) and Harvard Project Physics (Fraser & Walberg, 1991).

The availability of actual and preferred forms of some classroom environment instruments makes possible the investigation of differences between forms (e.g. differences between students' and teachers' perceptions of the same actual classroom environment and differences between the actual environment and that preferred by students or teachers). Results of studies on differences in students' and teachers' perceptions of the same classroom environment revealed two consistent and interesting trends – firstly, there is a discrepancy between students' actual and preferred classroom environment and secondly, teachers' perception of the actual classroom is more favourable than that of the students (Fraser & Fisher, 1983a; Fraser & Walberg, 1991; Fraser 1998).

Classroom environment dimensions have been used as criterion variables in a series of other studies aimed at investigating how the classroom environment varies with factors like teacher personality, class size, wait-time, grade level, subject matter, characteristics of the school-level environment and type of school (Fraser & Fisher, 1983b; Fraser, 1998).

2.2.8.3 Person-Environment Fit Studies of Whether Student Achieve Better in their Preferred Environment

Using both the actual and preferred forms of classroom environment instruments, it is possible to explore if students achieve better when actual environment is made more similar to the environment preferred by students. This person-environment interactional framework in classroom environment research extends the investigation of relationship between outcomes and actual environment to one that probes the relationship between outcomes and the match between students' preferred and actual environment. Findings from studies revealed that actual-preferred congruence (or person-environment fit) was an important determinant of student cognitive and affective achievement (Fraser & Fisher, 1983b, 1983c). The practical implication is that class achievement can be enhanced by increasing the congruency between the actual and preferred classroom environment.

2.2.8.4 Practical Attempts to Improve Classroom Environment

The array of classroom environment instruments can be put to practical use to improve classroom environment by going through a general five-step strategy, namely (a) Assessment, (b) Feedback, (c) Reflection and Discussion, (d) Intervention and (e) Reassessment.

Teachers can assess the classroom climate by administering the actual and preferred forms of classroom environment instrument at an interval of one week of each other. The data obtained from the instruments are a form of feedback to the teachers with regard to the students' perceptions of the environment, both actual and preferred. This feedback information is a basis for teachers' reflection and discussion on the aspects of the environment to be improved. The dimension for which a large discrepancy exists between the actual and preferred warrants the attention of the teacher. Nevertheless, it is worthy to note that the teacher is not automatically obliged to bring about any change in every dimension for which the actual-preferred discrepancy is large (Fraser & O'Brien, 1985). The choice of dimension for which improvement should be made depends on the teacher's judgment of the urgency and impact the dimension has on the classroom environment.

Intervention measures comprising strategies to improve the chosen dimension(s) of the classroom environment are introduced for a period of two months and at the end of which, a reassessment is made by administering the actual form of the instrument to see if students perceive the classroom environment differently. Although the reassessment marks the end of the teacher's attempt to improve the environment, it may also mean the beginning of another cycle, that is, the five-step strategy can be repeated cyclically until changes in the classroom environment have been effected to the desired levels (Fraser & O'Brien, 1985).

2.3 CONSTRUCTIVISM

Associated with the language of science education are expressions like 'construction of knowledge' and 'learners constructing meaning'. Just what then is 'constructivism' and its implications for the teaching and learning of science? The following paragraphs detail this epistemology under the headings of (a) basic ideas of constructivism, (b) implications of constructivism in the teaching and learning of science and (c) characteristics of a constructivist classroom.

2.3.1 Basic Ideas of Constructivism

Prevalent in most educational settings is the existential status students and teachers confer to knowledge and its production. This *'rapport au savoir'* (relationship to knowledge) inevitably determines how science is taught and learnt in schools (Désautels & Larochelle, 1998). With knowledge as a body of truths and facts existing outside the bodies of cognizing beings, science is then conceptualized as an act of searching for truths and facts (Lorsbach & Tobin, 1992) and science instruction is centred upon the learning of facts, or memorizing a 'rhetoric of conclusions' (Good, Wandersee, & Julien, 1993, p. 75).

Within cognitive science and information processing theories exists the view that conceptions held by each individual guide understanding and it was only in the middle of the 1970s that this view was given priority in science education research for the improvement of science instruction. This idea that students' pre-instructional conceptions play an important role in the learning process is labelled the 'constructivist view' (Duit & Treagust, 1995).

Construction is a theory of knowledge consisting of two basic principles, one psychological and the second epistemological, and emphasizes that knowledge cannot be separated from knowing (Treagust, Duit, & Fraser, 1996). This emphasis characterizes 'radical constructivism', and differentiates it from 'trivial constructivism', a weak constructivist view that learning is built on prior knowledge (Tobin & Tippins, 1993).

The first principle states that knowledge is not received passively but built up by the cognizing subject with the learner's existing knowledge or schema playing a central role in this process of meaning construction (Treagust, et al., 1996). As such, constructivism asserts that knowledge cannot be transferred intact from the head of a teacher to the heads of students. The students construct their own meanings from the words or visual images that they hear or see.

The epistemological principle of constructivism acknowledges the existence of an external reality but contends that cognizing beings can never know exactly what that reality is because knowledge about the 'world outside' is a result of human construction. As such, knowledge about that reality is known in a personal and subjective way and only constructions that are successful in dealing with the multiple contexts in which the learner is engaged remain viable and useful (Treagust et al., 1996). An analogy to illustrate this phenomenon is the idea of adaptation in Neo-Darwinist conceptions of evolution whereby organisms endowed with adaptive modifications as a result of variations in the genetic pool of a population are able to survive environmental constraints to pass their genetic traits to future offspring while those without the genetic make-up drop out of this process of natural selection.

Other than advocating that knowledge is personally constructed, it is inherent in constructivism that the process of personal construction of knowledge is socially mediated, that is, ‘knowledge only exist in the minds of cognizing beings, but cognizing beings only exist in a socio-cultural sense’ (Tobin & Tippins, 1993, p. 6). The influence one’s social setting has on the process of meaning making is termed ‘social constructivism’ and its implications are evident in the instructional pedagogies and learning environment of the classrooms.

With reference to science education, scientific knowledge does not exist as a separate entity from the knowers. On the contrary, it is viewed as ‘a set of socially negotiated understandings of the events and phenomena that comprise the experienced universe. Knowledge is accepted by the scientific community as viable because of its coherence with other understandings and its fit with experience’ (Tobin & Tippins, 1993, p. 4).

2.3.2 Implications of Constructivism on the Teaching and Learning of Science

Science is defined by Giambattista Vico, an Italian philosopher, humanist and rhetorical theorist as 'knowledge of the genus or mode by which a thing is made; and by this very knowledge the mind makes the thing, because in knowing it puts together the elements of that thing' (Bettencourt, 1993, p. 41). This profound definition implies that science does not exist as a body of knowledge separate from the knower. On the contrary, it is a set of socially negotiated and viable knowledge.

Constructivism being 'a theory of knowledge which involves a conception of the knower, a conception of the known, and a conception of the relation of knower-known' (Bettencourt, 1993, p. 39) implies that learning is an active process whereby new knowledge is built up by the cognizing subject with what the learner already knows playing an important role in this process (Treagust, et al., 1996).

The constructivist movement has resulted in a paradigm shift in the way science is taught and learnt in schools. Students are no longer regarded as 'blank slates' or *'tabula rasa'* whereby science knowledge is amassed through the teacher transmitting discrete bits of facts and students committing them to memory. Good et al. (1993) exhorted why memorization of scientific facts is an ineffective way of teaching and learning science with the following reasons:

(i) rote learning which is tantamount to memorization without conceptual integration is less useful and less durable than meaning learning;

(ii) scientific knowledge changes and may even contradict previously learned knowledge;

(iii) scientific facts are relatively 'low-level knowledge'; and being so, are much less useful than scientific concepts, principles and theories;

(iv) teaching is not merely knowledge transmission, on the contrary, it is a mutually beneficial interaction between teacher and learner and which serves as a catalyst to knowledge construction and meaning-making;

(v) facts are, by their very nature, potentially isolated, disconnected and misleading; and

(vi) facts alone do not empower the learner to learn science on his own.

The epistemological view that knowledge is built by individuals cannot be more aptly reflected in the metaphor of construction used by constructivists who advocate that new knowledge is strongly influenced by conceptions gained by the learner prior to the point of new learning. In science, this prior knowledge has been given a number of names, including alternative frameworks, children's science, alternative conceptions and mini-theories (Driver & Oldham, 1986). Learning by construction necessitates a change in this prior knowledge via either replacement, addition or modification of this extant knowledge (Cobern, 1993). A constructivist teacher recognizes the fact that students hold pre-instructional conceptions which may be substantially different from the scientific concepts to be taught. To make matters worse, most of these preconceptions are held strongly and are resistant to change (Treagust, et al., 1996).

However, it is worthwhile to note that not all preconceptions are misconceptions which pose as barriers to understanding. There are preconceptions that are in agreement with the new material. Such preconceptions have been termed 'anchoring conceptions' and knowing what they are prior to instruction will enable teachers to peg their instruction in such a way that students understand at the 'make sense' level instead of only at a formal level (Clement, Brown, & Zietsman, 1989).

Teachers who underestimate or disregard the influence pre-instructional conceptions have on their students' new learning may find, to their dismay, that their students' learning outcome is different from their intended instructional outcome. The importance that prior knowledge has on learning is reflected in Ausubel's assertion (quoted in Novak, 1990, p. 31): 'If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly'.

2.3.2.1 The Conceptual Change Model

The conceptual change model (or CCM) is a learning model from which teaching sequences can be designed to encourage students to change their ideas in useful and intended ways. The model describes learning as a process in which an individual changes his conceptions by capturing new conceptions, restructuring existing conceptions or exchanging existing conceptions for new conceptions. It is a dynamic state of balance similar to that maintained by a cyclist rather than the static state of a balance beam (Yager, 1991).

This dynamic state of balance is mediated by the two processes of assimilation and accommodation which are also termed ‘conceptual capture’ and ‘conceptual exchange’ respectively. The former involves making use of new information and transforming new knowledge to fit existing schemas and mental models while the latter involves altering, modifying or changing current mental models to accept or fit newly perceived knowledge.

Individuals, when encountered with phenomena that run contrary to their presently held understanding, make adjustments in their cognitive structures to accommodate the new situations through the simultaneous processes of assimilation and accommodation (Llewellyn, 2007). This process of equilibration leads to a new equilibrium, a state where mental structures are more useful, interconnected and elegant than the previous state. As such, this process of equilibration is termed *'equilibration majorante'* in French, an expression that means 'optimizing equilibration' (Bettencourt, 1993).

There are four conditions that must prevail before conceptual change can occur. They are (a) dissatisfaction with existing conceptions, (b) intelligibility of new conceptions, (c) plausibility of new conception and (d) fruitfulness of new conception (Posner, Strike, Hewson, & Gertzog, 1982).

If a learner is dissatisfied with his existing conception as being able to sufficiently explain a phenomenon or solve problems and that a new conception is at hand, the individual will find if the latter is intelligible. If so, she/he will next ascertain if the conception is consistent with and reconcilable with other conceptions accepted by the learner and whether she/he believes it to be true (plausible). If the conception is both intelligible and plausible to the learner, she/he will next decide if the conception achieves something of value for him, like solving otherwise insoluble problems or suggesting new possibilities, directions or ideas (fruitfulness). The extent to which the conception meets the conditions of intelligibility, plausibility and fruitfulness is termed the 'status' of the conception (Hewson & Thorley, 1989). The acceptance of a new conception in favour of an existing one is the result of the rise in status of the former and the corresponding lowering in status of the latter. The rise and fall in status of a conception is largely influenced by a learner's conceptual ecology which 'consists of many different kinds of knowledge, with some of the important kinds being epistemological commitments (e.g. to consistency or generalizability), metaphysical beliefs about the world (e.g. the nature of time), and analogies and metaphors that might serve to structure new information' (Hewson, 1996, p. 133).

2.3.2.2 A Constructivist Teaching Sequence

If getting learners to change their ideas is the intended outcome of instruction, then it is essential that students engage in activities which encourage them to construct scientific ideas for themselves. A number of schemes to guide the planning of sequences of activities aimed at promoting conceptual change in science classrooms has been suggested (Cosgrove & Osborne, 1985 cited in Driver & Oldham, 1986, p. 105) and the constructivist teaching sequence is one model whose sequence of activities serves to promote conceptual change (see Figure 2.3).

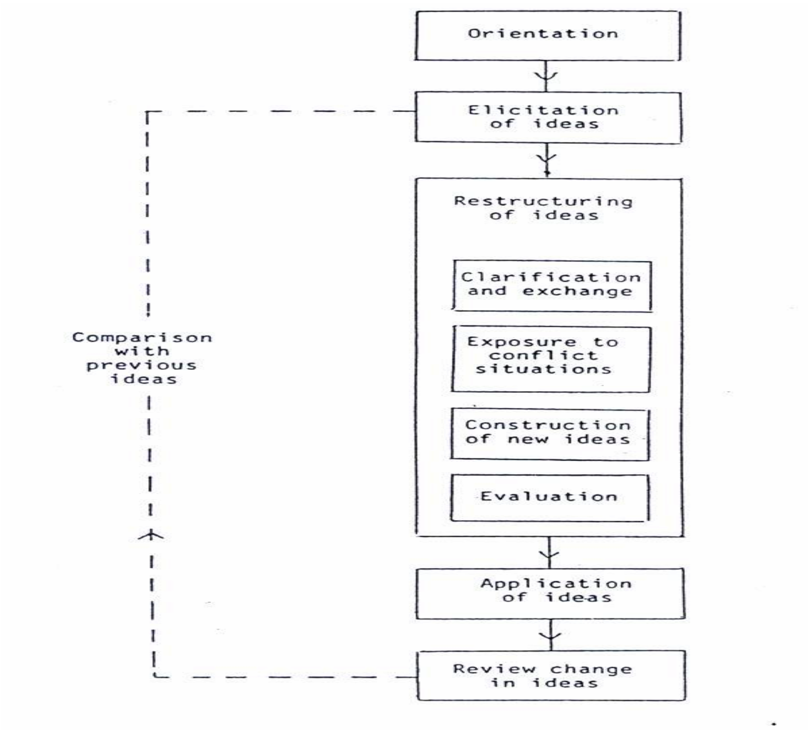

Figure 2.3. A constructivist teaching sequence.
[Source: Driver & Oldham, 1986, p. 105]

The sequence comprises five phases; orientation, elicitation, restructuring, application and review.

In the orientation phase, 'tuning-in' activities in the form of a song, jingle, video, rap etc may be introduced. Whatever forms the activities take, they are designed to develop in pupils a sense of purpose and motivation for learning the topic (Driver & Oldham, 1986).

Having aroused the interest of the students, the lesson is ready to proceed to the 'elicitation' phase during which pupils express explicitly their ideas, hence bringing them to conscious awareness. This is the time for teachers to ascertain the values, views or ideas pupils bring with them to this particular point of learning. These views and ideas will be linked, modified or discarded by the learner in the process of knowledge construction. As such, teachers may need to 'reconstruct their ideas about the teaching-learning process and to modify their teaching accordingly' (Driver, 1989, p. 86). The tools useful for the elicitation of prior knowledge or ideas are concept maps and the 'K-W-L' graphic organizer.

Concept maps are representation of 'relationships between concepts, and it is from these relationships that concepts derive their meaning' (Novak, 1996, p. 32). The uses of concept maps are extensive; other than being useful research tool to represent knowledge structures, they can be used to facilitate learning, identify misconceptions or alternative conceptions and evaluate learning (Novak, 1996).

The 'K-W-L' graphic organizer is a simple tool used for eliciting prior knowledge. A sample of the 'K-W-L' graphic organizer is shown in Figure 2.4.

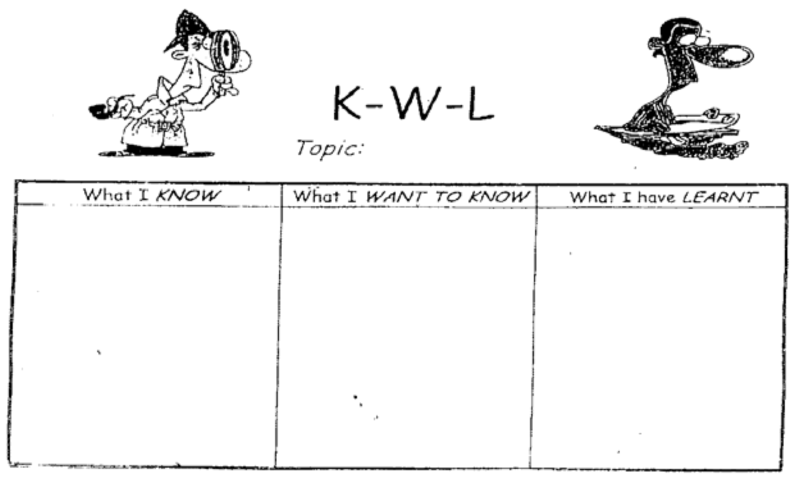

Figure 2.4. KWL graphic organizer.

[Source: Ministry of Education, 1999, p.17]

From the graphic organizer, other than being aware of what the pupils know, teachers are informed of what the pupils hope to learn and thus tailor their instructional strategies to meet the learning needs of the pupils. The last column of the organizer enables learners to do a self-evaluation of their learning objectives.

The elicitation phase is followed by the ‘restructuring’ phase which includes a number of different aspects. With pupils’ ideas ‘out in the open’, inadequacies may be pointed out, viewpoints may be challenged and differing conceptions thrown up for discussion. This is also a time for teachers to create conceptual conflict through the use of disconfirming demonstrations. The clarification and exchange of ideas may ‘sharpen’ the meanings pupils have constructed and develop in them an appreciation that the same phenomenon can be explained with a range of different notions (Driver & Oldham, 1986). Still within the restructuring phase, students proceed to the evaluation of alternative ideas, which may be tested against experience, either experimentally or thinking through their implications. As a consequence, students may experience cognitive dissonance and hence undergo a conceptual change either through assimilation or accommodation.

In the application phase, students are provided with the opportunity to use their developed ideas in a variety of situations, both familiar and novel. The extension of contexts within which these conceptions are seen to be useful serves to consolidate and reinforce these conceptions.

The final ‘review’ phase of the sequence deals mainly with reflection. Students are to reflect on their learning; how their ideas have changed, by comparing their current thinking with that at the commencement of the lesson (Driver & Oldham, 1986). The K-W-L graphic organizer is a useful tool for this purpose. Alternatively, instruments like journals or learning logs help students in this form of self-evaluation and consequently develop their meta-cognitive strategies.

Be it the conceptual change model or the constructivist teaching sequence, they are models of instructions from which inquiry-based lessons can be designed. As such, it is evident that constructivism constitutes the underlying principle of inquiry-based learning.

2.3.3 Characteristics of a Constructivist Classroom

Constructivism stands in contrast to the more deeply rooted ways of teaching that have typified many classrooms for many years. While learning has traditionally been viewed as a 'mimetic' activity, a process which involves students in reproducing chunks of information in quizzes or tests, constructivist teaching practices help learners to 'internalize and reshape, or transform, new information. Transformation occurs through the creation of new understandings that result from the emergence of new cognitive structures' (Brooks & Brooks, 1993, p. 15). Educational settings that encourage the active construction of meaning have the following characteristics (Brooks & Brooks, 1993):

(i) students are freed from the dreariness of fact-driven curriculums and thus able to focus on big ideas;
(ii) students are empowered to follow their interest, make connections, reformulate ideas and reach unique conclusions;
(iii) students are enlightened to the complexity of the world and the existence of multiple perspectives and that truth is very often a matter of interpretation; and
(iv) learning and assessment are elusive endeavours that are not easily managed.

A constructivist classroom can be accomplished through the establishment of the different roles that teachers and students might play and the kind of classroom climate.

2.3.3.1 The Teacher

Teachers play the dual role of classroom manager and an active participant in the classroom (Hewson, 1996). As classroom managers, they design tasks which are of relevance and meaning to the students so that learning becomes related to real problems. The tasks ought to be framed around cognitive activities like analyzing, interpreting and predicting so that construction of new understandings is fostered (Brooks & Brooks, 1993).

Playing the role of an active participant in learning requires teachers to seek elaboration of students' initial responses which enables them to understand more clearly how students think about a concept. Information about the students' present conceptions is useful in helping the teacher teach for conceptual change should the need arise.

2.3.3.2 The Learner

Just as teachers play an active role in learning in the constructivist classroom, the students have an active role to play too. Being empowered with the initiative and autonomy to solve authentic problems, play with ideas, explore issues and encounter new information, it is imperative that students take responsibility for their own learning, trust their own thinking and justify their conclusions using sensible arguments. In the process of learning, they must recognize the existence of different viewpoints and respect them, and should the need be, change their view in the face of another more viable one.

2.3.3.3 Classroom Climate

One very powerful way students come to change or reinforce conceptions is through social discourse. It is an empowering experience to be able to present one's ideas as well as to hear and reflect on the ideas of others. The classroom climate must be established such that the ideas of others, no matter how disagreeable, are respected and listened to carefully.

Participants in a constructivist classroom should be able to express their ideas or disagree with the ideas of others without feeling any fear of sanction or ridicule.

Creating a constructivist classroom requires bold changes – practices which break from the past to create new structures and norms and it is well worth it because constructivism, like a bird in flight, has an elusive elegance that remains beyond one's grasp. It is not a unitary construct because 'every day we learn something new about constructivism' (Tobin & Tippins, 1993, p. 20). Being an intellectual tool, constructivism has created deep impacts in many educational contexts. Be it in curriculum planning or teaching and learning in the classroom, pupils are seen metamorphosing into active, motivated and independent learners while constructivist educators find themselves on 'a journey of educational improvement that is comprehensive and on-going' (Tobin & Tippins, 1993, p. 20).

2.4 INQUIRY-BASED LEARNING IN SCIENCE

Education in this era is about educating students who will be spending half of their adulthood in the 21st Century, a period inundated with knowledge explosion and technological advancement. In the realm of science education, a knowledge-led curriculum without emphasis on processes has little relevance because of this knowledge explosion, the ease with which information can be accessed and the rate at which knowledge goes obsolete. The process alternative focuses on the 'primary or generic qualities' of science education which will be of value when the facts are out of date or forgotten (Millar, 1994). The Warwick Process Science Project reaffirms that 'if any qualities or generic skills are transferable then the processes must form a substantial proportion, and any preparation of young people must take into account the transferable skills which they will need to succeed' (Screen, 1986, cited in Millar, 1994, p. 165). Hence, there is a paradigm shift in science education in that classrooms are no longer settings where teachers transmit information to students while the latter sit in straight rows listening to the teacher or working on worksheets. Instead, there arises a need for a programme that promotes active learning, raising questions, opportunities to solve their questions as well as discourse and reflection (Llewellyn, 2007). Students are actively engaged in the construction of their own knowledge and understanding through the inquiry-based approach to the learning of science.

2.4.1 Defining Inquiry

In the context of science education, it is imperative that the modifier ‘scientific’ is implied in the phrase ‘teaching and learning through inquiry’ for it is scientific inquiry, not inquiry in general (being inquisitive and curious) that science educators are concerned with (Rutherford, 1964).

Scientific inquiry can be understood in at least two general ways; inquiry as content and inquiry as technique. The former ‘acknowledges that there is a pattern of inquiry characteristics of a given science, or of a given field with a science, and that such patterns form an integral part of what science is’ (Rutherford, 1964, p. 80). This idea is defined as ‘the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work’ (NRC, 1996, p. 23 cited in Singer, Marx, & Krajcik, 2000, p. 165). In addition to the variety of processes and ways of thinking that lead to the development of new knowledge in science, inquiry also refers to knowledge about these processes that scientists use to develop science knowledge (Llewellyn, 2007).

Inquiry as technique is the pedagogical approach that parallels what scientists do and the attitudes they display when they do science. No single ‘scientific method’ is adopted by scientists but rather, a plethora of them. However, within this uncertainty lies a common thread that scientists exercise a repertoire of skills like posing questions, making observations, hypothesizing, designing experiments, collecting and interpreting data, communicating findings and replicating experiments. It is analogous to the skilful exercise of a repertoire of ‘craft skills’ rather than the following of an algorithm (Polany, 1958; Ravetz, 1971, cited in Millar, 1994, p. 174).

Through participating in inquiry like scientists, students learn the process of generating science knowledge and using the science knowledge they acquire to understand the objects, organisms and events in their environment (Bass, Constant, & Carin, 2009).

However, Kyle (1980) cautioned against leading students to believe or think that they are performing scientific inquiry when in fact they are learning. He restricted the term 'scientific inquiry' to what scientists do. He defined it as 'the personal, internalized ability of an individual to synthesize the knowledge, which has been obtained through the learning of basic process skills and competencies, that enables a person to rationally inquire and solve problems by means of unrestrained inductive thinking' (p. 128). The scientific inquiry instructional technique inherent in the learning process involving the investigative, experimental or discovery methods of science teaching to equip students with competencies like number computation, spatial and manipulative skills and process skills like observing, classifying, measuring, describing and inferring is not scientific inquiry but a 'prerequisite to scientific inquiry' (Kyle, 1980, p. 126). The distinction is distinctly reflected in the following quote:

> The scientist is engaged in a full-time search for new, general or applied principles in his field. The student, on the other hand, is primarily engaged in an effort to learn the same basic subject matter in this field which the scientist learned in his student days, and also to learn something of the method and spirit of scientific inquiry… If [the student] is ever to discover [scientifically] he must first learn; and he cannot learn adequately by pretending he is a junior scientist (Ausubel, 1964 cited in Kyle, 1980, p. 128).

2.4.2 The Inquiry Cycle

The inquiry cycle shown in Figure 2.5 represents the phases of many scientific investigations and serves as a general format for teachers in their planning of inquiry-based investigations for their students who often enter and re-enter the phases at different aspects of their inquiry process. Hence, the cycle serves as a model to guide students through their investigations, rather than a linear sequential, “step-by-step” procedure.

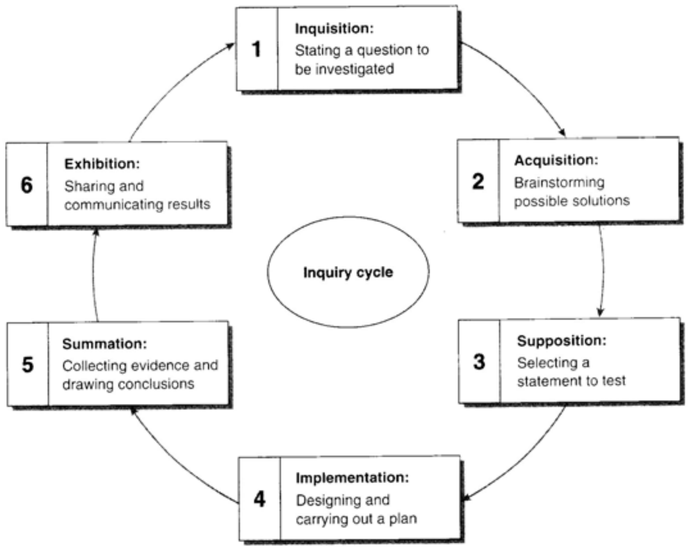

Figure 2.5. The inquiry cycle.
[Source: Llewellyn, 2007, p. 24]

At the inquisition phase, students pose a question to be investigated after having been thrown into cognitive dissonance through observing an open-ended exploration, a discrepant event or a demonstration that run counter-intuitive to their experience. Proceeding to the acquisition phase, students rely on their prior experience to brainstorm possible solutions to the inquiry. In the supposition phase, students formulate hypothesis to be tested. The design and implementation of the investigation to test the hypothesis is carried out at the ‘implementation’ phase. During the summation phase, students record and analyze their observations in order to address their hypothesis. Very often, at this phase, other discrepancies may arise which lead to more questions, thus bringing students back to the inquisition phase. Finally, at the exhibition phase, students make known their findings and new information in the form of a poster, written report or oral presentation.

With scientific inquiry being an integral part of the subject matter, science teaching is no longer centred on declarative knowledge (knowing ‘what’) whilst forgetting the procedural type (knowing ‘how’) (Gil-Perez &

Carrascosa-Alis, 1994). The familiar debate in science education of whether concepts or process skills should be given greater emphasis has little meaning for

> if the nature of scientific inquiry is taken to be an integral part of the subject matter itself, then neither the conclusions of science (the facts, laws, principles, theories, conceptual, schemes, etc.) nor the process of discovery and investigation which lead to those conclusions will be neglected. Content and inquiry will appear as the warp and woof of a single fabric, which is, after all, the way science really is (Rutherford, 1964, cited in Bianchini & Colburn, 2000, p. 181).

2.4.3 Levels of Inquiry

The essence of inquiry learning environment is student-centred instruction with sufficient guidance to insure direction and success in discovering scientific concepts and principles (Sund & Trowbridge, 1973, cited in Kyle, 1980, p. 124). Guidance or scaffolding is essential in enabling teachers make a smooth transition from familiar routines of conventional methods to the newly chartered waters of inquiry. The scaffolding is in the form of varying amount of guidance, from ‘guided’ to ‘open’, depending on student skills and needs (NRC, 2000, cited in Eick, Lee, & Balkcom, 2005). The varying degree of ‘openness’ in inquiry is synonymous with the concepts of different levels of inquiry. Rezba, Auldridge and Rhea (1999) (cited in Bell, Smetana, & Binns, 2005, p. 31) developed a four-level model of inquiry instruction.

The four-level model illustrates inquiry-based activities ranging from highly teacher-directed to highly student initiated. At the simplest level, that is, Level 1, sometimes referred to as a confirmation activity, students merely confirm a principle through an activity in which the question and procedures are provided and the results known in advance. At Level 2, also known as structured inquiry, students investigate a teacher-presented question through a prescribed procedure. Activities at Level 1 and 2 are commonly referred to as ‘cookbook labs’ as step-by-step instructions are given to the students. At Level 3, known as guided inquiry, students investigate a teacher-presented question using student designed procedures. At the highest level, Level 4, is the open inquiry in which problems, solutions and methods are left to the students, that is, they investigate topic-related questions that are student formulated through student designed procedures. The inquiry scale is a continuum in which teachers help their charges progress gradually from the lower to the higher levels over the course of a year, thus bringing about greater student success and satisfaction.

2.4.4 The 5E Learning Cycle

Inquiry-based instruction in the primary science classroom is based on the 5E learning model. Recent emphasis on constructivism and assessing prior knowledge resulted in the addition of the ‘Engagement’ stage to the original 4E learning model (Exploration, Explanation, Expansion, and Evaluation) and as a consequence, the 5E learning cycle was ‘evolved’. A pictorial representation of the 5E learning model is shown in Figure 2.6.

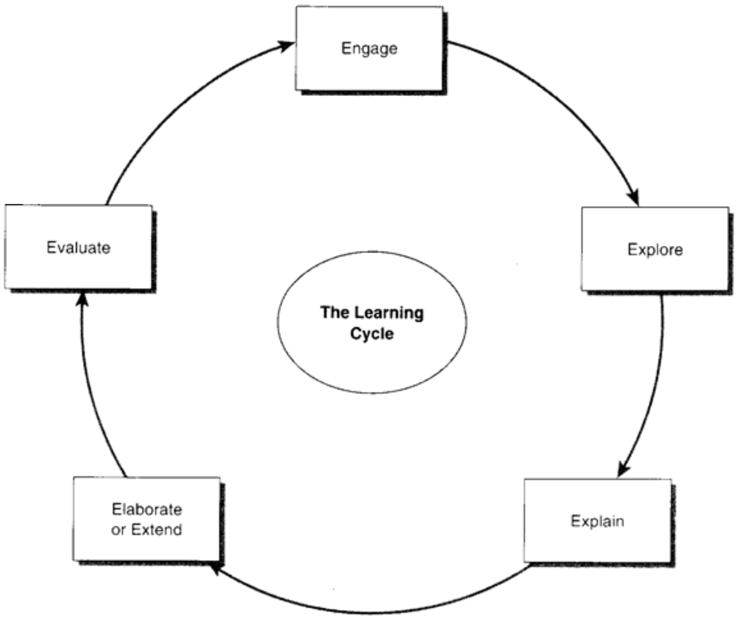

Figure 2.6. The 5E learning model.

[Source: Llewellyn, 2007, p. 135]

This instructional model is congruent with contemporary learning theory which suggests that students come to learning situations with knowledge and explanations of their world and that they learn best when they are to develop their understanding of concepts by making connections between new information and the knowledge they already have (Bybee, 2004). Lessons and units planned around the five stages of the 5E learning cycle will take students from concrete experiences, to the development of understanding, and to the application of principles (Llewellyn, 2007).

2.4.4.1 Engagement

The first phase of the learning model is **Engagement**. At this juncture, the stage is set for learning and the goal is to give students an opportunity to become motivated or excited about the information they will learn. Attention-grabbing demonstrations and discrepant events make good cognitive hooks to grasp students into learning. Discrepant events create cognitive dissonance or disequilibrium in students, thus activating students' attention and learning. It is also at this stage that teachers assess students' prior knowledge and identify misconceptions before proceeding with the learning process (Llewellyn, 2007).

2.4.4.2 Exploration

In the **Exploration** phase, students interact directly with the material, concepts or phenomenon through raising questions, developing statements to test, collecting evidence and data, recording and organizing information, sharing observations and working in cooperative groups. These exploratory activities serve as a common experience for a culturally diverse classroom. The teacher, though involved in the process, acts as a facilitator rather than gives direct instructions to students (Bybee, 1993 cited in Orgill & Thomas, 2007, p. 41).

2.4.4.3 Explanation

The **Explanation** stage, also known as the 'concept development' stage, is an appropriate time for teacher-led instruction. Most teachers recognize this stage as 'lecturing' or interactive discussions whereby they help students understand scientific explanations and introduce terminology to provide students with a common language about the content (Bybee, 1993, cited in Orgill & Thomas, 2007, p. 42). Students construct new meaning from their experience and work to assimilate or accommodate new information to make sense of their understanding.

2.4.4.4 Elaboration

The **Elaboration** or Extension stage allows students to apply knowledge they have acquired to new situations in their bid to expand their understanding (Bybee, 1993, cited in Orgill & Thomas, 2007, p. 44). It is a gateway to investigating questions generated at the Engagement stage or an opportunity to engage in an open-ended inquiry.

2.4.4.5 Evaluation

The lesson or unit is brought to a closure at the **Evaluation** stage during which teachers provide a means for students to assess their learning and make connections through various modes of assessment like oral questioning, unit test, essays, authentic tasks, portfolios, rubrics, monitoring charts, concept maps and student self-assessments. Although evaluation is presented as the final stage of the 5E model, it can and should occur at each stage of the instructional model (Orgill & Thomas, 2007).

2.4.5 Benefits of Inquiry-based Learning in Science

With inquiry-based learning, science instructions are characterized by students asking and refining questions in a bid to solve real problems, designing and conducting investigations, gathering and analyzing information and data, making interpretations, drawing conclusions and reporting findings (Singer, Marx, & Krajcik, 2000). In the process, students justify their ideas, reflect and evaluate their viability, invite and examine ideas of their peers. Experiences in problem-based learning, inquiry activities, dialogues with peers, teachers and even community members are advocated (Windschitl, 1999). This is in congruence with the National Science Education Standards which states that:

> Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (NRC 1996, p. 105)

Most science educators would agree that inquiry-based science instructions bring about the following five favourable outcomes (Chiappetta & Adams, 2004):

(i) Students understand fundamental facts, concepts, principles, laws and theories.
(ii) Students develop skills that enhance the acquisition of knowledge and understanding of natural phenomena.
(iii) Students cultivate the disposition to seek answers to questions and to question the truthfulness of statements about the natural world.
(iv) Students possess positive attitudes toward science.
(v) Students acquire the understanding about the nature of science.

Though the inquiry approach to science instruction takes many forms like hands-on-minds-on investigations, reading books, using Internet resources, talking and listening to scientists and teachers and direct teacher instruction on the concepts, principles and procedures of science, a common feature prevails – a shift from a teacher-centred classroom to that of a student-centred (Bass et al, 1970) and the very heart of students' experiences in science lessons is transformed; less emphasis is placed on the rote memorization of de-contextualized scientific facts and more emphasis on students' investigating the world around them and developing deeper understanding from their inquiries (Singer et al, 2000).

2.5 ATTITUDES TO SCIENCE

In dealing with the cognitive domain in science, the subject-matter content is divided into categories and sub-categories. Teachers and researchers with many years of experience are adept at specifying the behaviours desired of the student in acquiring and using the science content. Such desired student behaviours form the objectives of science instruction (Klopfer, 1976). These objectives in the cognitive domain are easily specified. However, the same cannot be said when specifying objectives in the affective domain. A large part of the difficulty arises from the lack of clarity in what is to be observed in student behaviours which are a manifestation of his or her feelings, appreciation, attitudes and values. This difficulty is compounded by 'the general uncertainty about the definition or specification of the phenomena related to science education about which we expect the student to exhibit feelings and attitudes' (Klopfer, 1976, p. 299). As such, cognitive growth and measurement have until recently been accorded greater importance than affective outcomes which are left largely to chance (Johnstone & Reid, 1981). The realization that non-cognitive outcomes like attitude are too important to be left to chance is evidenced in one of the goals of Project 2061 (AAAS, 1989). It spells that all students should possess a positive attitude towards science.

2.5.1 Attitude – Some Definitions

Just what is meant by 'attitude'? It is a concept originating in the early part of the 20th century and used in many different contexts (Koballa, 1988). Thurstone (1929) (cited in Johnstone & Reid, 1981, p. 206) defined 'attitude' as 'the affect for or against a psychological object' while Likert (1932) (cited in Johnstone & Reid, 1981, p. 206), using a less precise definition, referred to it as ‘a certain range within which responses move’. Krech (1946) (cited in Johnstone & Reid, 1981, p. 206) suggested that attitudes are ‘attempts at solution’ because he regarded attitudes as aspects of learning, in particular, of problem-solving. Doob (1947) (cited in Johnstone & Reid, 1981, p. 206) extended Krech’s viewpoint by suggesting that attitudes are theories of learning encompassing attitude development. The affective nature of attitudes was apparent in three other definitions by Katz and Sarnoff, Rhine and Triandis in 1954, 1958 and 1971, respectively. Katz and Sarnoff defined attitude as ‘a stable or fairly stable organization of cognitive and affective processes’, Rhine referred to attitude as a ‘concept with an evaluative dimension’ and to Triandis, attitude is ‘an idea charged with emotion’ (cited in Johnstone & Reid, 1981, p. 206). The one definition that seems to embody the essence of these numerous definitions is that of Fishbein and Ajzen (1975) (cited in Koballa, 1988, p. 116) who contended that ‘most investigators would probably agree that attitude can be described as a learned predisposition to respond in a consistently favourable or unfavourable manner toward an attitude object’.

Although ‘attitude’ has been defined in different backgrounds of psychology – latent constructs, cognitive processes and behavioural, a common characteristic prevails, that is, attitudes have three components – a knowledge component (cognitive), a feeling component (affective) and an action-tendency component (conative) (Johnstone & Reid, 1981; Gauld & Hukins, 1980). These cognitive, emotional and action-tendency components are evident in the manner Oppenheim (1992, p. 74-75) described attitude:

> attitudes… [are]… a state of readiness or predisposition to respond in a certain manner when confronted with certain stimuli … attitudes are reinforced by beliefs (the cognitive component), often attract strong feelings (the emotional component) which may lead to particular behavioural intents (the action-tendency component).

The possible relationship between the three components and their relationship to other influences is pictorially represented in Figure 2.7.

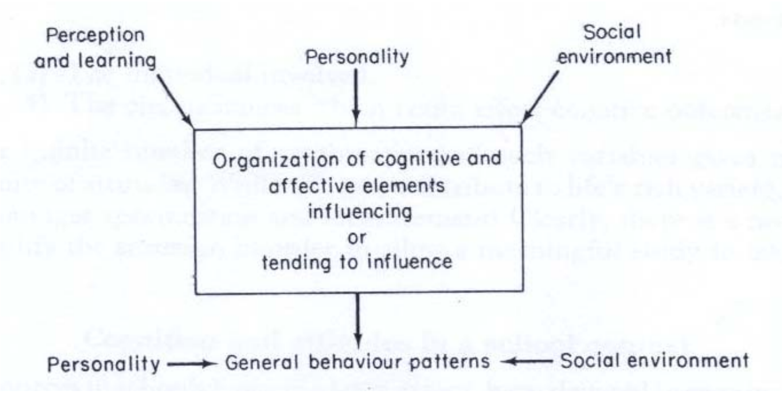

Figure 2.7. Relationship between the cognitive, affective and conative components and other influences.
[Source: Johnstone & Reid, 1981, p. 207]

Other than illustrating the influence of cognitive on attitude development, the construct nature of attitudes and the readiness to respond to outcomes, Figure 2.7 also highlights the circumstances that though attitude affects behaviour, the latter may also be modified by personality and social environment, making it at times, erroneous to deduce attitude from behaviour patterns.

Given the complex nature of 'attitude' and its numerous definitions by psychologists who used it as a unit of social psychological analysis, it is important that science educators define the term carefully if it is to be used to better understand and predict the science-related behaviours of students and teachers (Koballa, 1988).

2.5.2 Attitude Research in Science Education

In the field of science education, investigating students' attitude towards science became a substantive feature of work due to concern about the attitudes of secondary school students in England as well as a declining enrolment in college classes in the USA following the curriculum reform movements in the 1960s and 1970s (Reid, 2006). Ormerod and Duckworth

(1975) (cited in Osborne, Simon, & Collins, 2003, p. 1050) made the following comment in their review of students' attitudes to science in the UK:

> In 1965 a thorough inquiry began into the flow of students of science and technology in higher education…particular emphasis on the phenomenon which had become known as the 'swing from science'. Several explanations were suggested for the swing, among them a disaffection with science and technology amongst students.

A considerable research effort was mounted, leading to a wealth of literature on attitudes in science. However, these efforts brought about only minimal enhancement of the understanding of the attitude concept and advancement in attitude research. Some typical general criticisms of the research results are made by Mallinson (1977) who stated that 'frustration comes from the inconclusive, and in many cases contradictory findings of the studies' (p. 167), Peterson and Carlson (1979) who commented that 'attitude research is chaotic' (p. 500) and Schibeci (1984) who felt that it was 'disappointing that the set of conclusions which can be drawn from such a large body of literature is so limited' (p. 46).

The dismal results of attitude research have been attributed to three causes: (i) the lack of conceptual clarity in defining attitude toward science; (ii) the lack of a theoretical framework of the relationship of attitude with other variables; and (iii) immature and inadequate attitude instruments (Germann, 1988; Haladyna, Olsen, & Shaughnessy, 1982).

2.5.2.1 Lack of Conceptual Clarity

In attitude assessment, the term 'science' has had many meanings associated with it. It may mean science instruction, science careers, science as a school subject, science itself, specific science issues, work of scientists and scientific attitudes. These different constructs have been mixed in attitude assessment, resulting in a lack of clarity as to what the attitude was towards.

Attitude as it relates to science is divided into two areas; scientific attitude and attitude towards science. According to Aiken and Aiken (1969), 'scientific attitude' is another term for adherence to or knowledge of the 'scientific method'. It is a complex mixture of the desire to know and understand a questioning approach to all statements, a search for data and their meaning, a predisposition for objectivity and critical evaluation and a respect for logic. Cognitive in nature, scientific attitude has been characterized as 'thinking as scientists do, that is, acting on evidence in a disciplined way' (Munby, 1983, cited in Germann, 1988, p. 690). Since scientific attitudes are considered the supposed characteristics of scientists at work, students' acquisition of it was deemed an appropriate objective for science curricula.

The concept of attitude towards science has not been clear and has had diverse meanings (Krynowsky, 1988). It may address scientific attitudes, scientists, scientific careers, methods of teaching science, scientific interests, parts of a curriculum, or the subject of science in the classroom (Blosser, 1984, cited in Germann, 1988, p. 690). It may also refer to beliefs about processes, theoretical products, technological products, or the science-technology relationship (Munby, 1983, cited in Germann, 1988, p. 690). Osborne et. al.(2003) viewed attitudes towards science as possessing an affective nature for they described it as 'feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves' (p. 1053).

The lack of clarity in the concept of attitude towards science and its multi-dimensional nature make defining and measuring it in relation to behaviour problematic. As a consequence, research relating attitude to behaviour, with the ultimate goal of achieving stated instructional objectives through understanding and controlling student behaviour, is carried out on a hit-and-miss basis and the outcome, inconclusive. This is analogous to a microbiologist who fails to isolate the pure strain of the disease-causing organism in his/her bid to find a treatment for the disease (Peterson & Carlson, 1979).

2.5.2.2 Lack of a Theoretical Model

While theories of school learning, motivation and self-concept abound, there is no parallel in the study of attitudes. Science educators, from the practical perspective, are presented with research that sheds little light on what they can do, at the instructional programme level, to improve students' attitude towards the subject matter of science.

A theoretical framework shown in Figure 2.8 was developed by Haladyna, Olsen and Shaughnessy (1982) to examine the three essential features, namely, the students, the teacher and the learning environment, which are thought to influence students' attitude towards science.

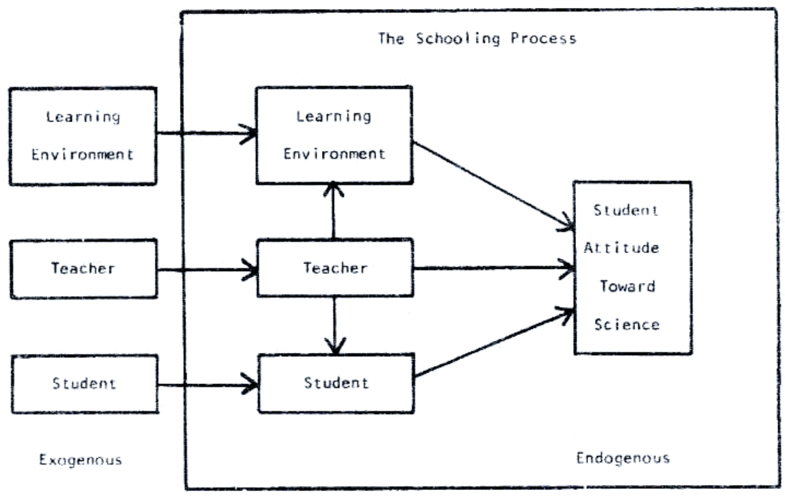

Figure 2.8. Illustration of the roles of exogenous and endogenous variables on attitudes towards science.
[Source: Haladyna, Olsen, & Shaughnessy, 1982, p. 673]

Content and focus constitute the two dimensions of the model. Content refers to any of the three areas of schooling, namely student, teacher or learning environment, under which variables employed by many studies of students' attitudes towards science can be subsumed.

Focus refers to the location of variables with respect to the organization being studied. Focus can be exogenous or endogenous. Exogenous variables are characteristics that are beyond the immediate manipulation of the educational process. Examples are age and gender of students and teachers, physical condition of the school building and the socioeconomic status of the students. Endogenous variables are characteristics which are within the system and thus under the influence, both direct as well as indirect, of the schooling process and are thus seen as critical in the development of attitude towards the subject matter of science. Examples of endogenous variables are teacher praise and reinforcement of students, relationships between students and the formality of the classroom environment (Haladyna, Olsen, & Shaughnessy, 1983). The theoretical model can be summarized using a symbolic expression of $Y = F [S, T, E]$ where Y is the dependent variable, that is, attitude towards science, S is the construct representing student variables, T is the construct representing teacher variables and E is the learning environment (Haladyna, Olsen, & Shaughnessy, 1982).

Findings from studies using this model reveal that while there is no evidence to support any meaningful relationships between exogenous student variables and science attitudes, student attitudes towards science are strongly related to student variables like students' sense of the importance of science and their level of fatalism, teacher quality variables like enthusiasm, knowledge, praise, support, fairness and commitment to learning and classroom learning environment variables like students' sense of satisfaction with their work, positive and organized classroom environment (Haladyna, Olsen, & Shaughnessy, 1982).

2.5.2.3 Inadequate Attitude Instruments

The instruments for the measurement of attitude towards science have been described as 'immature' and 'inadequate' (Munby, 1983, cited in Germann, 1988, p. 691) due to their inability to provide appropriate psychometric evidence of reliability and validity. The statistical measures of reliability are merely measures of internal consistency with almost no evidence on test-retest reliability, when in reality genuine reliability is assessed using the questions on more than one occasion (Reid, 2006).

Validity, measuring what the instrument is purported to measure, is another very important construct in attitudinal measurement. Evidence can be gathered through asking groups of 'experts', conducting sample interviews, developing the questions following discussions with the population concerned or by some external observation. However, it is important to know that attitudes are not perfect predictors of behaviour and as such, validity is not established in an absolute manner (Reid, 2006).

2.6 CHAPTER SUMMARY

The heart of the TLLM initiative is engaged learning and on this journey of TLLM, inquiry-based learning is a vehicle in science instruction. Since the principles of inquiry-based learning are rooted in the theory of constructivism, it was appropriate that an attempt had been made to study the degree of constructivism prevalent in most classrooms and the use of the CLES for this purpose was most suitable. The QTI functioned as a complementary instrument as it shed light on the interaction between students and teachers, providing a more complete picture of the classroom learning environment, an important aspect of TLLM as 'Tone of environment' is one of the 'petals' in the PETALS framework of TLLM.

It was also of interest to ascertain if constructivism in the classroom learning environment was in any way associated with students' attitude toward science. Hence, the use of the ten-item Likert scale questionnaire entitled 'Attitude To Science Lessons'.

Armed with greater knowledge about students' attitude, science educators are in a better position to take measures to enhance any attitude which may be lacking and which has an impact on the outcomes of science education. This intervention may bring about greater desired outcomes in science education for is it not that ‘the best milk comes from contented cows?’ (Fraser, 1982a, p. 559)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the research questions, significance, research design with regard to sampling, instruments used and data collection procedures. Following the discussion on the research design and procedures, there is a segment detailing the ethical issues that needed to be taken into consideration at the different stages of data collection.

3.2 RESEARCH TITLE AND SIGNIFICANCE OF THE STUDY

The title of the research study reads 'Students' Learning Environment and Attitude Toward Science in light of the Teach Less Learn More (TLLM) Initiative'.

As implied in the title, the TLLM initiative ignited the conduct of this research study. With TLLM, the teaching and learning of science in primary schools experienced a paradigm shift. The primary science syllabus was revised and implemented in 2008. Amongst the changes was a content reduction in the curriculum, resulting in a 20% freed-up time called the 'white space' during which schools were able to implement customized school-based programmes to bring about more engaged learning. In addition, schools were relooking at the forms of school-based assessment. The pedagogy emphasized was inquiry-based learning which has constructivism as its underlying principle.

It is of interest then to find out how extensive the constructivist learning environment had permeated into the classrooms, the interactions that took place between teachers and students and students' attitude toward science lessons, one year following the implementation of the revised curriculum, through the use of questionnaires like the Constructivist Learning Environment Survey (CLES), Questionnaire on Teacher Interaction (QTI) and Attitude Scale.

As different schools had students of varying academic abilities, it would be of no surprise that schools embraced this initiative with different degrees of enthusiasm, activities and modes of assessment during this era of curriculum revision. The questionnaire designed for this purpose and administered to the Heads of Department (Science) would provide a glimpse of the activities that were taking place in different schools and the findings could be consolidated into a repository of good practices.

The research questions as presented in Chapter 1 are as follows:

(i) Are the CLES (Actual and Preferred), QTI and Attitude Scale valid and reliable instruments for use in Singapore?

(ii) Are there significant differences between the actual and preferred levels of constructivism in the classroom as perceived by eleven-year-olds?

(iii) Are there any significant associations between the constructivist learning environment and the attitude of students to science lessons?

(iv) What are the students' perceptions of the classroom learning environment as portrayed by their science teachers' interpersonal behaviour?

(v) What are some of the customized programmes being used by teachers to bring about engaged learning in pupils?

(vi) What forms of summative and formative assessments have been implemented in schools as a consequence of the TLLM initiative?

3.3 RESEARCH DESIGN

Since the revised science curriculum was implemented in January 2008, data collection for the research was scheduled to take place in the last quarter of 2009, after teachers and pupils had attuned themselves to the revised curriculum.

Quantitative as well as qualitative data were gathered and analyzed in this research. The instruments used for quantitative data collection and analysis were the CLES, QTI and Attitude Scale. Qualitative data were gathered through the use of a specially designed questionnaire.

The targeted respondents of the quantitative aspect of this research were students in Primary 5 (eleven-year-olds) in 2009 since they constituted the pioneer cohort of the revised science curriculum. The population size of this cohort was estimated to be 56,000. It was impossible to gather data from tens of thousands of eleven-year-olds in all the primary schools in Singapore. According to Gay and Airasian (cited in Mertler & Charles, 1998, p. 146), 'once population sizes of a certain magnitude (about N=5,000) are exceeded, population sizes become irrelevant and a sample size of n=400 will provide adequate representation'. In Singapore, the average number of pupils in each class is 40. Consequently, students from ten classes, spread amongst five schools, made up the sample. The average enrolment of each class was between 35 and 40 students.

As the inquiry-based approach is founded on the theory of constructivism, the Actual and Preferred Forms of the CLES were administered to the students to assess if there was a significant difference between pupils' preferred and actual level of constructivism in their science learning environment. The QTI was administered to provide an insight into the classroom environment with regard to interaction between teachers and students. The Attitude Scale was used to assess pupils' attitude toward science in the domain of their enjoyment of science lessons.

Qualitative research requires the use of deliberate sampling known as 'purposive sampling'. As the name implies, the sample is chosen based on some purpose or focus in mind (Punch, 1998). Being the ones to lead the science department in their respective schools, all the HODs (Science) constituted the critical mass of respondents of a questionnaire designed to gather data on the different customized school-based programmes to bring about engaged learning.

3.4 INSTRUMENTS USED

3.4.1 Constructivist Learning Environment Survey (CLES)

Two forms of the CLES were available for use to gather students' perceptions of their classroom learning environment. They were the Actual and Preferred Forms. Item wording is almost identical in the Actual and Preferred Forms except that the words 'I wish' are included in the Preferred Form to remind students that they are rating their preferred or ideal classroom rather than the actual. For example, the statement 'In this class, I get the chance to talk to other students' in the Actual Form of the CLES was changed in the Preferred Form to 'In this class, I wish that I got the chance to talk to other students'.

To assess the constructivist learning environment in the classrooms, the 30-item CLES (Preferred and Actual Forms) were used. The items in the CLES are grouped under five scales, namely Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation. Table 3.1 shows the description and a sample item for each scale.

Table 3.1
Description of Scales and Sample Items for the Constructivist Learning Environment Survey (CLES)

Scale name	Description	Sample item
Personal Relevance	Relevance of learning to students' lives	In this science class, I learn about the world outside the school.
Uncertainty	Provisional status of scientific knowledge	In this science class, I learn the views of science have changed over time.
Critical Voice	Legitimacy of expressing a critical opinion	In this science class, it's OK to ask the teacher, 'Why do we have to do this?'
Shared Control	Participation in the planning, conducting and assessing of learning	In this science class, I help the teacher to plan what I'm going to learn.
Student Negotiation	Involvement with other students in assessing viability of new ideas	In this science class, I ask other students to explain their ideas.

[Source: Kim, Fisher, & Fraser, 1999, p. 241.]

There are six items in each of the five scales. With the exception of one item (Item 6), all items are positively worded. Table 3.2 shows the scale membership of items in the CLES.

Table 3.2
Allocation of Items to the CLES Scales

Scale	Item Numbers					
Personal Relevance	1	2	3	4	5	6
Uncertainty	7	8	9	10	11	12
Critical Voice	13	14	15	16	17	18
Shared Control	19	20	21	22	23	24
Student Negotiation	25	26	27	28	29	30

N.B. Item 6 should be reverse-scored
[Source: Taylor, Dawson, & Fraser, 1995.]

The response to each item is in the form of a 5-point Likert-type frequency response scale which comprises the categories: *Almost Always* (5 points), *Often* (4 points), *Sometimes* (3 points), *Seldom* (2 points) and *Almost Never* (1 point). Reverse scoring is used for Item 6 which is negatively worded. The maximum possible score of each six-item scale is 30 and the minimum possible scale score is 6.

3.4.1.1 Internal Consistency

Cronbach (1951) (cited in Fraser, 1977, p. 321) contended that 'a test score is only interpretable when the test possesses substantial internal consistency and when each item in the test measures the same construct as the rest of the items'. The Cronbach alpha reliability coefficients are measures of the internal consistency of each scale in learning environment instruments and alpha coefficient values in excess of 0.70 are generally satisfactory degrees of internal consistency (Fraser, 1986 cited in Taylor et al., 1995).

The internal consistency of the 30-item CLES had been ascertained in previous studies to be statistically robust as shown in Table 3.3.

Table 3.3
Descriptive Statistics of the 30-item CLES (N=494)

CLES scale	Mean Score	Standard Deviation	Alpha Reliability
Personal Relevance	20.6	4.8	0.82
Uncertainty	18.7	4.3	0.72
Critical Voice	18.7	6.2	0.88
Shared Control	10.9	5.1	0.91
Student Negotiation	19.9	5.5	0.89

[Source: Taylor, Dawson, & Fraser, 1995.]

It is also worthy to note that the mean scale scores and standard deviation shown in Table 3.3 served as a first set of normative data for comparing the results of future research studies in school science that make use of the 30-item CLES (Taylor et al., 1995).

3.4.1.2 Discriminant Validity

Other than being internally consistent, scales of a multi-scale learning environment instrument should also possess discriminant validity in that 'each scale should measure a unique construct not measured by any of the other scales in the battery' (Fraser, 1977, p. 322). The independence of a set of scales can be statistically determined by calculating a scale *inter-*

correlation matrix which is a measure of the extent to which the scores of each scale are independent of those of the other scales. Table 3.4 shows an inter-correlation matrix for the 30-item CLES scores.

Table 3.4
Inter-correlation of Scale Scores for the 30-item CLES (N=494)

	Uncertainty	Critical Voice	Shared Control	Student Negotiation
Personal Relevance	0.33	0.28	0.17	0.35
Uncertainty		0.29	0.28	0.28
Critical Voice			0.30	0.38
Shared Control				0.27

[Source: Taylor, Dawson, & Fraser, 1995.]

The values which range from a low of 0.17 to a high of 0.38 indicate that each of the five CLES scales has a satisfactory degree of independence, that is, the CLES scales assess distinct, but somewhat overlapping, aspects of classroom environments.

With the six-item CLES scales proven to be statistically robust and viable, the CLES is an instrument of choice for monitoring systemic constructivist-oriented reforms in science education.

3.4.2 Questionnaire on Teacher Interaction (QTI)

The QTI is divided into eight scales which correspond to the eight sectors of the model (Wubbels, Créton, & Hooymayers, 1985). In the Dutch version (developed in the early 1980s), each sector scale consists of about 10 items, making a total of 77 items, which are answered on a five-point Likert scale with responses varying from 'Always' to 'Never'. In 1991, an American version comprising a total of 64 items, with eight items for each of the eight scales and based on the same Likert response format was developed (Wubbels & Levy, 1991). In order to make the QTI a more economical instrument, a short version with 48 items spread equally among the eight scales of teacher behaviour was developed in Australia (Fisher, Fraser, & Cresswell, 1995; Lee, Fraser, & Fisher, 2003; Wubbels, Créton, Levy, & Hooymayers, 1993).

All three versions of the QTI have been validated in different countries and found to display satisfactory internal consistency as shown in Table 3.5.

Table 3.5
Internal Consistency (Cronbach Alpha Reliability) for QTI Scales for Students and Teachers in Three Countries

QTI Scale	Reliability					
	Students			Teachers		
	USA	Australia	The Netherlands	USA	Australia	The Netherlands
DC Leadership	0.80	0.83	0.83	0.75	0.74	0.81
CD Helpful/friendly	0.88	0.85	0.90	0.74	0.82	0.78
CS Understanding	0.88	0.82	0.90	0.76	0.78	0.83
SC Student responsibility/freedom	0.76	0.68	0.74	0.82	0.60	0.72
SO Uncertain	0.79	0.78	0.79	0.79	0.78	0.83
OS Dissatisfied	0.83	0.78	0.86	0.75	0.62	0.83
OD Admonishing	0.84	0.80	0.81	0.81	0.67	0.71
DO Strict	0.80	0.72	0.78	0.84	0.78	0.61
Sample Size	1606	792	1105	66	46	66

[Source: Wubbels, 1993, p. 7.]

One advantage of the QTI is that it can be used to obtain the perceptions of interpersonal behaviour of either students or teachers. In addition, students can be asked for their perceptions of their actual teacher or ideal teacher. Similarly, teachers can be asked for their perceptions of their own behaviour or the behaviour which they consider to be ideal. As such, four sets of perception scores can be obtained through the use of the QTI (Fisher et al., 1995).

3.4.2.1 The QTI for Students in Elementary Schools

An adaptation was made of the long 64-item version and the short 48-item version to form a short 48-item version suitable for use in elementary schools (Goh & Fraser, 1996, 1997). The elementary version of the QTI has the same eight scales and contains 48 items, i.e., six items per scale. However, some items with a high reading level found in the secondary school version have been modified and reworded into simpler language more suitable for younger students. For example, under the scale of Helpful/Friendly, the item ‘This teacher takes a personal interest in us’ was modified to ‘This teacher cares about us’. Table 3.6 provides examples of how some of the original items under each of the eight scales, with their description, were modified for use with elementary students.

Table 3.6
Examples of Wording of Secondary and Elementary Versions of the QTI

Scale	Description	Secondary version	Elementary version
Leadership	... the teacher provides leadership to the class and holds students’ attention	This teacher talks enthusiastically about his/her subject.	We all listen to this teacher.
Helpful/Friendly	... the teacher is friendly and helpful towards students	This teacher takes a personal interest in us.	This teacher cares about us.
Understanding	... the teacher shows understanding/concern/care for students	This teacher realises when we do not understand.	This teacher knows when we do not understand.
Student responsibility/ Freedom	... students are given opportunity to assume responsibility for their own activities	We had the opportunity to choose assignments which were most interesting to us.	This teacher allows us to choose what we want to work on.
Uncertain	... the teacher exhibits his/her uncertainty	This teacher seems uncertain.	This teacher doesn’t seem sure.
Dissatisfied	... the teacher shows unhappiness/dissatisfaction with students	This teacher seems dissatisfied.	This teacher is unhappy.
Admonishing	... the teacher shows anger/temper/impatience in class	This teacher makes mocking remarks.	This teacher makes fun of us.
Strict	... the teacher is strict with and demanding of students	This teacher is severe/tough when marking papers.	This teacher is strict when marking our work.

[Source: Goh & Fraser, 1997, p. 107.]

The response alternatives of the elementary version of the QTI used by Goh and Fraser (1997) also differ from those in the secondary school version in that the former has a three-point Likert response format consisting of 'Seldom', 'Sometimes' and 'Most of the Time' as opposed to the five point response scale from 'Always' to 'Never' in the secondary school version. The three-point scale makes it simpler and easier for younger students to express their opinions regarding their teachers' interpersonal relationship with them. As the students surveyed in this research study were upper primary students, the elementary version of QTI with four-point Likert response scale comprising 'Never', 'Seldom', 'Sometimes' and 'Most of the Time' was used. The questionnaire remained a simple and easy-to-comprehend questionnaire for the students.

The 48 items of the QTI are arranged in a cyclic order, in blocks of 8, with one item in each block measuring the behaviour in each corresponding sector of the circumplex model. Table 3.7 illustrates the allocation of the 48 items in the QTI into eight scales, together with a sample item for each scale.

Table 3.7
Allocation of Items into Scales and Sample Item for Each QTI Scale

QTI Scale	No. of Items	Item Numbers in Scale	Sample Item
Leadership (DC)	6	1, 9, 17, 25, 33, 41	We all listen to this teacher.
Helpful/Friendly (CD)	6	2, 10, 18, 26, 34, 42	This teacher is friendly.
Understanding (CS)	6	3, 11, 19, 27, 35, 43	This teacher trusts us.
Student responsibility/ Freedom (SC)	6	4, 12, 20, 28, 36, 44	This teacher gives us a lot of free time in class.
Uncertain (SO)	6	5, 13, 21, 29, 37, 45	This teacher doesn't seem sure.
Dissatisfied (OS)	6	6, 14, 22, 30, 38, 46	This teacher is unhappy.
Admonishing (OD)	6	7, 15, 23, 31, 39, 47	This teacher gets angry quickly.
Strict (DO)	6	8, 16, 24, 32, 40, 48	This teacher is strict.

[Source: Goh & Fraser, 1997, p. 108.]

3.4.2.2 Internal Consistency of the QTI (Elementary School Version)

The revised version of the QTI for use in the elementary school was validated by administering it to 1,512 students, aged 10 to 11 years, in 13 elementary schools in Singapore (Goh & Fraser, 1997). The Cronbach alpha coefficient was computed for each QTI scale at two levels of analysis (the individual student and class mean) as a measure of internal consistency reliability. It can be seen from Table 3.8 that the QTI scales have high indices of internal consistency reliability at the class mean level of analysis.

Table 3.8
Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of Analysis for the Questionnaire on Teacher Interaction (Elementary)

QTI Scale	Alpha Reliability	
	Individual (N=1512)	Class mean (N=39)
Leadership (DC)	0.63	0.90
Helpful/Friendly (CD)	0.78	0.96
Understanding (CS)	0.65	0.94
Student responsibility/Freedom (SC)	0.58	0.73
Uncertain (SO)	0.50	0.83
Dissatisfied (OS)	0.76	0.96
Admonishing (OD)	0.74	0.93
Strict (DO)	0.58	0.81

[Source: Goh & Fraser, 1997, p. 109.]

The findings illustrated in Table 3.8 were comparable to those of the secondary school version validated in The Netherlands, the USA and Australia (Wubbels, 1993; Wubbels & Levy, 1991 cited in Goh & Fraser, 1997, p. 108).

3.4.2.3 Scale inter-correlation

According to the circumplex model of the interpersonal teacher behaviour (refer to Figure 2.2), adjacent behaviour scales should correlate highest and positively with each other and the degree of correlation diminishes as the scales become increasingly different as they move further apart from each other until they are diametrically opposite to each other. For example, Understanding (CS) and Helpful/Friendly (CD) should correlate highest and positively with each other but Understanding (CS) and Admonishing (OD) should have the highest negative correlation, being diametrically opposite to each other. The QTI scale inter-correlations shown in Table 3.9 satisfy this assumption with minor discrepancies.

Table 3.9
Scale Inter-correlation for Each QTI Scale Using Individual Students and Classes as Units of Analysis

QTI Scale	Scale Inter-correlations							
	Lea (DC)	HFr (CD)	Und (CS)	SRe (SC)	Unc (SO)	Dis (OS)	Adm (OD)	Str (DO)
Leadership (DC)	-	0.60	0.60	0.10	-0.34	-0.43	-0.42	0.11
Helpful/Friendly (CD)	0.90	-	0.65	0.26	-0.28	-0.61	-0.59	-0.13
Understanding (CS)	0.92	0.91	-	0.32	-0.24	-0.48	-0.48	-0.03
Student Responsibility/ Freedom (SC)	0.52	0.61	0.64	-	0.19	-0.11	-0.11	-0.21
Uncertain (SO)	-0.74	-0.61	-0.67	-0.20	-	0.42	0.41	-0.01
Dissatisfied (OS)	-0.85	-0.90	-0.89	-0.57	0.69	-	0.76	0.31
Admonishing (OD)	-0.76	-0.83	-0.86	-0.57	0.65	0.95	-	0.32
Strict (DO)	-0.21	-0.42	-0.38	-0.38	0.16	0.57	0.65	-

Data above the diagonal are for individual students while data below the diagonal are for class means.
[Source: Goh & Fraser, 1997, p. 110.]

Since the QTI items have been simplified to make it a suitable instrument for use with elementary school students and its robustness and viability proven statistically, it was the instrument selected for use in this research.

3.4.3 Attitude Scale

The instrument used to measure students' attitude towards science was the Attitude Scale entitled 'Attitude to Science Lessons'. It was a 10-item questionnaire with a response format of a 3-point Likert scale; 1 for

‘Disagree’, 2 for ‘Not sure’ and 3 for ‘Agree’. The Attitude Scale was adapted and modified from the scale ‘Enjoyment of Science Lesson’ of the *Test of Science-Related Attitude* (TOSRA). Since the Attitude Scale was modified from the TOSRA, a short description of the TOSRA and issues related to the measurement of attitude would be discussed in the following paragraphs.

3.4.3.1 The Test of Science-Related Attitude (TOSRA)

Inherent in TOSRA is the recognition that the concept of ‘attitudes to science’ is a multi-dimensional construct. As such, this instrument has seven scales, each measuring a unique construct. There are 10 items under each scale. Table 3.10 illustrates the constructs measured by the seven scales and how these scales fit into Klopfer’s scheme of classification of affective domain in the realm of science education (Klopfer, 1976). A sample item from each scale is also included in Table 3.10.

Table 3.10
Scale Name, Klopfer’s Classification, and Sample Item for Each TOSRA Scale

Scale Name	Klopfer’s Classification	Sample Item
Social Implications of Science	H.1: Manifestation of favourable attitudes toward science and scientists	Scientific discoveries are doing more harm than good. (-)
Normality of Scientists		Scientists usually like to go to their laboratories when they have a day off. (-)
Attitude toward Scientific Inquiry	H.2: Acceptance of scientific inquiry as a way of thought	I would prefer to find out why some things happen by doing and experiment than by being told. (+)
Adoption of Scientific Attitudes	H.3: Adoption of ‘scientific attitudes’	I like to listen to people whose opinions are different from mine. (+)
Enjoyment of Science Lessons	H.4: Enjoyment of science learning experiences	Science lessons bore me. (-)
Leisure Interest in Science	H.5: Development of interests in science and science-related activities	I dislike reading newspaper articles about science. (-)
Career Interest in Science	H.6: Development of interest in pursuing a career in science	I would like to be a scientist when I leave school. (+)

[Source: Fraser, 1978, p. 510.]

The items in TOSRA involve a response format which requires students to express their degree of agreement with each statement on a five-point Likert scale. Scoring involves allocating 5,4,3,2 and 1 for Strongly Agree (SA), Agree (A), Not Sure (N), Disagree (D) and Strongly Disagree (SD) respectively for positive (+) items. Reverse scoring is carried out for negative (-) items.

The TOSRA has been validated by administering it to 1,337 students in Years 7, 8, 9 and 10 level in Sydney metropolitan area and found to be a psychometrically sound instrument (Fraser, 1981). The Cronbach alpha coefficients and indices of mean correlation with other scales are shown in Table 3.11.

Table 3.11
Reliability and Discriminant Validity (Mean Correlation with Other Scales of Each TOSRA Scale)

Scale	α Reliability in Year				Mean correlation with other scales
	7	8	9	10	
Social Implications of Science	0.81	0.82	0.75	0.82	0.39
Normality of Scientists	0.72	0.70	0.72	0.78	0.27
Attitude to Inquiry	0.81	0.82	0.81	0.86	0.13
Adoption of Scientific Attitudes	0.66	0.64	0.69	0.67	0.33
Enjoyment of Science Lessons	0.93	0.92	0.92	0.93	0.39
Leisure Interest in Science	0.88	0.85	0.87	0.89	0.39
Career Interest in Science	0.90	0.88	0.88	0.91	0.40
Mean of nine scales	0.82	0.80	0.81	0.84	0.33

[Source: Fraser, 1981, p. 5.]

3.4.3.2 The Attitude Scale and the 'Dining Room Table' Phenomenon

Researchers investigating attitudes towards science need to recognize that attitudes are not composed of a single unitary construct but 'consist of a large number of sub-constructs all of which contribute in varying proportions towards an individual's attitudes towards science' (Osborne et al., 2003, p. 1054). The implication for the use of attitude scales which measure attitudes towards science is that each scale should measure a single construct and items written for each scale must all be related to measuring the construct that the scale is purported to measure because ‘a disparate collection of items, reflecting attitude towards a wide variety of attitude objects, does not constitute a scale, and cannot yield a meaningful score’ (Gardner, 1975, p. 12).

Gardner (1975, 1995) further cautioned researchers against committing the measurement flaw of adding up the different scale scores to obtain a grand total score as a single measurement of attitude towards science. Gardner illustrated the weakness of this erroneous practice using the ‘dining room table analogy’. The mass, length and height of a dining room table can all be measured meaningfully. However, adding these variables to form a ‘Dining Room Table Index’ results in a variable that is meaningless and cannot be interpreted.

Taking the TOSRA and from which the Attitude Scale used in this study into consideration, the TOSRA, with its seven scales each measuring a different construct (internally consistent and unidimensional), acknowledges that scientific attitude is a complex and multi-dimensional construct. The Attitude Scale, used in this study, derived from the modification of the ‘Enjoyment of Science Lessons’ scale of the TOSRA served as a unidimensional scale of measuring distinctly one construct, that is, the students’ enjoyment of science lessons.

3.4.4 The Questionnaire for Heads of Department, Science

The qualitative aspect of this study was based on the analysis of data gathered using the investigator-designed questionnaire. The Heads of Department (Science) of all the schools were the targeted respondents of this survey in which they were requested to furnish information on the types of activities carried out in their respective school in lieu of the 20% ‘white space’ in the science curriculum and the types of formative and summative assessments implemented. Specifically, the following were posed in the questionnaire administered to the Heads of Department (Science):

(i) Please state in point form and describe briefly the activities carried out in your school in lieu of the 20% ‘white-space’ in the science curriculum. Please specify whether these activities are class-based, level-based or school based.

(ii) Please state the different forms of assessments (both formative and summative) used in your school.

3.5 DATA COLLECTION AND ANALYSIS

3.5.1 Administration of Questionnaires

The CLES (Preferred and Actual Forms), QTI and Attitude Scale were administered to 333 students from 10 intact classes drawn from five mainstream primary schools (two classes per school) in the third quarter of 2009. The classes selected were the middle ability students as they constituted the majority of the Primary 5 student population in Singapore. Intact classes were surveyed instead of a random selection of students from the Primary 5 cohort in each school so as to minimize disruption to the regular instructional programme of the schools.

The CLES (Actual Form) and QTI were administered to each class within a 45-minute period by the investigator after a brief introduction on the rationale of the students’ partaking of the survey. A concern that had to be taken into consideration when administering the questionnaire was the issue of ‘reactivity’ which had been defined as ‘the extent to which the process of collecting the data changes the data’ (Punch, 1998, p. 258). The students might be influenced by ‘social desirability’, giving responses that would please their teachers or make themselves appear good. To pre-empt the occurrence of such a phenomenon, the students were instructed to submit anonymous returns of their questionnaires. During the 45-minute period, the investigator moved around the class to answer any query that arose but care was taken not to influence students’ response to the items.

The CLES (Preferred Form) and Attitude Scale were administered to the same class by the investigator one week later. The time allocated for the administration of these two questionnaires was again 45 minutes. Before the commencement of the survey, the investigator brought to the students' attention the difference between the CLES (Actual) which they completed the week before and the CLES (Preferred) which they were about to respond to. As with the practice of the week before, the investigator moved around in class, attending to students who had queries but at the same time taking the precaution of not influencing students in their responses.

The investigator-designed questionnaire was administered to the HODs (Science) when they convened annually in the first quarter of 2010 for an information dissemination session conducted by the personnel from the Curriculum Planning and Development Division of MOE. This convention of HODs (Science) was an opportune time to administer this survey.

3.5.2 Data Analysis

With reference to the first research question, the data obtained from the CLES (Actual and Preferred Forms), QTI and the Attitude Scale were validated to ascertain if they were reliable and valid instruments for use in Singapore. This was carried out by calculating the Cronbach Reliability Coefficients and inter-scale correlation coefficient to measure, respectively, the internal consistency and discriminant validity of each instrument.

With reference to the second research question on determining if there were any significant differences between the actual and preferred levels of constructivism in the classes surveyed, a t-test was performed for each scale of the CLES to determine whether or not to reject the following null hypothesis:

H_0: There is no significant difference between the mean of the Preferred and that of the Actual scale of the CLES

H_A: There is a significant difference between the mean of the Preferred and that of the Actual scale of the CLES

The t-test was carried out at the collective level with students' scores as the unit of analysis (N=333) and at the individual class level, using the class mean as the unit of analysis. The former provided a general view of the level of constructivism while the latter provided one with a closer look at the level of constructivism inherent in each unique classroom learning environment.

The third research question on significant association between the constructivist learning environment and the attitude of students to science lessons was answered by performing a simple correlation to yield a Pearson product-moment correlation coefficient, r, to determine if there was any association, and if so, the direction and strength of relationship between the variables. A multiple correlation coefficient, R, was calculated to determine the correlation between the combined scales of the CLES and students' attitude to science lessons and the coefficient of multiple determination, R^2, calculated to yield information on the proportion of variance in students' attitude to science lessons as being accounted for by the combined scales of the CLES. Multiple regression was performed to obtain the standardized regression coefficient, β, to ascertain which individual CLES scales, if any, contributed most to explaining the variance.

Research question 4 which concerned the students' perceptions of the classroom learning environment in terms of their science teachers' interpersonal behaviour was answered by studying the item mean of the QTI scale, using the students' score as the unit of analysis (N=333) and creating a QTI profile of the entire sample. Ten sector profiles were also created for the ten classes surveyed to provide a more detailed picture of the teacher's interpersonal behaviour in each class.

Research questions 5 and 6 entailed data collected and analyzed qualitatively via surveys to the HODs (Science) of each school. As the questionnaire contained sub-divided segments on customized programmes and forms of assessments, the responses were extracted and generalized under the respective segment.

3.6 ASSUMPTIONS

The following segments describe briefly the assumptions that were made in the conduct of this study.

3.6.1 Exposure to Science Instruction

All the students surveyed, despite coming from five different schools, were assumed to have been equally exposed to three years of science instruction as science is a core subject that is formally taught from Primary 3 in the education system of Singapore.

3.6.2 Competency in Answering the CLES

Though the CLES is designed for use in the secondary schools, the items are worded in a straightforward and comprehensible manner. Thus, it had been assumed that it was within the reading level of students in Primary 5 and as a consequence, the students would be able to comprehend the items and respond accordingly.

3.6.3 Responses to Questionnaires

As anonymity was maintained in all questionnaires and students were reminded before the commencement of the survey that there were no right or wrong answers to each item, it was thus assumed that a certain level of assurance had been given to the respondents who in turn would provide honest and candid responses in their answering of the questionnaires.

3.7 ETHICAL CONSIDERATIONS

The high regard that researchers command brings with it ethical principles that researchers are expected to conform and such research ethics should be considered at the onset of the research project (Oliver, 2003). The following paragraphs detail the ethical issues that needed to be taken into consideration at the different stages of this research.

3.7.1 Ethical Issues Before Data Collection

As a teacher carrying out a research study, permission had to be sought from the Ministry of Education (MOE). A research proposal submitted to and approved by both Curtin University and the MOE would accrue me with the confidence to embark on my research, especially in unanticipated circumstances, knowing that it had met accepted standards.

Once the approval for me to collect data had been obtained from the Curtin Ethics Committee and the MOE, I wrote to the head of the Curriculum Planning and Development Division (CPDD) of MOE to seek permission for a time slot to administer my questionnaire for HODs (Science), during their annual meeting in the auditorium of the MOE building. Permission had to be sought, too, from the principals of the five schools from which the students would be administered the CLES, QTI and Attitude Scale.

The head of CPDD and principals were metaphorically referred to as 'gatekeepers' - 'individuals who have management or administrative control in an organization, and who can decide in absolute terms whether you be permitted to carry out your research' (Oliver, 2003, p. 39). Being gatekeepers, these people would inevitably be concerned about the impact of my research on their organizations, for example, how it would affect the day-to-day functioning of their organizations or if the data obtained would be disclosed outside the organization. As such, I had an ethical obligation to fully inform them of the nature of my research study and the areas where the research might have an impact upon the organization. This information enabled the gatekeepers to make an informed decision and had the reassurance that the research process would not have any adverse effect on the organization.

Once I had got past the 'gatekeepers', I could gain access to the data subjects; the HODs (Science), students and their teachers. The HODs (Science) needed to be fully informed of how data from the questionnaire aided in the research study. They might worry that their honest inputs in the questionnaire would be made known to their principals and consequently jeopardize their principals' opinion of them. To alleviate this inherent apprehension, the HODs (Science) were told to hand in anonymous responses. In addition, they were informed of my intention to pool together the data such that individual respondents were subsumed under the total aggregated data, an alternative technique to the use of fictional names to ensure anonymity (Oliver, 2003).

As for the CLES, QTI and Attitude Scale to be administered to the students, the issues of the principle of informed consent and anonymity were more complex. Teachers and students are what Oliver (2003) referred to as 'vulnerable groups of people' in the hierarchical organization of a school because when the principal had consented to partake of this research survey, the students and teachers needed to comply even though they would very much prefer not to. As a researcher, I needed to exercise sensitivity to these groups of respondents. They were entitled to be fully informed about the nature of the research and how the data would be used and be assured that they would be none the worse after the survey. Each party was given a separate participant information sheet explaining the objectives of the study and a consent form for the students’ parents. The consent of the teachers was not sought as once the principal had agreed to allow the students to take part in this research, the teachers had to toe the line.

3.7.2 Ethical Issues During Data Collection

The data-collection phase of research entails close interaction between researcher and respondent and as a result, generates situations involving ethical issues (Oliver, 2003). The ethical principle that intrusion and inconvenience should be minimized was adhered to, given that this study made use of solely questionnaires, some of which requiring only 45 minutes of curriculum time per occasion. Since all the HODs (Science) were to complete the questionnaires during their annual meeting, they would not be inconvenienced at their workplace.

3.7.3 Ethical Issues After Data Collection

After the data collection had been completed, the ethical responsibilities of a researcher continued into the next phase of research, namely, data analysis and interpretation and the publication of the results of the research study.

Being one who had not been specially trained in the field of statistics, there was a need for me to take special care in the application of statistical techniques. I avoided using complex statistical techniques whose underlying assumptions or statistical or mathematical bases I did not understand. In instances where such techniques were essential to the research, it was imperative that I sought professional help. Excessive analysis, a phenomenon Nie et al. (quoted in Sammons, 1989, p. 50) termed 'grand fishing expeditions' should be avoided. Instead, I used only the statistical procedures which had significant bearing on my research study.

Other than performing a descriptive function, data from statistics can be used for making inferences. Care had to be taken by me to avoid what Robinson (quoted in Sammons, 1989, p. 48) termed 'ecological fallacy', that is, 'the mistake of attempting to generalize the results of analyses conducted at one level to another'. Since my study involved eleven-year-old students, I should not make a generalization that the findings were a reflection of the entire primary school student population. It was important that I specified the level of analysis right at the beginning of my investigation.

After the data had been analyzed, I needed to think about what I intended to do with the data; to dispose of them immediately, to retain them for a period of time in case some questions might arise regarding some of the analysis or to store them for future use. Whatever the decision, my research participants needed to be informed and consent sought again in cases where the data had to be used in future for another study, either as an extension of my current research or one of a totally different nature.

The writing of the research report carried with it, too, ethical issues which should not be overlooked. An ethical issue commonly associated with writing and publication is 'plagiarism' - 'the use of another person's ideas or writing without any acknowledgement of the source of that material' (Oliver, 2003, p. 132). Extreme care had to be taken by me, right from the onset of my writing journey, not to flout this 'golden rule' of the writing and publication domain.

The research report that I put up should provide comprehensive details with regard to the entire research study. Details such as rationale for a particular choice of methodologies and analysis, sample size, response rates, sampling error (if any) and reliability and validity of instruments used would enable future researchers to scrutinize the study for the purpose of replication or extension of the research.

The need for a balanced, objective and accurate research report entailed me to be able to recognize the possible limitations to accuracy and to express them explicitly in the report. As it is not uncommon to experience unexpected turns of event or unanticipated outcomes which result in making changes to research designs, methodologies or analysis, I had an ethical obligation to examine and explain this element of subjectivity to the readers of my research. According to Seale (quoted in Oliver, 2003, p. 141), it is 'becoming increasingly common for researchers to provide a reflective account as part of the conclusion of the research report, in order to explore the manner in which their own perspective on the world may have influenced the collection and analysis of data', it was thus a good idea to include in my research report my reflection to illuminate my entire research study.

Just as onerous as writing the research report was the task of reading the entire report by a reader or another researcher to gain a rapid grasp of the contents to ascertain if my work was relevant to their areas of interest. As such, the role that synopses or abstracts play in the dissemination of research should not be underestimated (Oliver, 2003). Given the significance of synopses or abstracts, it was pertinent that I wrote a clear and concise abstract or synopsis summarizing the principal features of my research design, the data-collection and analysis techniques, the outcomes of the research and the limitations of those results.

A matter which frequently does not receive the careful attention it merits has to be highlighted. Sammons (1989) observed that many researchers fail to provide the authority which granted them access to data details of their results and copies of articles. Shipman (quoted in Sammons, 1989, p. 55) supported this observation with a comment made by a former director - 'It was as if researchers were not interested in dissemination and had little idea of the courtesies of research. Teachers are not paid to help research. They should at least be given first sight of the results'. In view of this common oversight, I made an attempt to present my findings to the authorities like the principals, and to my research participants, the HODs (Science) and the teachers.

All completed questionnaires were kept in the safety of my home. Raw data as well as computed ones were stored in external hard disks, kept also in the safety of my home and password protected. After the completion of the thesis, the hard copies of the questionnaires and the electronic copies of all data are to be stored in a secure place in my supervisor's office in SMEC for a period of five years, after which they will be destroyed. Electronic data will continue to be password protected during this five-year period.

3.8 CHAPTER SUMMARY

The research design, methodology, instruments and ethical issues related to this study had been discussed in this chapter. As the research was conceptualized from the TLLM initiative whose five dimensions of engaged learning are encapsulated in the PETALS Framework, the research design and methodology can be aptly summarized using the image of a diligent bumblebee as shown in Figure 3.1 since, frequently, there exists an association between flowers and bees.

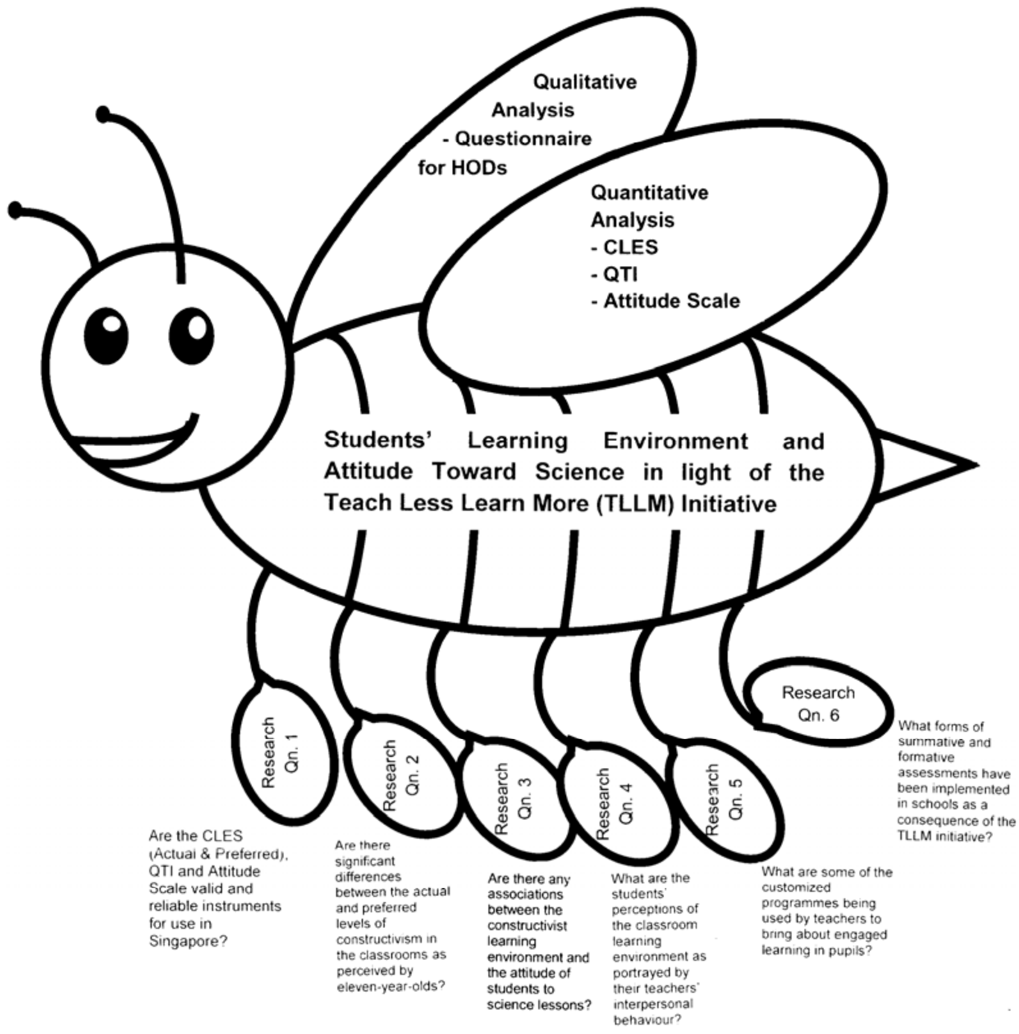

Figure 3.1. Diagrammatic representation of the research design.

The research question, being at the heart of this study, is distinctly reflected in the main body of the bumblebee, with each of the six legs of the insect bearing each of the six research questions. Powering the flight of the insect are two wings which are analogous to the two types of analyses carried out in this research, steering and determining the direction of this study. Described in the next chapter are the results and discussions pertaining to this study.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter describes the results of the study based on the research questions previously presented in Chapters 1 and 3:

(i) Are the CLES (Actual and Preferred Forms), QTI and Attitude Scale valid and reliable instruments for use in Singapore?
(ii) Are there significant differences between the actual and preferred levels of constructivism in the classrooms as perceived by eleven-year-olds?
(iii) Are there any significant associations between the constructivist learning environment and the attitude of students to science lessons?
(iv) What are the students' perceptions of the classroom learning environment as portrayed by their science teachers' interpersonal behaviour?
(v) What are some of the customized programmes being used by teachers to bring about engaged learning in pupils?
(vi) What forms of formative and summative assessments have been implemented in schools as a consequence of the TLLM initiative?

4.2 RESEARCH QUESTION 1: ARE THE CLES (ACTUAL AND PREFERRED FORMS), QTI AND ATTITUDE SCALE VALID AND RELIABLE INSTRUMENTS FOR USE IN SINGAPORE?

The Cronbach alpha coefficient and the scale inter-correlations of the CLES and QTI (Elementary) were calculated to ascertain if the two instruments possess internal consistency and discriminant validity, in the case of the CLES, and the circumplex nature of the QTI, when put to use in the elementary schools in Singapore. The internal consistency of the Attitude

Scale (Attitude To Science Lessons) was also ascertained using the Cronbach alpha coefficient.

4.2.1 Internal Consistency of the CLES (Actual & Preferred Forms)

Table 4.1 reports two statistics, namely, the internal consistency (alpha reliability coefficient) and discriminant validity, for the 30-item Actual Form of the CLES using the individual student score (N=333) as the unit of analysis.

Table 4.1
Internal Consistency (Cronbach Reliability Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for the Actual Form of the CLES

Scale	Alpha Reliability	Mean Correlation
Personal Relevance	0.64	0.26
Uncertainty	0.50	0.30
Critical Voice	0.75	0.24
Shared Control	0.85	0.31
Student Negotiation	0.82	0.30

The reliability data in Table 4.1 suggest that the CLES scales have acceptable internal consistency with the alpha coefficient ranging from 0.85 to 0.50. The low reading of 0.50 occurred for the Uncertainty scale. This scale measures the extent to which opportunities are provided for students to experience that scientific knowledge is evolving and culturally and socially mediated. It boils down to the issue of the Nature of Science (NOS). Examining the science syllabus revealed that no mention was made about the characteristics of scientific knowledge, that is, it being durable yet tentative, culturally laden and socially negotiated. Boo (1995) carried out a study involving pre and in-service teachers in Singapore on their understanding of the nature of science. The findings revealed that the majority of the participants' views were limited and superficial. Similar results were reported in another study by Boo and Toh (1998) involving practising teachers in Singapore. Many were of the opinion that science is a static collection of immutable facts and theories about the natural world and which can be proven true by experimentation.

If teachers themselves were clueless about NOS, no exception could be expected of students. Examples of items under the Uncertainty scale read 'I learn that science has changed over time' and 'I learn about the different sciences used by people in other cultures' might have proven too abstract for the eleven-year-old students, resulting in their inability to fully comprehend the statements and as a consequence, the lowest alpha reliability coefficient amongst the five scales. The items should have been rewritten to peg them at the level of comprehension of these eleven-year-olds, pilot tested and administered. This proposition could be seriously taken into account when using the CLES with students in the elementary schools in future.

Table 4.2 reports two statistics, namely, the internal consistency (alpha reliability coefficient) and discriminant validity, for the 30-item Preferred Form of the CLES using the individual student score (N=333) as the unit of analysis.

Table 4.2
Internal Consistency (Cronbach Reliability Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for the Preferred Form of the CLES

Scale	Alpha Reliability	Mean Correlation
Personal Relevance	0.82	0.31
Uncertainty	0.66	0.35
Critical Voice	0.81	0.31
Shared Control	0.90	0.39
Student Negotiation	0.89	0.40

The reliability data in Table 4.2 suggest that the CLES scales have acceptable internal consistency with the alpha coefficient ranging from 0.90 to 0.66. In fact, the alpha coefficients for all the five scales of the Preferred Form of the CLES are higher than that of the corresponding scales of the Actual Form of the CLES.

4.2.2 Scale Inter-correlation of the CLES (Actual & Preferred Forms)

Data about discriminant validity were generated using the mean correlation of a scale with the other scales as a convenient index. The extent to which each scale discriminated against one another in the Actual Form of the CLES is shown in Table 4.3.

Table 4.3
Inter-correlation of Scale Scores for 30-item Actual Form of the CLES (N=333)

	Uncertainty	Critical Voice	Shared Control	Student Negotiation
Personal Relevance	0.32	0.14	0.23	0.34
Uncertainty		0.21	0.33	0.31
Critical Voice			0.38	0.24
Shared Control				0.30

The inter-correlation matrix for the 30-item Actual Form of the CLES scores was obtained from the 333 eleven-year-old students. The values ranged from 0.14 (*Personal Relevance – Critical Voice*) to 0.38 (*Critical Voice – Shared Control*), an indication that each of the five CLES scales of the Actual Form had a satisfactory degree of independence.

The inter-correlation matrix for the 30-item Preferred Form of the CLES is shown in Table 4.4.

Table 4.4
Inter-correlation of Scale Scores for the 30-item Preferred Form of the CLES (N=333)

	Uncertainty	Critical Voice	Shared Control	Student Negotiation
Personal Relevance	0.41	0.14	0.28	0.42
Uncertainty		0.25	0.30	0.42
Critical Voice			0.53	0.30
Shared Control				0.46

The values ranged from 0.14 (*Personal Relevance – Critical Voice*) to 0.53 (*Critical Voice – Shared Control*), an indication that each of the five CLES scales of the Preferred Form had a satisfactory degree of independence.

4.2.3 Internal Consistency of the QTI (Elementary)

The Cronbach alpha coefficient was computed for each QTI scale and the findings are shown in Table 4.5.

Table 4.5
Internal Consistency (Cronbach Reliability Coefficient) for the Questionnaire on Teacher Interaction (Elementary)

QTI Scale	Alpha Reliability
Leadership (DC)	0.71
Helpful/Friendly (CD)	0.85
Understanding (CS)	0.79
Student Responsibility/Freedom (SC)	0.73
Uncertain (SO)	0.51
Dissatisfied (OS)	0.71
Admonishing (OD)	0.77
Strict (DO)	0.62

Table 4.5 reports the internal consistency reliability using the individual student score (N=333) as the unit of analysis. The reliability (Cronbach reliability coefficient) for different QTI scales ranged from 0.51 to 0.85. The data in Table 4.5 suggested that the QTI (Elementary) had good reliability with seven out of eight scales (namely, Leadership, Helpful/Friendly, Understanding, Student Responsibility/Freedom, Dissatisfied, Admonishing and Strict), having values between 0.62 and 0.85. These values were comparable to those reported by Goh & Fraser (1997) whose study involved the use of the QTI (Elementary) with 1,512 students in Singapore. An observation worth highlighting was that in this study and that of Goh and Fraser (1997) involving Singaporean students in the elementary schools, the highest reliability occurred for Helpful/Friendly teacher behaviour and the lowest for Uncertain teacher behaviour.

4.2.4 Scale Inter-correlations of the QTI (Elementary)

The pattern of inter-scale correlation, using the individual student score (N=333) as the unit of analysis, was calculated to investigate the circumplex structure of the elementary version of the QTI and the findings are presented in Table 4.6.

Table 4.6
Scale Inter-correlations for Each QTI Scale

QTI Scale	Scale Inter-correlations							
	Lea (DC)	HFr (CD)	Und (CS)	SRe (SC)	Unc (SO)	Dis (OS)	Adm (OD)	Str (DO)
Leadership (DC)	-	0.75	0.70	0.49	-0.36	-0.45	-0.41	-0.04
Helpful/Friendly (CD)		-	0.78	0.61	-0.30	-0.60	-0.58	-0.24
Understanding (CS)			-	0.65	-0.28	-0.52	-0.50	-0.16
Student Responsibility/ Freedom (SC)				-	0.01	-0.43	-0.45	-0.27
Uncertain (SO)					-	0.38	0.32	0.11
Dissatisfied (OS)						-	0.78	0.46
Admonishing (OD)							-	0.50
Strict (DO)								-

Consistent with the circumplex structure of the QTI as depicted in Figure 2.6, generally the correlation of each scale was the greatest with the adjacent scale. For example, Helpful/Friendly and Understanding correlated highest and positively with each other and the magnitude of the correlation decreased as the scales became further apart from each other until they were diametrically opposite to each other, and in which case, the highest negative correlation registered. For example, Helpful/Friendly and Dissatisfied had the greatest negative correlation. Overall, the QTI scale inter-correlations shown in Table 4.6 are generally consistent with the circumplex nature of the QTI, except for minor discrepancies.

4.2.5 Internal Consistency of the Attitude Scale (Attitude To Science Lessons)

The alpha reliability coefficient of the Attitude Scale is shown in Table 4.7.

Table 4.7
Mean, Standard Deviation and Internal Consistency (Cronbach Reliability Coefficient) of the 10-item Attitude Scale (Attitude To Science Lessons)

Attitude Scale	Mean	Standard Deviation	Alpha Reliability
Attitude To Science Lessons	2.53	0.40	0.84

The Cronbach reliability coefficient was 0.84. This implied that the ten items of the scale had a high degree of internal consistency, that is, they consistently measured what they were purported to measure in terms of students' enjoyment of science lessons.

4.3 RESEARCH QUESTION 2: ARE THERE SIGNIFICANT DIFFERENCES BETWEEN THE ACTUAL AND PREFERRED LEVELS OF CONSTRUCTIVISM IN THE CLASSROOMS AS PERCEIVED BY ELEVEN-YEAR-OLDS?

Students' perceptions of their constructivist science classroom learning environment were studied. Comparisons were made between the preferred and actual perceptions, at the collective level of the total number of students sampled as well as at the individual class level.

4.3.1 Comparison between the Preferred and Actual Forms of the CLES at the collective level

The scale means, standard deviation and t-values were calculated. The mean of each scale of the Preferred and Actual Form of the CLES is graphically depicted in Figure 4.1.

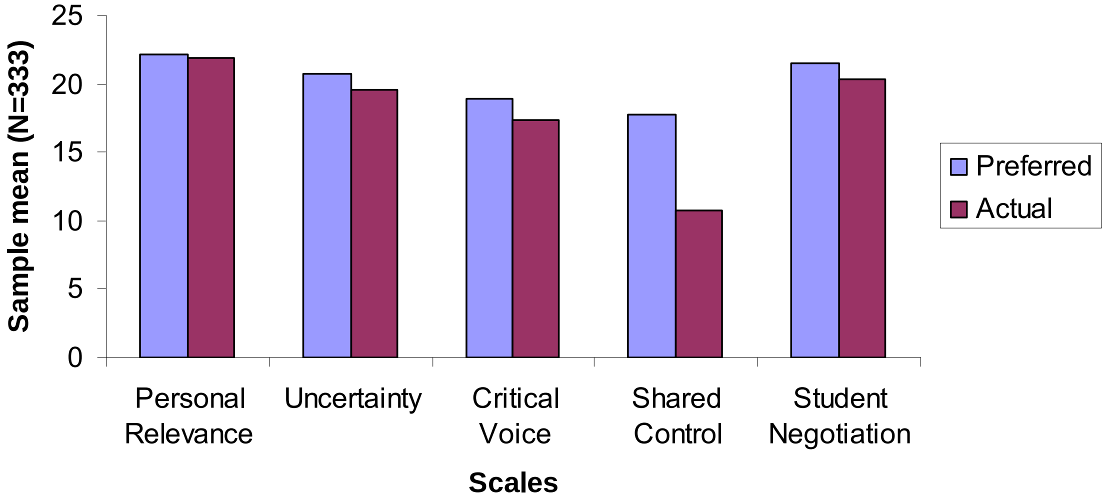

Figure 4.1. Comparison between the Preferred and Actual Forms of the CLES of sample.

In order to ascertain if there were any significant differences between the means, a t-value for equal variances for each scale was calculated and the findings tabulated in Table 4.8.

Table 4.8
Scale Mean, Standard Deviation, Difference in Mean and t-value for the Preferred (Pref) and Actual (Act) Forms of the CLES

Scale	Mean		Standard Deviation		Difference	t-value
	Pref	Act	Pref	Act	Pref - Act	
Personal Relevance	3.70	3.65	0.79	0.62	0.05	0.87
Uncertainty	3.46	3.26	0.73	0.64	0.20	3.81**
Critical Voice	3.14	2.89	0.94	0.88	0.25	3.67**
Shared Control	2.96	2.15	1.11	0.90	0.81	10.21**
Student Negotiation	3.59	3.38	0.97	0.88	0.21	2.90**

*p<0.05
**p<0.01
***p<0.001

An examination of Figure 4.1 and Table 4.8 revealed a discrepancy between the Preferred and Actual Forms of the CLES, with the preferred scores consistently higher than that of the actual for all the five scales. These differences were significant (p<0.01) for the scales of Uncertainty, Critical Voice, Shared Control and Student Negotiation, with Shared Control registering the greatest significant difference.

The Uncertainty scale measures the extent to which students are provided with the learning opportunities to make them become aware that scientific knowledge or truth is not static and unchanging. Instead, it is evolving with new discoveries and mediated culturally and socially. This aspect of science education involves addressing the issues of the nature of science and is lacking in the science curriculum of the elementary schools in Singapore. This could be a possible explanation for the significant difference in the scores of Preferred and Actual Forms of the CLES for the Uncertainty scale.

The culture of Shared Control is characterized by students and teachers discussing and agreeing on how teaching and learning should be carried out in terms of lesson activities, delivery and assessment of and for learning. However, planning and implementation of learning activities and the assessment of learning are left entirely to the discretion of the teachers whose decisions are guided by the national curriculum in the primary schools in Singapore. Getting the students to have a say in what forms of lesson activities and how they should be delivered is unheard of as the students are deemed too young and lack the pedagogical content knowledge to be involved in the decision-making process of important tasks like teaching and learning, thus leading to the great disparity between the preferred and actual level of Shared Control.

The significant difference in Critical Voice could be attributed to the fact that though the present generation of primary school going students are deemed more outspoken than those ten or twenty years ago, most still hold their teachers in high regard and as such, outright criticism or questioning of lesson activities or rationales are seen as being insolent or disrespectful and therefore, unacceptable. Perhaps students do harbour such thoughts and tendency to verbalize their questions or criticisms but refrain from doing so as the culture of the classroom learning environment does not condone such acts.

Of the four scales which registered significant differences between the means of the Preferred and Actual Forms of the CLES, the smallest significant difference was in the scale of Student Negotiation. The mitigating factor could be the promotion of cooperative learning strategies in the classrooms. Students are given opportunities to carry out discussions with their peers but the result of the study implies that more could be done.

The scale of Personal Relevance saw no significant difference between the means of the preferred and that of the actual. This phenomenon could be a reflection that teachers had been successful in leading students to see the relevance of science in their everyday life through activities carried out both within and beyond the confines of the classrooms, the details of which are given in Section 4.6 of this study. The results of two items in the Attitude Scale, namely, ‘I want to find out more about the world in which we live’ and ‘Finding out about new things is important’ can be studied in relation to the scale of Personal Relevance of the CLES because the items reflect the desire of students to seek scientific knowledge about the natural world in which they live and the importance they attached to this aspect of their science learning. Figures 4.2 and 4.3 depict the responses of students to these two statements in the Attitude Scale.

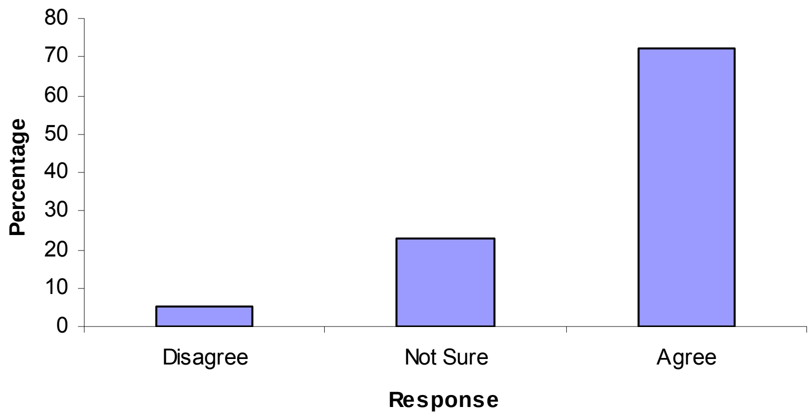

Figure 4.2. Responses of students for Item 5 of the Attitude Scale - ‘I want to find out more about the world in which we live’.

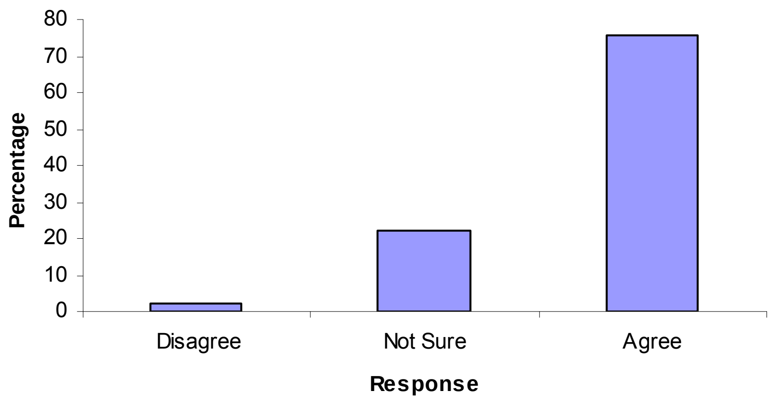

Figure 4.3. Responses of students for Item 6 of the Attitude Scale - 'Finding out about new things is important'.

The results shown in Figures 4.2 and 4.3 indicate that the students have a strong desire to learn more about their natural world. The absence of a significant difference between the Preferred and Actual Forms of the CLES for the scale of Personal Relevance means that the science learning environment did provide students with sufficient learning opportunities to satisfy their thirst for scientific knowledge and lead them to come to the realization of the applicability of science in their everyday life.

4.3.2 Comparison between the Preferred and Actual Forms of the CLES at the level of individual classes

Using the class mean as the unit of analysis, the preferred and actual constructivist classroom learning environment of the ten classes sampled were analyzed. To maintain anonymity, the names of the schools and classes had been replaced with letters and numbers. Since five schools were involved in the survey, with two classes in each school sampled, the classes were renamed 5A1, 5A2, 5B1, 5B2, 5C1, 5C2, 5D1, 5D2, 5E1 and 5E2. The number '5' indicates that the students were in Primary 5 classes, the letters take the place of the names of the school and the number following the letter represents the class in the school. Figures 4.4 to 4.13 show the results of the ten classes.

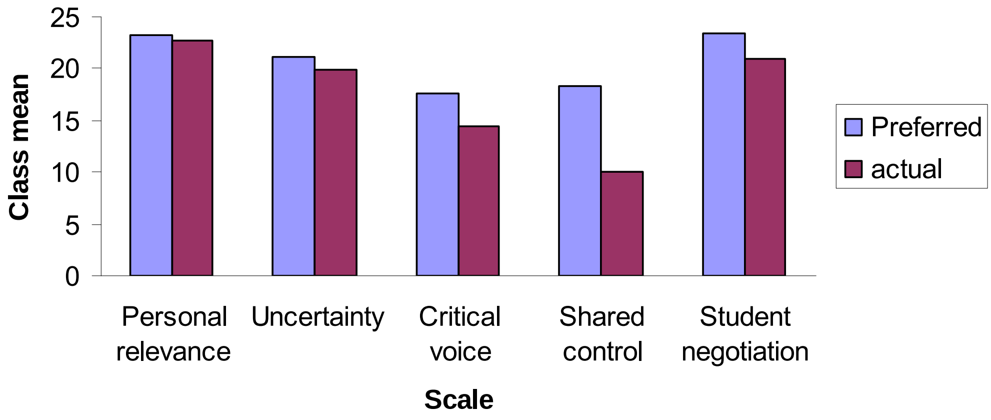

Figure 4.4. Comparison between the Preferred and Actual Forms of the CLES of Class 5A1.

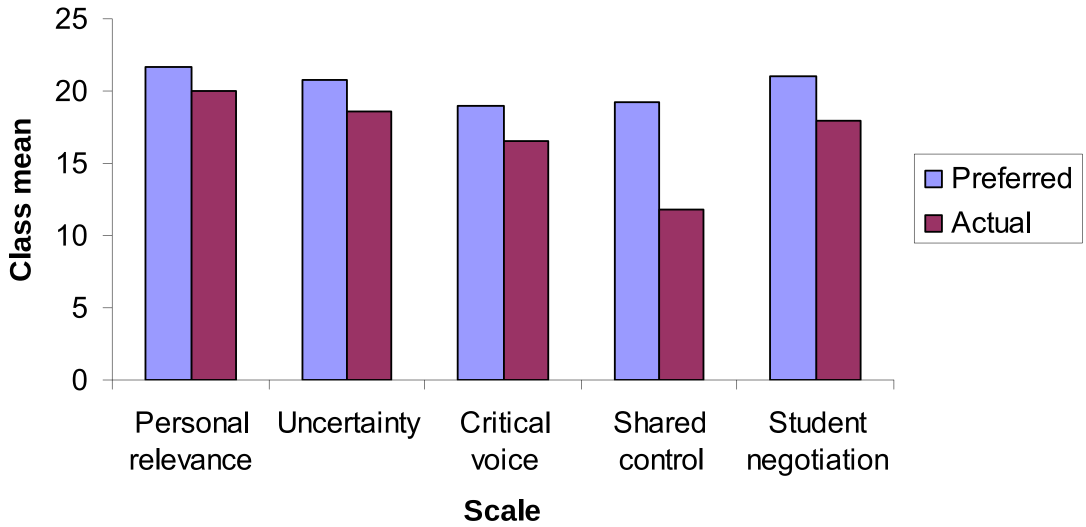

Figure 4.5. Comparison between the Preferred and Actual Forms of the CLES of Class 5A2.

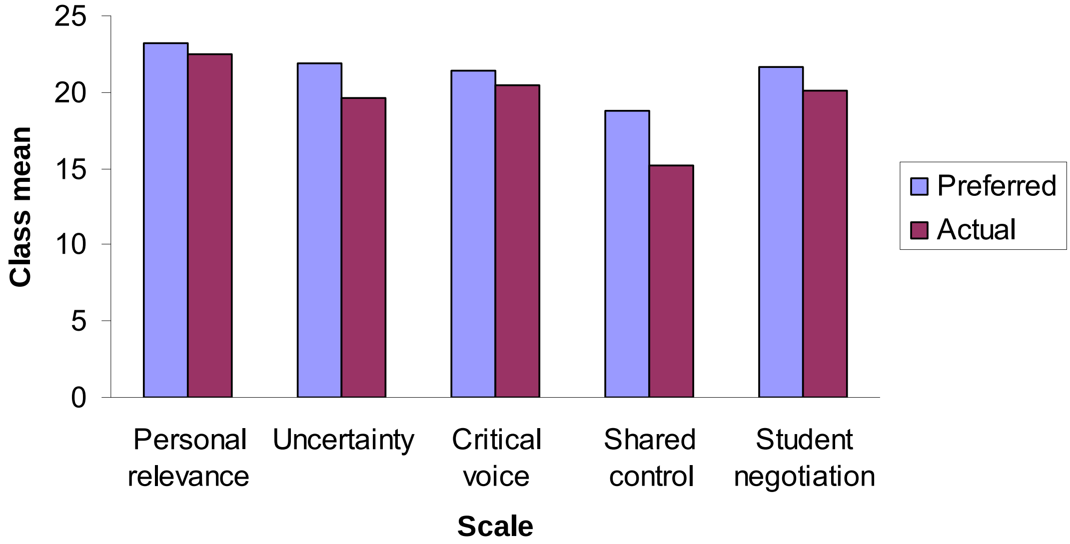

Figure 4.6. Comparison between the Preferred and Actual Forms of the CLES of Class 5B1.

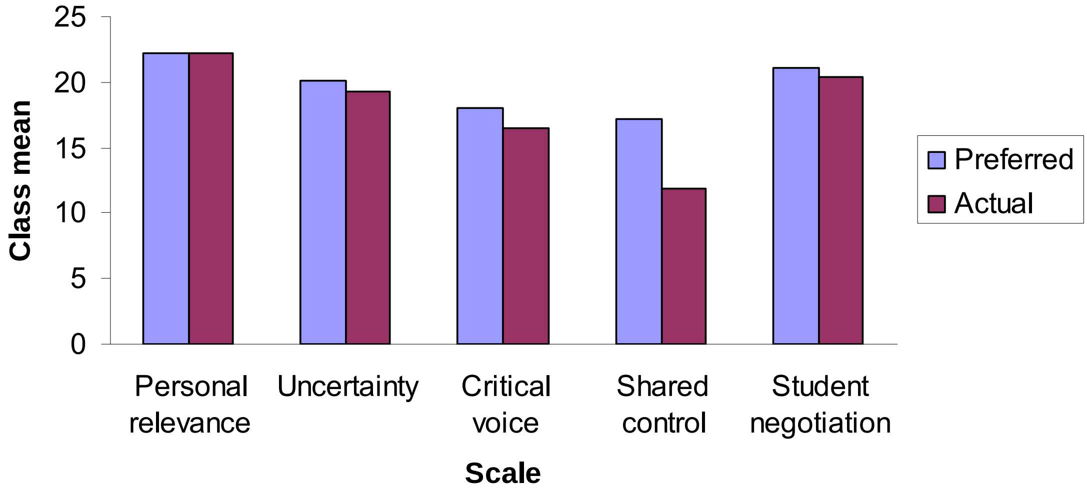

Figure 4.7. Comparison between the Preferred and Actual Forms of the CLES of Class 5B2.

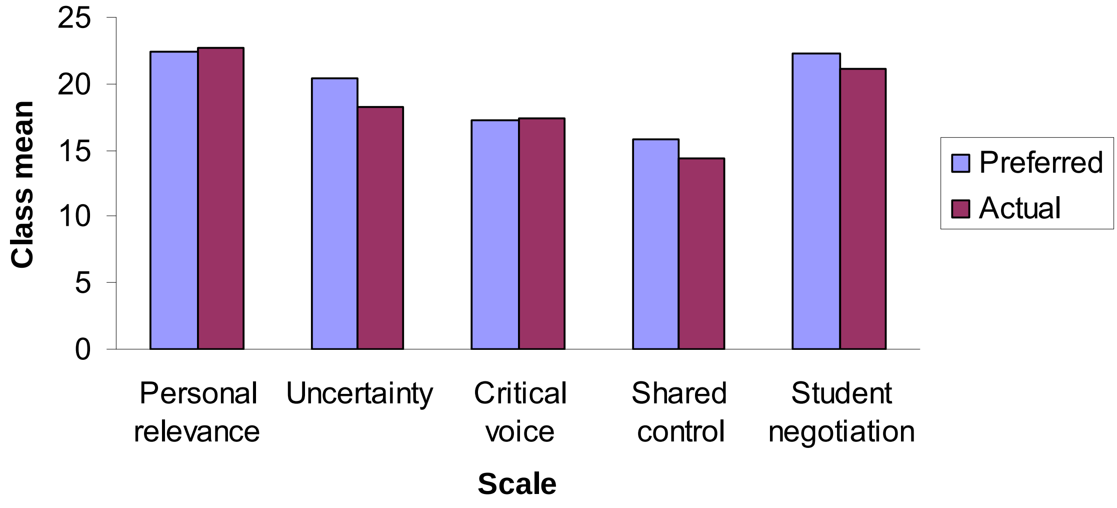

Figure 4.8. Comparison between the Preferred and Actual Forms of the CLES of Class 5C1.

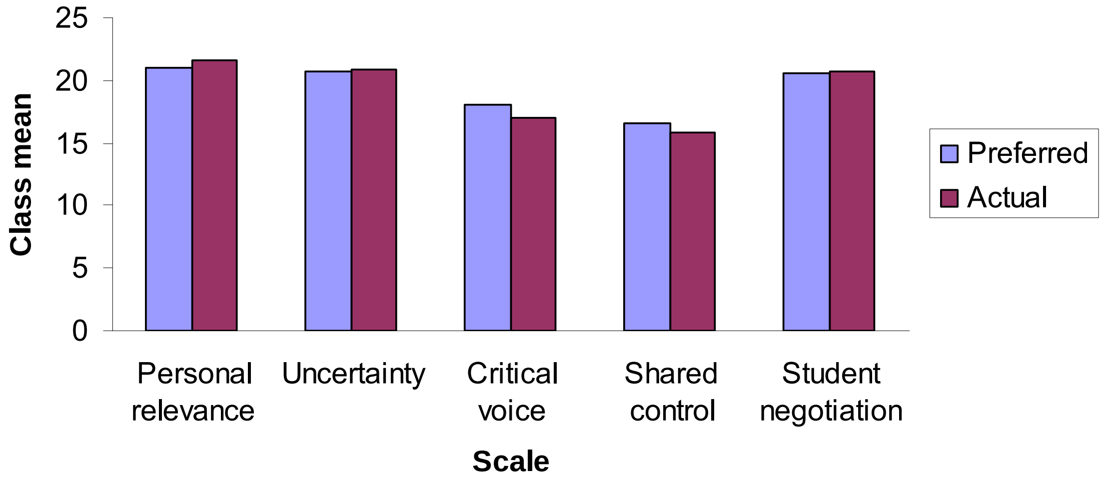

Figure 4.9. Comparison between the Preferred and Actual Forms of the CLES of Class 5C2.

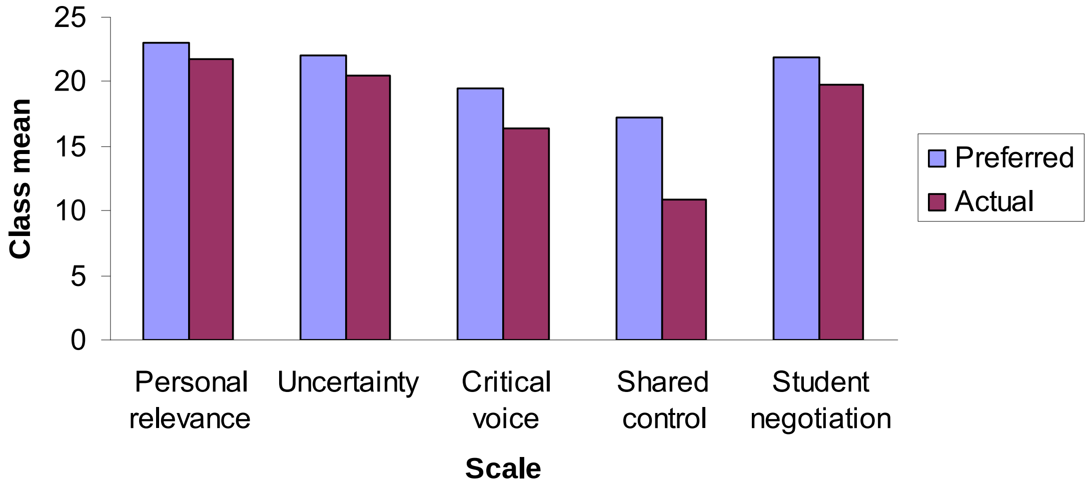

Figure 4.10. Comparison between the Preferred and Actual Forms of the CLES of Class 5D1.

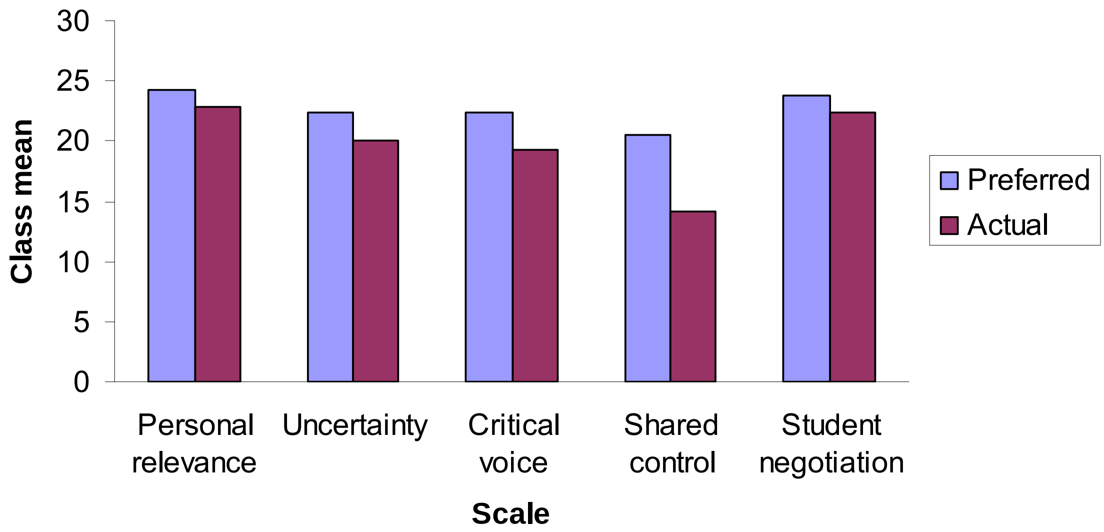

Figure 4.11. Comparison between the Preferred and Actual Forms of the CLES of Class 5D2.

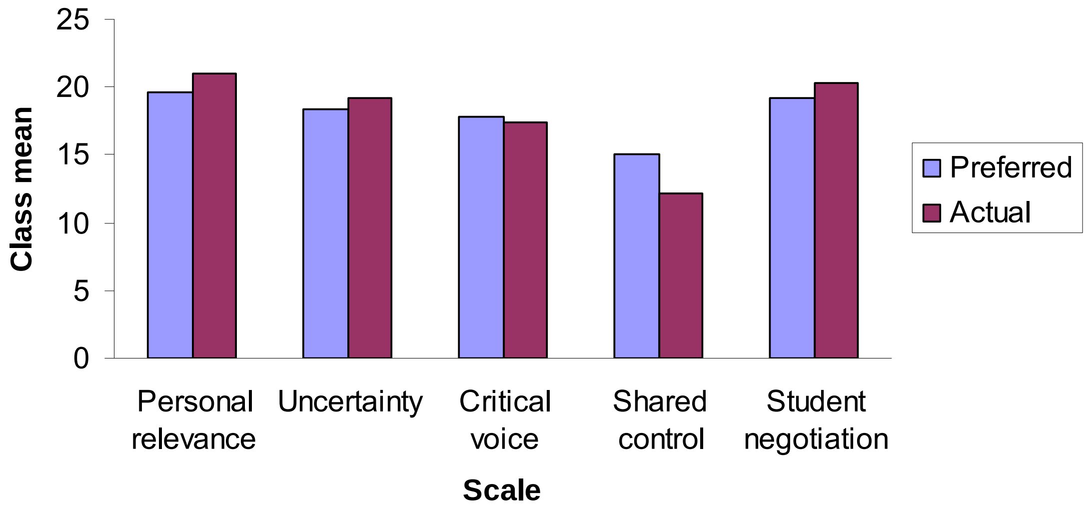

Figure 4.12. Comparison between the Preferred and Actual Forms of the CLES of Class 5E1.

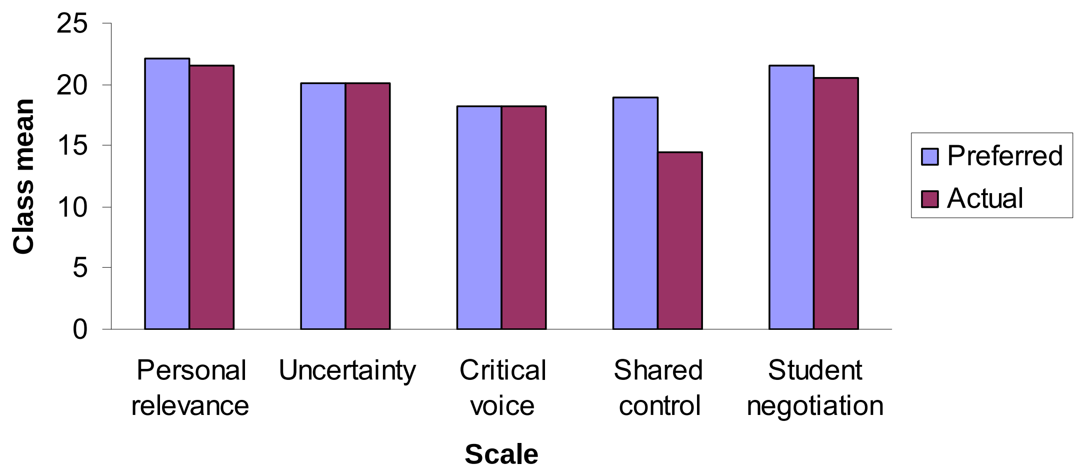

Figure 4.13. Comparison between the Preferred and Actual Forms of the CLES of Class 5E2.

In order to ascertain if there were any significant differences between the preferred mean and actual mean of each scale, a t-test was performed and the t-test values are presented in Tables 4.9 to 4.13.

Table 4.9
Class Mean and t-value for the Scale of Personal Relevance

Class	Mean		Difference	t-value
	Preferred	Actual	Preferred - Actual	
5A1	23.21	22.64	0.57	0.57
5A2	21.63	20.05	1.58	1.49
5B1	23.22	22.53	0.69	0.78
5B2	22.16	22.21	-0.05	-0.06
5C1	22.35	22.64	-0.29	-0.31
5C2	21.00	21.57	-0.57	-0.47
5D1	23.04	21.71	1.33	1.08
5D2	24.26	22.87	1.39	1.06
5E1	19.64	21.06	-1.42	-1.69
5E2	22.17	21.52	0.65	0.62

*$p<0.05$

The findings presented in Table 4.9 indicated that there were no significant differences between the preferred and actual means for all the ten classes for the scale of Personal Relevance. This was consistent with the findings in the Personal Relevance scale of the collective results in section 4.3.1 of this study.

Table 4.10
Class Mean and t-value for the Scale of Uncertainty

Class	Mean		Difference	t-value
	Preferred	Actual	Preferred - Actual	
5A1	21.08	19.82	1.26	1.34
5A2	20.83	18.55	2.28	2.28*
5B1	21.88	19.60	2.28	2.60*
5B2	20.16	19.29	0.87	0.93
5C1	20.44	18.24	2.2	2.24*
5C2	20.73	20.80	-0.07	-0.07
5D1	22.08	20.50	1.58	1.34
5D2	22.35	20.09	2.26	1.66
5E1	18.36	19.22	-0.86	-0.89
5E2	20.07	20.14	-0.07	-0.07

*$p<0.05$

Table 4.10 shows that only three classes registered a significant difference between the means of the preferred and actual for the scale of Uncertainty. It is interesting to note that there were three classes whose mean from the actual slightly surpassed that of the preferred. It would be useful to find out from the students what their teachers did to raise their awareness of the tentative, socially and culturally mediated nature of scientific knowledge.

Table 4.11
Class Mean and t-value for the Scale of Critical Voice

Class	Mean		Difference	t-value
	Preferred	Actual	Preferred - Actual	
5A1	17.54	14.46	3.08	2.48*
5A2	19.00	16.55	2.45	2.06*
5B1	21.43	20.40	1.03	0.87
5B2	18.00	16.55	1.45	1.05
5C1	17.24	17.35	-0.11	-0.09
5C2	18.00	17.00	1.00	0.84
5D1	19.54	16.42	3.12	2.22*
5D2	22.39	19.35	3.04	1.65
5E1	17.78	17.44	0.34	0.30
5E2	18.24	18.21	0.03	0.03

*p<0.05

As with the scale of Uncertainty, Table 4.11 shows that three classes out of the ten surveyed posed a significant difference between the means of the Preferred and Actual Form for the scale of Critical Voice although the readings for the preferred were higher than that of the actual in all the classes except for one.

Table 4.12
Class Mean and t-value for the Scale of Shared Control

Class	Mean		Difference	t-value
	Preferred	Actual	Preferred - Actual	
5A1	18.36	10.05	8.31	5.58*
5A2	19.22	11.78	7.44	5.73*
5B1	18.83	15.25	3.58	2.53*
5B2	17.11	11.84	5.27	3.91*
5C1	15.85	14.41	1.44	1.09
5C2	16.50	15.77	0.73	0.50
5D1	17.17	10.88	6.29	3.63*
5D2	20.52	14.13	6.39	3.21*
5E1	15.00	12.19	2.81	2.35*
5E2	18.93	14.45	4.48	3.13*

*p<0.05

The readings in Table 4.12 showed a remarkably significant difference in the mean of the preferred and actual for the scale of Shared Control for nine out of the ten classes. The results reflected the authoritative environment that prevails in many of the classes in the schools in Singapore. The teachers remain very much the power-wielding authority figures and main decision-makers, with the students as docile participants in the business of learning science in their elementary years of schooling. This finding corresponded with the significant difference evident in the collective data finding in section 4.3.1 for the scale of Shared Control.

Table 4.13

Class Mean and t-value for the Scale of Student Negotiation

Class	Mean		Difference	t-value
	Preferred	Actual	Preferred - Actual	
5A1	23.36	20.92	2.44	1.94
5A2	20.95	17.98	2.97	2.41*
5B1	21.60	20.08	1.52	1.28
5B2	21.08	20.37	0.71	0.53
5C1	22.34	21.06	1.28	0.92
5C2	20.57	20.67	-0.10	-0.07
5D1	21.88	19.75	2.13	1.58
5D2	23.78	22.43	1.35	0.83
5E1	19.17	20.25	-1.08	-0.83
5E2	21.52	20.55	0.97	0.67

*$p<0.05$

Table 4.13 shows that only one class registered a significant difference between the mean of the preferred and that of the actual for the scale of Student Negotiation. As discussed in section 4.3.1, this positive outcome could be attributed to the wide implementation of the cooperative learning strategies in the schools in Singapore. However, there is still room for improvement as the scores of the preferred were higher than that of the actual for eight classes out of the ten surveyed. Many students feel that more could be done to provide them with opportunities to engage in intellectual discourse with their peers.

4.4. RESEARCH QUESTION 3: ARE THERE ANY SIGNIFICANT ASSOCIATIONS BETWEEN THE CONSTRUCTIVIST LEARNING ENVIRONMENT AND THE ATTITUDE OF STUDENTS TO SCIENCE LESSONS?

Prior to presenting and discussing the data on associations between the constructivist learning environment and the attitude of students to science lessons, in the dimension of their enjoyment of science lessons, the findings for each item of the Attitude Scale are presented.

4.4.1 Attitude of Students to Science Lessons

The Attitude Scale comprised ten items. The responses of the students for each item were graphically presented in Figures 4.14 to 4.23.

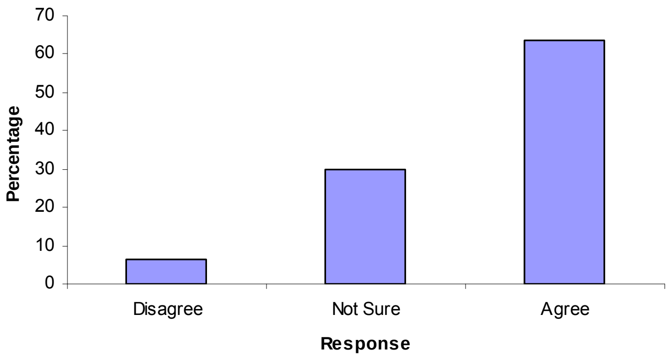

Figure 4.14. Responses of students for item 1 of the Attitude Scale - 'I look forward to science lessons'.

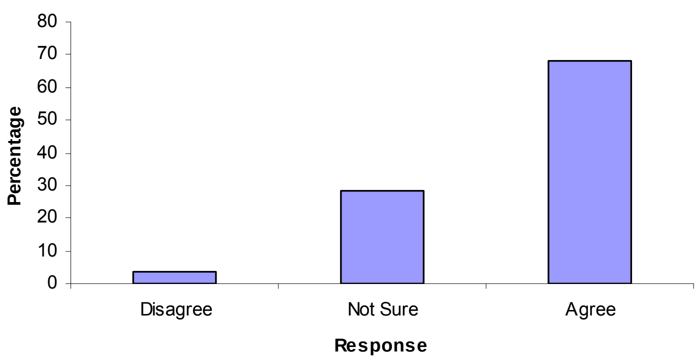

Figure 4.15. Responses of students for item 2 of the Attitude Scale - 'Science lessons are fun'.

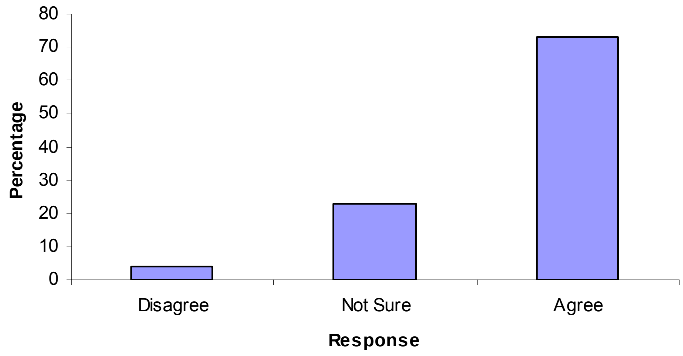

Figure 4.16. Responses of students for item 3 of the Attitude Scale - 'I enjoy the activities we do in science'.

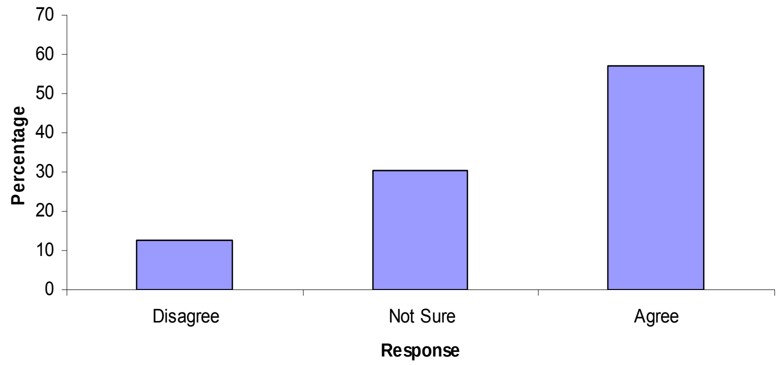

Figure 4.17. Responses of students for item 4 of the Attitude Scale - 'What we do in science are among the most interesting we do at school'.

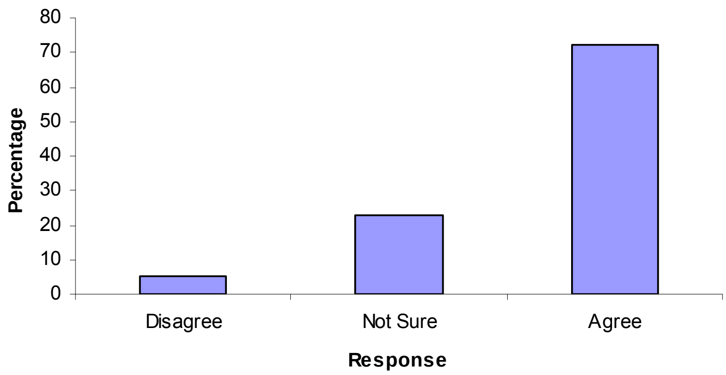

Figure 4.18. Responses of students for item 5 of the Attitude Scale - 'I want to find out more about the world in which we live'.

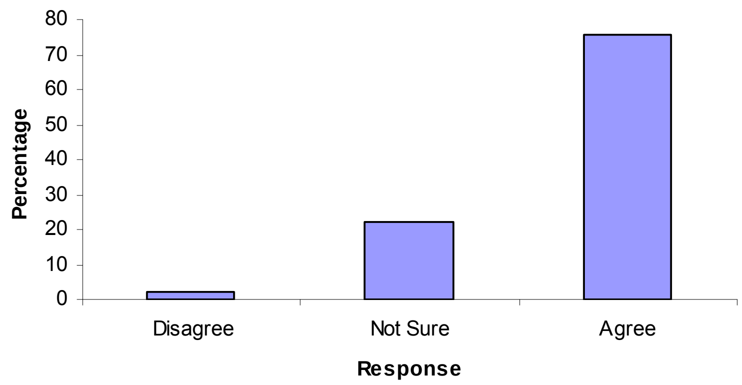

Figure 4.19. Responses of students for item 6 of the Attitude Scale - 'Finding out about new things is important'.

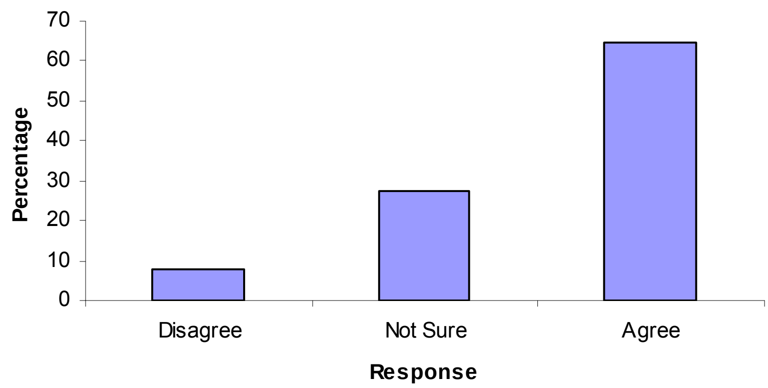

Figure 4.20. Responses of students for item 7 of the Attitude Scale - 'I enjoy science lessons in this class'.

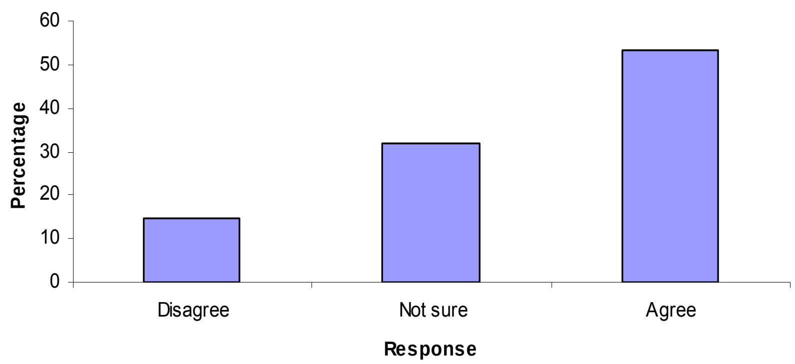

Figure 4.21. Responses of students for item 8 of the Attitude Scale - 'I like talking to my friends about what we do in science'.

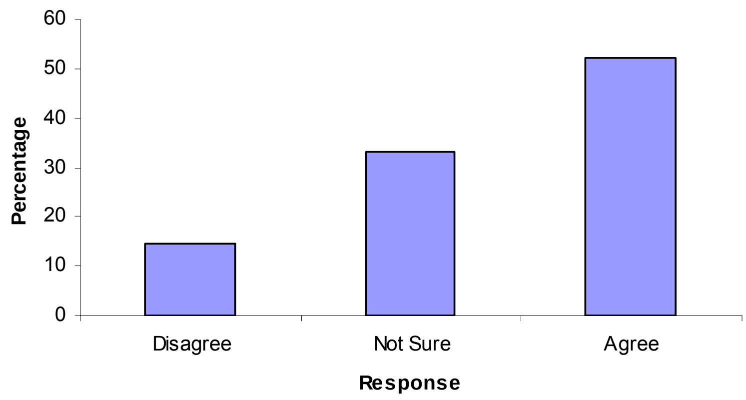

Figure 4.22. Responses of students for item 9 of the Attitude Scale - 'We should have more science lessons each week'.

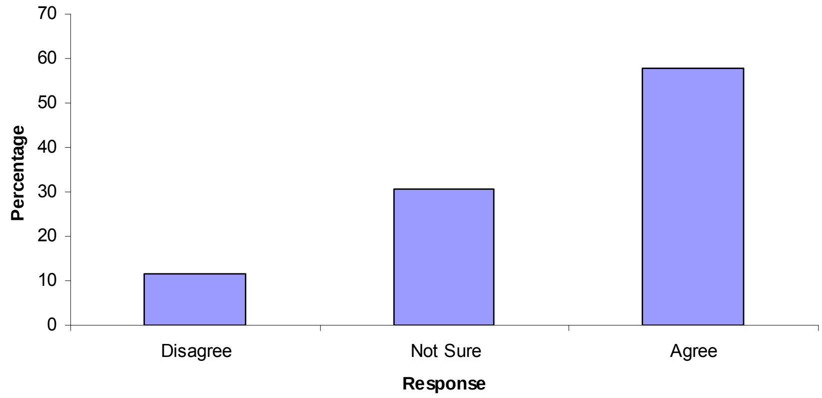

Figure 4.23. Responses of students for item 10 of the Attitude Scale - 'I feel satisfied after a science lesson'.

The positive responses which ranged from approximately 60% to 70% for almost all the items of the Attitude Scale is an indication that the students do enjoy their science lessons. This heart-warming phenomenon could be attributed to factors like the social dynamics in the classrooms, the instructional methodologies employed and the interesting enrichment activities incorporated into the science curriculum of the schools.

4.4.2 Association between the CLES and the Attitude Scale

Simple correlations were performed to determine if there were any significant associations between each scale of the CLES (Actual Form) and the Attitude Scale in terms of students' enjoyment of science lessons. Multiple regression analysis was also conducted to identify possible predictors of students' enjoyment of science lessons. The results from both simple correlations and multiple regression analyses were compared. The findings are shown in Table 4.14.

Table 4.14
Association between the CLES Scales (Actual Form) and the Attitude Scale in terms of Simple Correlations (r), Standardized Regression Coefficient (β) and Multiple Correlation (R)

Scale	Attitude to Science Lessons	
	Correlation (*r*)	Regression Coefficient (*β*)
Personal Relevance	0.01	0.03*
Uncertainty	-0.08	-0.10
Critical Voice	-0.02	-0.01*
Shared Control	-0.04	-0.03*
Student Negotiation	0.05	0.08
Multiple Correlation, R = 0.12		

*p<0.05

4.4.2.1 Simple Correlations

The simple correlation coefficients (*r*) were calculated for the Actual Form of the CLES and the Attitude Scale which measured students' enjoyment of their science lessons.

The values for *r* showed that there were no significant correlations between all the environment scales and students' enjoyment of science lessons for the Actual Form of the CLES. This could be explained by the fact that in the primary schools of Singapore, a wide array of science activities are carried out beyond the four walls of the classrooms where this research was carried out, at institutions like the Singapore Science Centre, nature reserves like the Bukit Timah Nature Reserve, Labrador Nature Reserve and on field trips to the mangrove swamps at Sungei Buloh Nature Reserve or the sea side at Pasir Ris Beach.

4.4.2.2 Multiple Regression Analysis

Multiple regression analysis was performed for attitude with respect to the entire set of the constructivist environment scales (Actual Form). The multiple correlation (R) found between the Attitude Scale and the Actual Form of the CLES was 0.12, yielding a value of 0.01 for R^2 which was the coefficient of multiple determination. This value for R indicated that the combined scales of the CLES had no significant correlation with the attitude of students with regard to their enjoyment of science lessons. The value for R^2 indicated that the proportion of variance in students' enjoyment of science lessons as accounted for by the combined scales of the CLES was negligible.

The standardized regression coefficient (β) was computed to ascertain which individual CLES scales, if any, contributed most to explaining the variance in the Attitude Scale and three scales were identified ($p<0.05$). However, all identified scales had only weak influence on the variance in the Attitude Scale.

The fact that the scales of the CLES had no strong association with and were not predictor variables for the variance in students' enjoyment of science lessons led to the conclusion that students' enjoyment of science lessons was independent of the constructivist learning environment in the classrooms. Though learning environment had been viewed as a critical endogenous variable in the development of attitudes, it could refer to other aspects of the learning environment like the social dynamics between teachers and students, students and students and the variability and difficulty of tasks rather than the constructivist culture. A host of other variables like enjoyment of classmates, school environment, classroom organization and conduct of instruction with regard to goal direction and material usage were also highly related to students' attitude toward science lessons (Haladyna, Olsen & Shaughnessy, 1983).

4.5 RESEARCH QUESTION 4: WHAT ARE THE STUDENTS' PERCEPTIONS OF THE CLASSROOM LEARNING ENVIRONMENT AS PORTRAYED BY THEIR SCIENCE TEACHERS' INTERPERSONAL BEHAVIOUR?

The QTI (Elementary) was used to measure students' perceptions of their classroom learning environment with regard to their teachers' inter-personal behaviour. Sector profiles were created for the collective data as well as the individual classes surveyed. The mean and standard deviation were calculated from the collective data and are shown in Table 4.15. A simple correlation was also performed from the collective data to ascertain which scales of the QTI, if any, have a significant correlation with the students' enjoyment of science lessons. The correlation coefficients (*r*) for each scale are shown in Table 4.16

4.5.1 QTI (Elementary)

Table 4.15 shows the item mean and standard deviation for each scale.

Table 4.15
Average Item Mean and Average Item Standard Deviation for QTI (Elementary) scales with Individual Score as the Unit of Analysis (N=333)

Scale	No. of items	Average item mean	Average item standard deviation
Leadership (DC)	6	3.34	0.49
Helpful/Friendly (CD)	6	3.22	0.64
Understanding (CS)	6	3.17	0.58
Student Responsibility/Freedom (SC)	6	2.20	0.54
Uncertain (SO)	6	1.55	0.42
Dissatisfied (OS)	6	1.80	0.53
Admonishing (OD)	6	1.97	0.63
Strict (DO)	6	2.64	0.54

It could be inferred from the item means in Table 4.15 that overall, students perceived their teachers as displaying more cooperative behaviours (Leadership, Helpful/Friendly and Understanding) than opposition behaviours (Uncertain, Dissatisfied and Admonishing). The findings are presented in the circumplex model as shown in Figure 4.24.

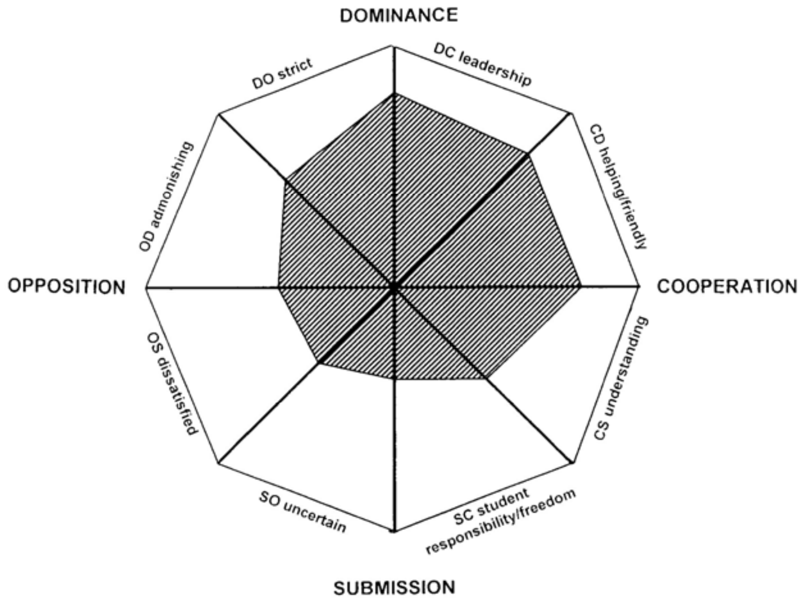

Figure 4.24. Profile of teachers' inter-personal behaviour using individual score as the unit of analysis (N=333).

The mean scores for the scales of Leadership, Helpful/Friendly and Understanding were above 3, which correspond to between 'Sometimes' and 'Most of the time' in the questionnaire. The implication is that students perceived relatively strong leadership from their teachers during their lessons but this strong leadership is peppered with their teachers being helpful, friendly and understanding. The mean score of 2.20 for the Student Responsibility/Freedom scale corresponds to between 'Seldom' and 'Sometimes' in the questionnaire and thus reflects the teachers' tendency of not giving students the freedom to choose what they liked to do in class, how they wanted to go about their learning tasks or who they wanted to work with. This finding is consistent with the significant difference found between the mean of the Preferred and that of the Actual CLES for the scale of Shared Control.

The mean score of 2.64 for the Strict scale almost corresponds to 'Sometimes' in the questionnaire and implies that though adopting a helpful, friendly and understanding disposition, teachers do not compromise on the expectations of their students and will not condone lackadaisical work or disruptive behaviour. The strictness displayed is correspondingly reflected in the significant difference found between the mean of the Preferred and that of the Actual CLES for the scale of Critical Voice. The Uncertain, Dissatisfied and Admonishing scales showed relatively low item means and with reference to the Likert scale in the questionnaire, these three behaviours almost were seldom displayed during the science lessons. The implication is that teachers are certain of how the lessons should proceed and refrain from displaying a harsh and admonishing behaviour, thus creating an environment conducive to learning.

4.5.2 Teacher Interpersonal Behaviour of Individual Classes

The sector profiles of the ten classes were created and shown in Figures 4.25 to 4.34. As with the CLES findings in Section 4.3.2, the names of the schools and classes have been renamed to maintain anonymity.

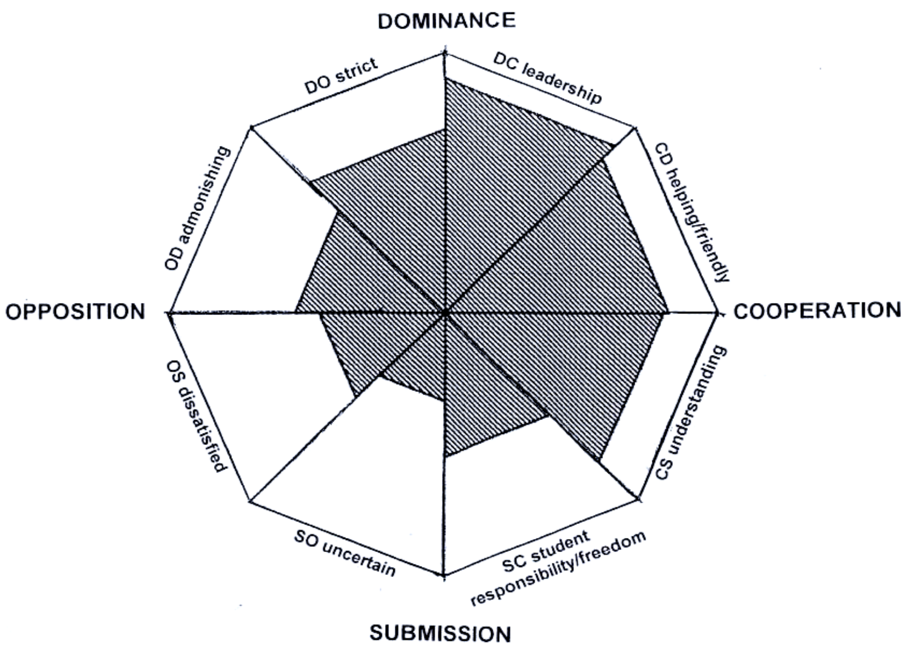

Figure 4.25. QTI profile of Class 5A1.

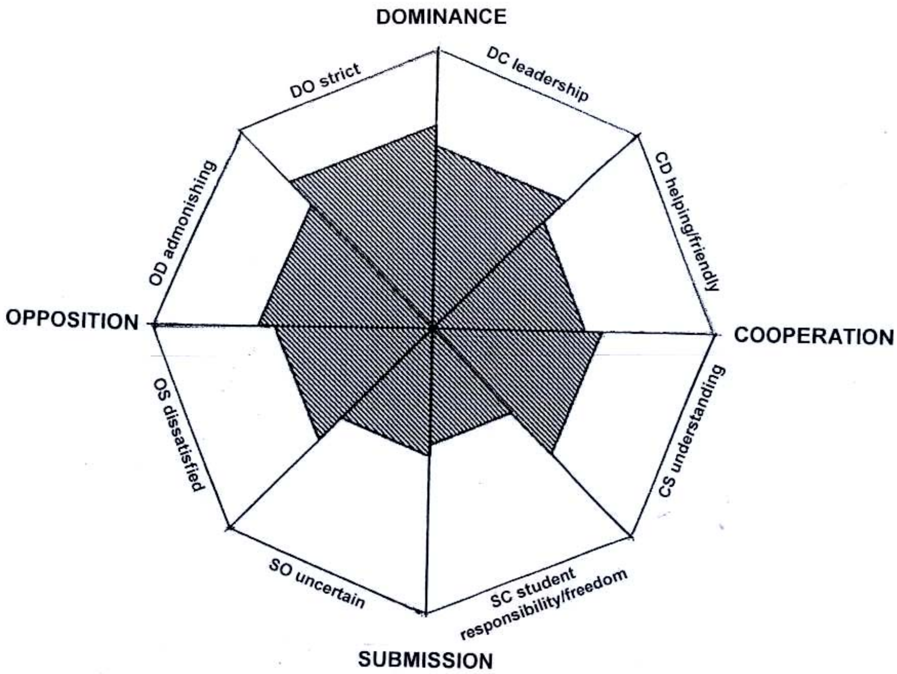

Figure 4.26. QTI profile of Class 5A2.

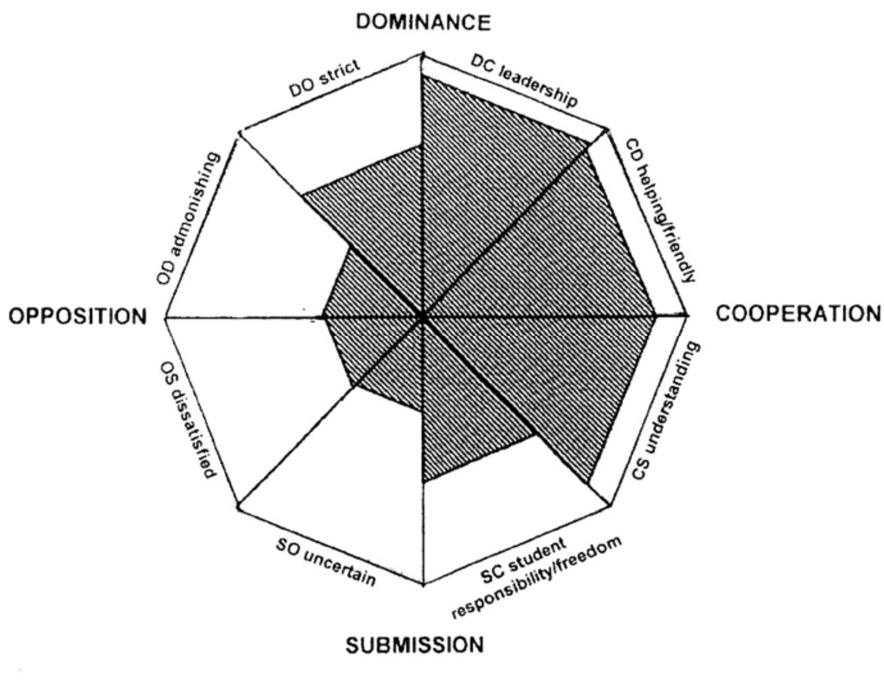

Figure 4.27. QTI profile of Class 5B1.

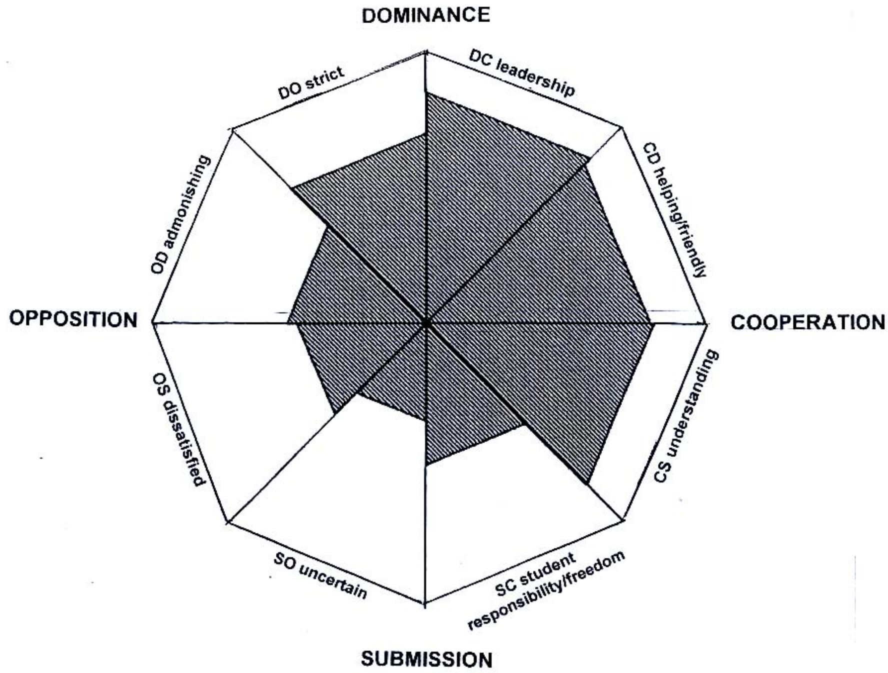

Figure 4.28. QTI profile of Class 5B2.

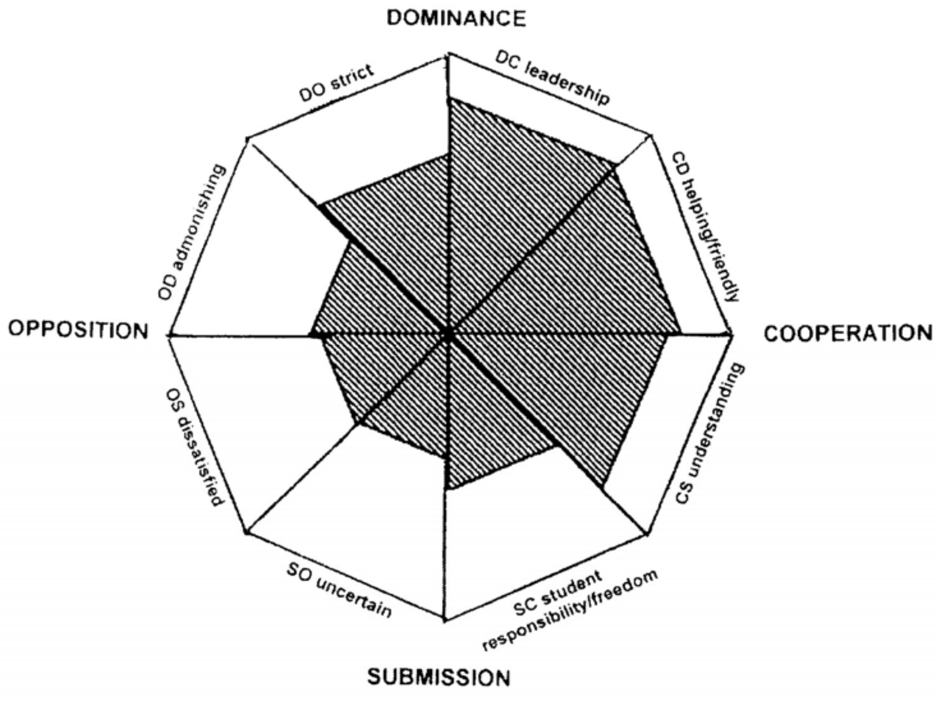

Figure 4.29. QTI profile of Class 5C1.

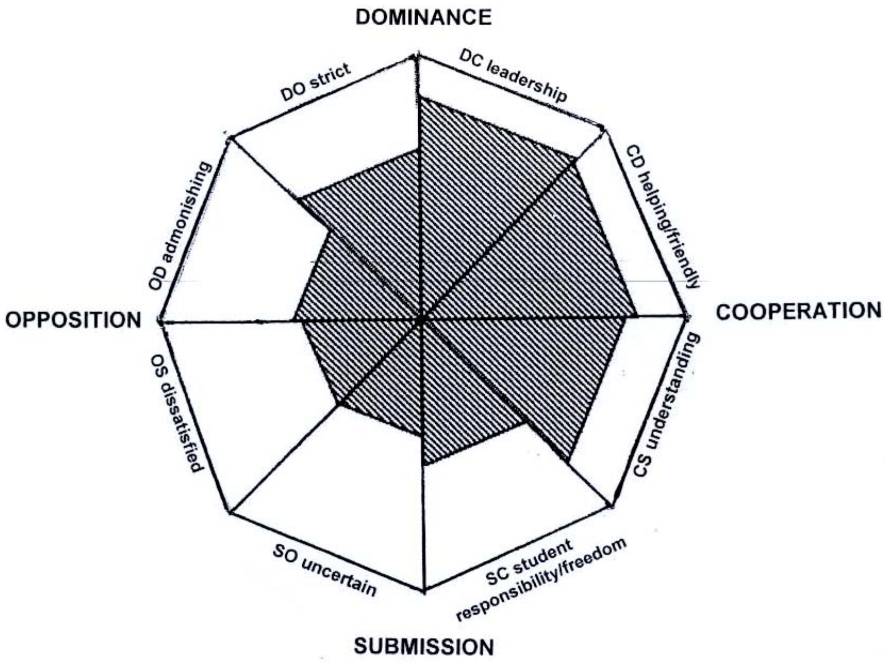

Figure 4.30. QTI profile of Class 5C2.

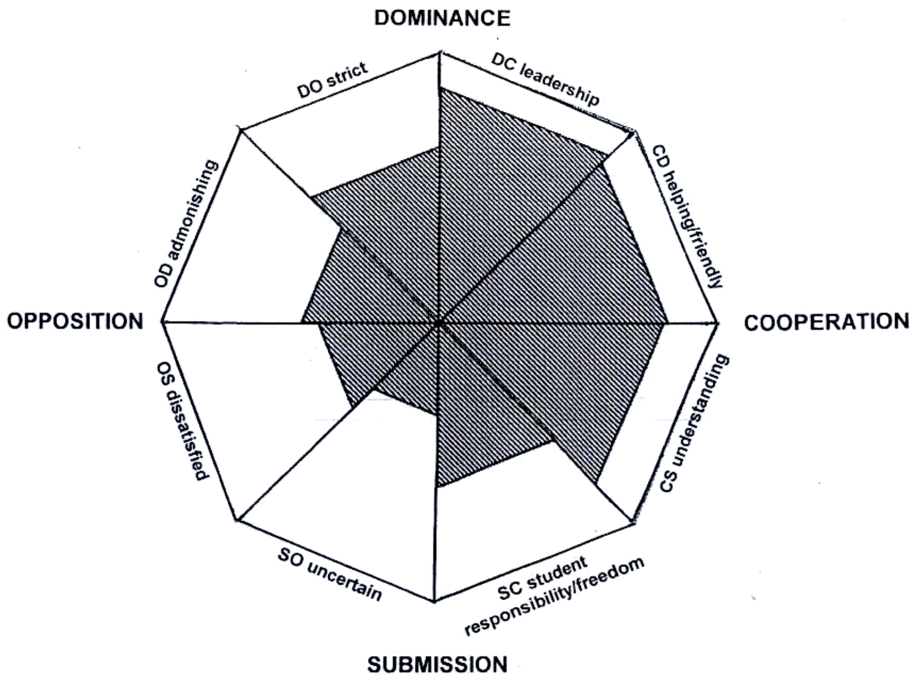

Figure 4.31. QTI profile of Class 5D1.

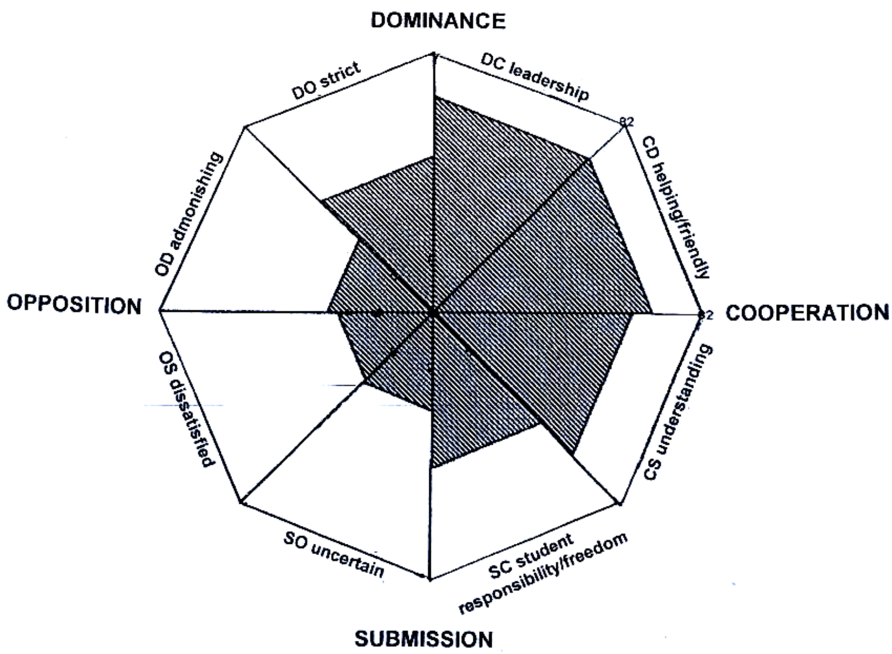

Figure 4.32. QTI profile of Class 5D2.

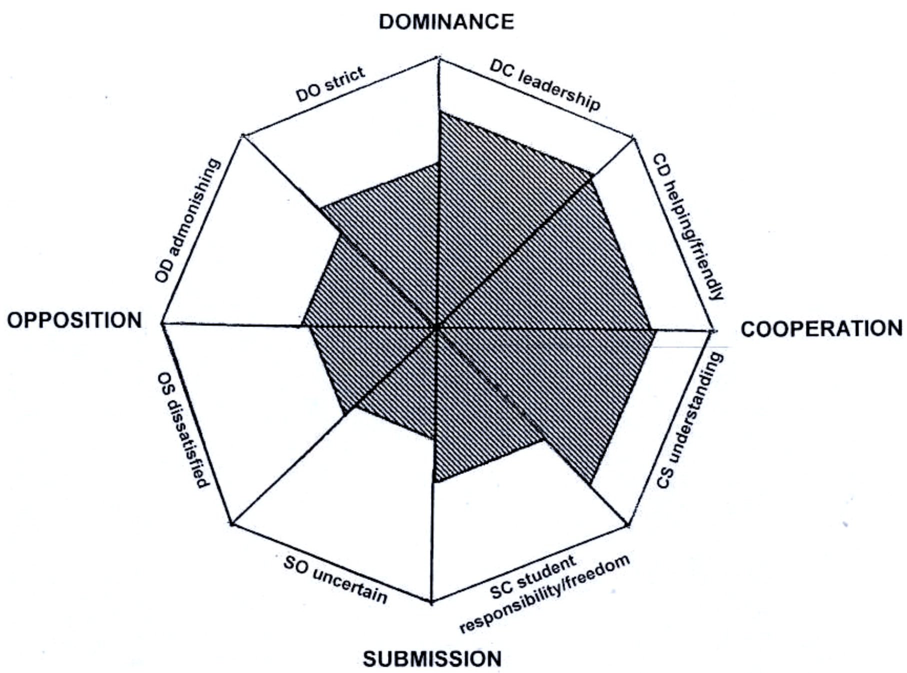

Figure 4.33. QTI profile of Class 5E1.

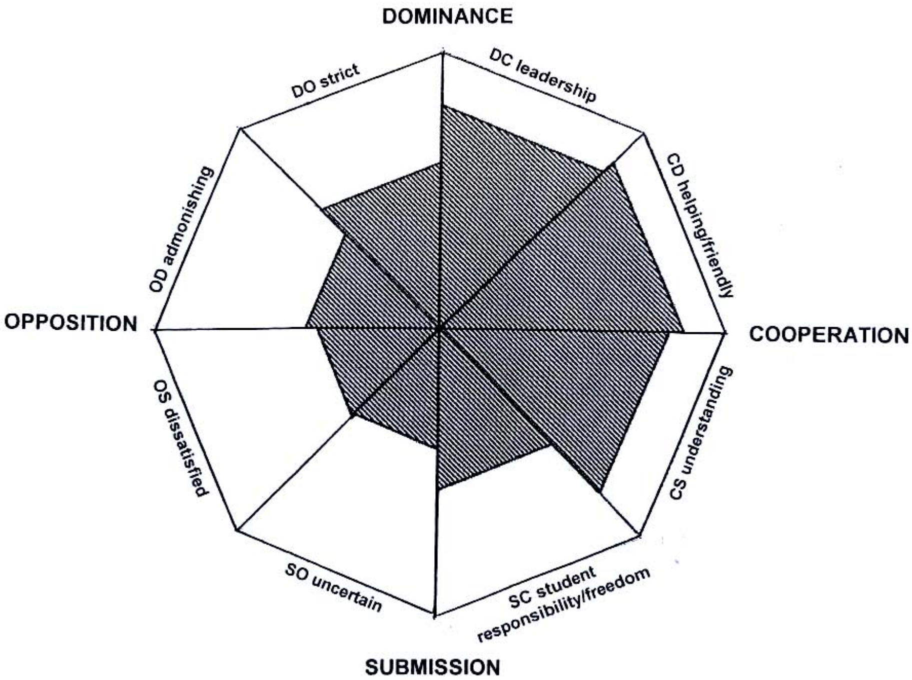

Figure 4.34. QTI profile of Class 5E2.

With the exception of one class (5A2), the remaining nine classes showed a generally similar pattern of teacher interpersonal behaviour, that is, the teachers were perceived to display strong leadership, were helpful or friendly and understanding. Despite possessing the attributes of being confident and caring teachers, they (the teachers) were perceived to be strict too. The individual class profiles were consistent with the profile created using the collective data as shown in Figure 4.24.

4.5.3 Simple Correlation

A simple correlation with attitude was performed using the collective data and the correlation coefficient (*r*) for each scale of the QTI is shown in Table 4.16.

Table 4.16
Association between the QTI (Elementary) Scales and the Attitude Scale in terms of Correlation Coefficient, r, Standardized Regression Coefficient (β) and Multiple Correlation (R)

	Attitude To Science Lessons	
Scale	Correlation (*r*)	Regression Coefficient (*β*)
Leadership (DC)	0.18**	-0.02
Helpful/Friendly (CD)	0.23**	0.33**
Understanding (CS)	0.17**	-0.02
Student Responsibility/Freedom (SC)	0.12*	0.04
Uncertain (SO)	-0.13*	-0.13*
Dissatisfied (OS)	-0.002	0.29
Admonishing (OD)	-0.07	-0.10
Strict (DO)	0.04	0.06
Multiple Correlation, R=0.31**		

*p<0.05
**p<0.01

The results in Table 4.16 reveal that of all the eight scales of the QTI, the scales of Leadership, Helpful/Friendly and Understanding register the relatively highest positive correlation (p<0.01) with students' enjoyment of science lessons. It reflects that the interaction behaviour of the teacher has, to a certain extent, a bearing on students' level of enjoyment of their science lessons though the latter is also influenced by external factors like the students' familial socio-economic status and students' prior experience in science education and internal dynamics of the peer group one was in as students learn not just from their teacher but also from their contemporaries (Tymms, 1997).

4.5.4 Multiple Regression Analysis

Multiple regression analysis was performed for attitude with respect to the entire set of the QTI (Elementary). The multiple correlation (R) found between the Attitude Scale and the QTI (Elementary) was 0.31. This value for R indicated that the combined scales of the QTI had a significant correlation with the attitude of students with regard to their enjoyment of science lessons.

The standardized regression coefficient (β) was computed to ascertain which individual QTI scales, if any, contributed most to explaining the variance in the Attitude Scale and two scales of the QTI, namely, Helpful/Friendly and Uncertain were identified.

4.6 RESEARCH QUESTION 5: WHAT ARE SOME OF THE CUSTOMIZED PROGRAMMES BEING USED BY TEACHERS TO BRING ABOUT ENGAGED LEARNING IN PUPILS?

The first half of an open-ended questionnaire with the instruction was administered to the Head of Department (Science) of different primary schools:

> Please state in point form and describe briefly the activities carried out in your school in lieu of the 20% 'white-space' in the science curriculum. Please specify whether these activities are class-based, level-based or school-based.

The responses to the questionnaire were analyzed qualitatively. There are 172 primary schools in Singapore and 126 responses were obtained. This sample made up approximately 73% of the entire population. Responses submitted varied in brevity, with some HODs putting in effort to elaborate on their schools' programmes while others simply indicated the names coined for the programmes or projects of their schools. In the latter situation, not much information could be obtained regarding the customized programmes of the schools. Nevertheless, there was indeed a wide array of activities designed and implemented by different schools in light of the TLLM initiative. These activities could be categorized into learning journeys, enrichment programmes and participation in competitions and the following paragraphs provide details of each of the category.

4.6.1 Learning Journeys

A distinct and prominent thread that was evident in all the responses was the participation of students in lessons conducted by the Singapore Science Centre and the Singapore Zoological Gardens. Besides being tourist attractions and exhibit-laden destinations for learning, the Singapore Science Centre and Singapore Zoological Gardens each has an education department which designs and conducts lessons which are closely aligned to the national syllabus. The icing on the cake is that such lessons are free of charge or pegged at a nominal sum if the schools are institution members of these organizations. These lessons make use of manipulative or interactive devices which are very often not available in primary schools, for example, a life-sized preserved specimen of the paw of a polar bear or the more sophisticated scientific equipment for carrying out gel electrophoresis. Thus, many schools regard signing their students up for such lessons as providing them with the 'visual and kinesthetic learning experiences that are qualitatively different from the experiences associated with classroom lessons or printed text' (Flexer & Borun, 1994, p. 863).

All the schools surveyed considered such lessons valuable supplements to the classroom instructions and as a consequence, made reservations for lessons for their students from Primary 3 to Primary 6.

Other than structured lessons at the Singapore Science Centre and the Singapore Zoological Gardens, field trips, either guided by experienced guides or by teachers who are familiar with the learning activities, were organized, with students of different age groups scheduled to visit different places. This is a reflection of the schools' awareness of the value in field trips providing a process-oriented rather than content-oriented approach to learning and thus enabling students to 'actively construct information from the environment, rather than passively absorbing it from teachers' (Orion, 1993, p. 325). One school, Yangzheng Primary, had dedicated a day, named the TLLM Day, on which all their Primary 3 and Primary 5 students, teachers and parent volunteers went on a learning journey to the Jurong Bird Park and the Hort Park, respectively.

The survey revealed that though Singapore is a small island, city and state, there is no lack of destination for schools planning field trips. The most frequently cited places were the Botanic Garden which houses the Jacob-Ballas Garden for Children, the Sungei Buloh Wetland Reserve (a mangrove swamp habitat), the Bukit Timah Nature Reserve, the Hort Park, the NeWater plant and the Marina Barrage. Other places which were sporadically mentioned in the questionnaire included the McRitchie Reservoir, the Changi Beach, Labrador Nature Reserve, East Coast Park, Pasir Ris Park, Tanjong Chek Jawa which is located on the island of Pulau Ubin, Raffles Museum of Biodiversity Research, Underwater World on the island of Sentosa, Jurong Bird Park, Changi Airport Terminal 3, farms like the vegetable, mushroom or frog farm and factories like the Yakult factory or the Gardenia bread factory. The selection of destinations for students of different age groups was dependent on the content knowledge to be acquired on the field trips, the cognitive development of the students and the level of safety inherent in the different places. The incorporation of field trips in the science curriculum of all the schools surveyed bears testimony to the schools' belief in research findings that significant and long-lasting cognitive learning takes place on field trips (Falk & Balling, 1980).

4.6.2 Enrichment Activities

The enrichment activities organized were as varied and unique as the culture of each individual school. Enrichment activities spanned the spectrum of both life and physical sciences. In the realm of life sciences, examples of enrichment activities included growing coloured corns to learn about pollination, plant growth and genetic variation (such projects were given fanciful names like 'Rainbow Corn-nection' and 'A-Maizing Project' by some schools), hydroponics to learn about the techniques of soilless agriculture, growing silkworm to produce silk while learning about life cycle of insects and metamorphosis (this project, hailed from Westgrove Primary, had been befittingly named ‘Project Silkroad’) and orchid hybridization to learn about pollination, genetics of breeding and simple techniques of aseptic tissue culture (the project had been named ‘ALOHA’, that is, ‘Active Learning through Orchid Hybridization in Action’, in one school).

Examples of enrichment activities in the realm of physical sciences include creating and launching water rockets and in the process, learning and understanding scientific principles and controlling variables, toy creation which had been given programme names like Toys@Work or MIST (My Innovative Science Toy) to foster creativity and the spirit of innovation, in addition to deepening students’ understanding of scientific knowledge and honing their skills of applying scientific concepts. The best few products were usually submitted as entries for the Sony Creative Science Award Competition which is elaborated in Section 4.6.3.

The response provided by a Head of Department indicated the existence of an inquiry-based approach carried out in her school to enable students to learn the basics of electricity. Named ‘OhMEGA’ (Moulding, Enriching and Guiding teachers and pupils to Achieve excellence in science teaching and learning), this programme emphasized learning with understanding through the provision of hands-on experiments for students.

Amongst the wide assortment of enrichment activities listed, two most frequently mentioned activities were the Primary Science Activities Club and doing science investigative projects. Approximately 90% of the respondents cited the Primary Science Activities Club as part of their science curriculum and 60% of the respondents indicated the existence of science investigative projects in their schools.

Jointly organized by the Singapore Science Centre, the Science Teachers Association of Singapore, the Singapore Association for the Advancement of Science and the Singapore National Academy of Science, and supported by the Ministry of Education, the Primary Science Activities Club, though had been around for almost two decades, remains a popular programme to engage students' interest in science by providing them with opportunities to develop initiative and creativity as they carried out self-directed activities in the different branches of science like entomology, ornithology, zoology, genetics, chemistry, physics and astronomy, just to name a few. Upon the completion of a set of activities pertaining to a branch of science, the students were awarded a badge and a certificate.

The relatively high percentage of schools (approximately 60%) that carried out science investigative projects came as no surprise as the revised science syllabus, in conjunction with the TLLM initiative, emphasized inquiry-based learning and such investigative projects simulate the inquiry methods employed by members of the scientific community in their quest to understand the natural world around them.

In many schools, the common target groups of students for these projects were either students in Primary 4 or Primary 5 while a few schools involved students from as young as Primary 3. Many schools exempted students in Primary 6 as the focus for them was the preparation for a high-stake national examination, the Primary School Leaving Examination (PSLE).

The projects were first carried out at the class level where students, working in groups, were exposed to the scientific processes of identifying a problem, formulating hypothesis, designing experimental set-ups, collecting and interpreting data, drawing conclusion and communicating their findings to their teachers or peers. These scientific processes encompass the five essential features of inquiry-based lessons in which students engage in scientifically-oriented questions, give priority to evidence in responding to questions, formulate explanations from evidence, connect explanations to scientific knowledge and communicate and justify explanations (NRC, 2000). Examples of investigative projects were students' quest in designing and building a container which would prevent eggs from breaking when dropped from a height of two storeys or students designing the most stable building using straws.

In schools which adopted a competitive nature in this programme, each class was required to submit the best two projects as entries for competition at their respective level. If there was no element of competition, then the investigative project movement would culminate in a school-wide activity, usually held on one day or over a week. On this occasion, students were given the opportunities to showcase their projects in a carnival-like setting and answer queries posed to them by their teachers or peers. The one-day school-wide activity was given fanciful names by different schools. Examples included Young Innovators' Day, Young Investigators' Day, Scienzation Day and Navalites' Discovery Day (programme of Naval Base Primary School). Some schools had even given the entire programme impressive names like Project SUPER (Science Using Project work for Enquiry and Research) and STAR (Science Through Active Research).

4.6.3 Students' Participation in Competitions

In order to enthuse students in science and at the same time capitalize on the element of competition to gauge the students' level of competency, many schools encouraged their students to take part in national competitions like the Sony Creative Science Award, BP-RI Science Odyssey, the Tan Kah Kee Young Inventors' Award and the International Competitions and Assessments for Schools (ICAS). The two most commonly cited competitions in the questionnaire were the Sony Creative Science Award and the ICAS, with 50% of the schools surveyed taking part in the Sony Creative Science Award and 75% of the schools surveyed taking part in the ICAS.

The Sony Creative Science Award or SCSA is a competition organized by the Singapore Science Centre and SONY Electronics Asia Pacific Pte Ltd, with support from the Ministry of Education and Agency for Science, Technology and Research (A*STAR). This contest, being the only one of its kind in Singapore, has as its main objective, the development and promotion of interest and creativity in science among primary school students. Entries for the competition were toys that had been safely created by students using any suitable material, were safe to play with and most importantly, demonstrated at least one scientific principle. Winning entries were displayed on the day of the award presentation ceremony.

ICAS is conducted annually by Educational Assessment Australia, UNSW Global Pte Ltd, a non-profit provider of education, training and consulting services and a wholly owned enterprise of the University of New South Wales.

In science, the ICAS assesses students' scientific skills like knowledge, measuring and observing, interpreting data, predicting or concluding from data, investigating and reasoning or problem-solving. A follow-up of the assessment includes the provision of detailed diagnostic paper, online reports on students' progress from previous years and UNSW Global certificates specifying the students' level of achievement.

The competition had proven popular amongst schools as it was used as a yardstick by the stakeholders, namely the Heads of Department and parents, to measure students' competency in science in the international arena.

4.7 RESEARCH QUESTION 6: WHAT FORMS OF SUMMATIVE AND FORMATIVE ASSESSMENTS HAVE BEEN IMPLEMENTED IN SCHOOLS AS A CONSEQUENCE OF THE TLLM INITIATIVE?

The second part of the questionnaire administered to the various Heads of Department (Science) from different schools had this posed to them:

> Please state the different forms of assessments (both
> formative and summative) used in your school.

About 65% of the respondents cited the Continual Assessments (CAs), held in Terms 1 and 3, and Semestral Assessments (SAs), held in Terms 2 and 4, as the formal pen-and-paper tests in their schools while the remaining 35% indicated that their schools had chosen to do away with the CAs, leaving only the SAs, administered in May and November. While the SAs were of a summative nature, the CAs took a more formative form, giving feedback to students and stakeholders not only on the outcome of the instructional process but also the strengths and areas of weaknesses that needed to be addressed. In schools which had done away with CAs, regular class tests were administered twice in each of Terms 1 and 3.

Performance-based assessment took the form of the science practical test and this was carried out for students from Primary 3 to Primary 6 in all the schools surveyed. One well-known primary school had even named this assessment ‘Science Nova’. In these practical tests, which were conducted over a duration of 30 minutes, students were assessed on their basic process skills like observation, comparing, classifying, measuring and using apparatus, generating ideas or conclusion and communicating their ideas or findings. The scores obtained were counted towards either the CA2, SA1 or SA2 marks, depending on the practices of the schools.

One common practice was observed to be prevalent in all the schools surveyed – the practical tests were not carried out in Term 1 of the academic year. All the schools administered this assessment only from Term 2 onwards. One reason cited by some respondents was that having the test in Term 2 or later enabled the students to be better prepared as they had more opportunities to hone their process skills during their science laboratory lessons. The weighting assigned to this assessment varied between 10% and 20% of either the CA or SA marks, depending on the practices of the schools.

Another practice that was pervasive in all the schools surveyed was that though the Primary 6 students took the practical tests, their scores were not counted towards the CA or SA marks at all. In other words, this group of graduating students was assessed solely on their written CA, SA and preliminary examination, a reflection of the importance accorded to the preparation of these students for the high-stake national examination, the PSLE, which is solely a pen-and-paper examination.

Of the schools surveyed, a minority of them made an attempt to weave interesting forms of alternative assessments for their students from Primary 3 to Primary 5, in addition to the usual science practical tests. Two schools implemented the drawing of concept maps or concept cartoons as an alternative mode of assessment. One school targeted this form of assessment at its Primary 3 students in Term 3, with a weighting of 10% of the CA2 marks, Primary 4 students in Terms 1 and 3, with a weighting of 10% in each of the CA1 and CA2 marks. Interestingly, the Primary 5 students were assigned the tasks but their marks were not factored into their assessment grades for the academic year while the Primary 6 students were not at all involved in this alternative mode of assessment.

In Kong Hwa Primary, alternative assessment in Term 1 for their Primary 3 students saw the students embarking on an experiential learning on plants. These students first germinated seeds in plastic containers until such time for the saplings to be transplanted into the school's Vegetable Garden. Once in the garden, the students continued to nurture their plants by watering and weeding them. The students had to create and design their own science scrap book to record what they had learnt about plant growth, life cycle of plants and their reflection on this learning journey.

Another novel idea for alternative assessment hailed from West View Primary. Targeting at Primary 3 and 4 students, the assessment took the form of experiential learning trail and harnessed the use of cutting-edge technology found in the features of i-Phone. Upon embarkation on an inter-disciplinary trail, students, in groups, were engaged in activities which required them to use i-Phones to capture pictures, audio and video, gather data and access on-line resources and navigate using the built-in compass with GPS features. The data captured were uploaded onto a virtual blog where other group members could access, view and comment.

Other more routine modes of alternative assessments listed by the respondents included diagnostic topical tests administered at the end of each topic and a science progress checklist that highlighted the students' strengths and weaknesses in science. Such information proved not only useful to the teachers but also to parents who were collaborators in the business of education.

4.8 CHAPTER SUMMARY

The results of the analyses of the data, both quantitative and qualitative, were presented and discussed in this chapter. The next chapter, which is the concluding chapter, summarizes the salient points of the preceding chapters and highlights certain issues pertinent to future research should attempts be made to replicate or extend this research exercise in the near future.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

In this concluding chapter, an overview of the study, along with its major findings, implications and limitations are presented. Issues pertaining to future research which may arise through the replication or extension of this study are also discussed.

5.2 OVERVIEW OF THESIS

This research study was ignited by the TLLM initiative which saw a paradigm shift in the teaching and learning of science in Singapore. Greater emphasis was placed on inquiry learning which rests on the bedrock of the theory of constructivism. A 20% freed-up time named the 'white-space' provided an avenue for schools to customize programmes to bring about more engaged learning.

It then was of interest to conduct a study on the constructivist learning environment in the classrooms, students' perception of their teachers' inter-personal behaviour and students' enjoyment of science lessons. These three dimensions were measured using instruments like the 30-item CLES (Actual and Preferred Forms), the QTI (Elementary) and the Attitude Scale, respectively, administered to 333 eleven-year-old middle ability students from ten intact classes in five mainstream primary schools (two classes per school).

The CLES (Actual and Preferred Forms), QTI (Elementary) and the Attitude Scale were validated to ascertain if they were valid and reliable instruments for use in Singapore schools. Using the CLES scores, tests were carried out to determine if there were significant differences between the preferred and actual levels of constructivist learning environment, both at the collective level as well as at the individual class level. An attempt was also made to establish if there were any associations between the constructivist learning environment and students' attitude to science lessons.

Based on the students' scores on the QTI (Elementary), a QTI profile of the entire sample as well as the QTI profile of each individual class was created to provide an insight into students' perception of their teachers' interpersonal behaviour in general and at the individual class level.

Information on the various school-based programmes to bring about engaged learning and the different forms of assessments was gathered using an investigator-designed questionnaire.

5.3 MAJOR FINDINGS OF THE STUDY

The findings are summarized in order of the research questions presented in Chapters 1 and 3 of this study.

5.3.1 Validity and Reliability of the Instruments

A calculation of the Cronbach alpha coefficient and the scale inter-correlations of the CLES (Actual and Preferred Forms) and the QTI (Elementary) was made to find out if these two instruments were statistically robust instruments for use in the elementary schools in Singapore. The internal consistency of the Attitude Scale was also ascertained using the Cronbach alpha coefficient.

Results showed that in general, the scales of the CLES had acceptable internal consistency. The scale inter-correlation indices of the five scales of the CLES showed all five scales had a satisfactory degree of independence.

The Cronbach alpha coefficient for each QTI scale suggested that overall, the QTI was a reliable instrument for use in Singapore schools and the scale inter-correlations proved to be generally consistent with the circumplex nature of the QTI.

The Attitude Scale was found to contain items which had a high degree of internal consistency, as indicated by its high reliability coefficient.

5.3.2 Comparison between the Actual and Preferred Levels of the Constructivist Learning Environment

At the collective level (N = 333), the mean of each scale of the Preferred and that of the Actual Forms of the CLES and the t-test values showed significant differences between the preferred and actual level of the constructivist learning environment with respect to four scales, namely, Uncertainty, Critical Voice, Shared Control and Student Negotiation.

The preferred scores were consistently higher than that of the actual. The most significant difference was in the dimension of Shared Control. The vast disparity in Shared Control was reflected at the individual class level, with eight out of the ten classes surveyed registering preferred scores being significantly greater than that of the actual.

5.3.3 Environment-Attitude Association

Simple correlations were performed to determine if there was any association between each scale of the CLES (Actual Form) and the Attitude Scale with regard to students' enjoyment of science lessons. Multiple regression analysis was also performed to identify possible predictors of students' enjoyment of science lessons.

The values of the simple correlation efficient *(r)* indicated that there was no significant correlation between all the CLES scales (Actual Form) and students' enjoyment of science lessons.

The values of the coefficient of multiple determination *(R^2)* showed that the proportion of variance in students' enjoyment of science lessons as accounted for by the combined scales of the CLES was negligible.

A computation of the standardized regression coefficient *(β)* revealed that three scales from the Actual Form of the CLES, namely, Personal Relevance, Shared Control and Student Negotiation, had a weak influence on the variance in the Attitude Scale.

Since the scales of the CLES were found to have no strong association with and were not predictor variables for the variance in students' enjoyment of science lessons, it implied that students' enjoyment of science lessons was independent of the constructivist learning environment in the classrooms. Perhaps students' enjoyment of science lessons was, in greater part, influenced by the wide array of enrichment activities and learning journeys they were exposed to, that is, these activities had a direct causal relationship with students' enjoyment of science lessons.

Apart from the constructivist learning environment in the classroom, there were other dimensions like social dynamics between teachers and students, students and students, classroom organization and conduct of instructions within the classrooms, all of which could be highly related to students' attitude towards science lessons.

5.3.4 Students' Perception of Teachers' Interpersonal Behaviour and QTI - Attitude Association

Data from the QTI (Elementary) were analyzed and the QTI sector profiles were created both at the collective as well as the individual class level.
At the collective level, teachers were perceived to be certain about the direction in which instruction should proceed in the classrooms and hence, took the lead in instructional matters. They were also perceived to be highly helpful, friendly and understanding but strict and stringent in allowing student responsibility or freedom.

At the individual class level, nine out of the ten sector profiles showed a similar trend as that of the collective level.

The sector profiles typify the characteristics of teachers in the elementary schools in Singapore. Students look up to them as knowledgeable individuals, present in the classrooms to help and guide their learning. Teachers, too, had been taught during their pre-service training in classroom management the importance of leading the students rather than being led by the nose by their students. These could largely explain the strong leadership displayed by teachers and perceived by their students.

In their bid to keep a tight rein on classroom discipline, teachers were strict and judicious in dispensing student freedom and responsibility. On the other hand, they were not individuals who ruled with an iron fist in the classrooms. Being well aware that their charges were still of a tender age, they displayed traits of loving kindness and tenderness towards their students. Thus, teachers were perceived to be strict but at the same time helpful, friendly and understanding by their students.

A simple correlation with attitude was performed for each scale of the QTI. The scales of Leadership, Helpful/Friendly and Understanding had the relatively highest positive correlation with students' enjoyment of science lessons compared to the other scales. The value of the multiple correlations (R) indicated that the combined scales of the QTI had a significant correlation with the attitude of students with regard to their enjoyment of science lessons. This implies that the social dynamics in the classrooms are indeed related to students' enjoyment of science lessons, although it cannot be concluded that this relationship is one of cause-and-effect.

The standardized regression coefficient (β) revealed that two scales of the QTI, namely, Helpful/Friendly and Uncertain contributed most to explaining the variance in the Attitude Scale.

5.3.5 Programmes for Engaged Learning

The programmes designed by schools to bring about engaged learning were as diverse and varied as the culture of each school. It is almost impossible to describe each and every programme due to the sheer multitude and uniqueness of the programmes. These extensive activities, however, could be broadly classified into the three categories of 'learning journeys', 'enrichment activities' and 'competitions'.

All the schools had their students go on learning journeys, albeit to different venues. The common ones were the Singapore Science Centre, the Singapore Zoological Gardens, the Botanic Gardens, the Sungei Buloh Wetland Reserve, the HortPark and the NeWater Plant.

Enrichment activities took a variety of forms, ranging from genetics and hybridization of orchids in the realm of biological sciences, to creating toys and launching water rockets in the realm of physical sciences.

The long-standing Primary Science Activities Club was still regarded as activities which could bring about engaged learning. The increased emphasis on science inquiry resulted in the burgeoning popularity of investigative projects in many schools. Students were encouraged to be young inventors, investigators or innovators as they were taught the scientific processes of problem-solving.

Many schools enrolled their students in national competitions of different nature, thus broadening their exposure to the different areas of science and sharpening their competitive edge.

In all these activities, whether it be learning journeys, enrichment activities or competitions, learning had certainly gone beyond the confines of the classrooms and together, they were observed to bring about a heightening of students' enjoyment in the learning of science.

5.3.6 Forms of Assessments

Assessments, generally, take the form of the two Continual Assessments (CAs) in Terms 1 and 3 and two Semestral Assessments (SAs) in Terms 2 and 4. These are pen-and-paper forms of assessments, the marks of which count towards the final grade of the students at the end of the academic year. Schools which have done away with CAs grade their students' investigative projects and the marks are recorded in place of the pen-and-paper CAs grade.

The science practical test was a very popular mode of performance-based assessment, prevalent in all schools. Other alternative modes of assessments included topical tests, twice-a-term class tests, diagnostic tests, concept mapping, concept cartoons, science scrap books, learning logs and virtual blogs in some schools.

5.4 IMPLICATIONS OF RESEARCH STUDY

The CLES, originally designed for use in the secondary schools, has been shown to be quite suitable for use in upper primary classes in this research, thus, adding to the repertoire of classroom learning environment instruments available for use in the primary schools.

Through the use of both the CLES and QTI, considerable insight into the classroom learning environment as well as students' perception of their teachers' interpersonal behaviour could be obtained. This awareness of the classroom learning environment is valuable feedback in assessing the impact of the TLLM initiative. Results of the analysis of the CLES data point out succinctly that there is still room for improvement in creating a constructivist classroom learning environment in the schools in Singapore. There is a need to reflect on ways to bridge the gap between the preferred and actual levels of constructivist classroom learning environment, beginning with the scale which is of the greatest legitimate cause for concern.

All said and done, it is with immense gratification that the results of the analysis of the individual classes had been sent to the respective teachers and having been provided with this invaluable feedback, hopefully further actions have been taken by them to bring their classroom learning environment to greater heights.

The responses obtained regarding school-based programmes provided an insight into the extent schools had gone about embracing the idea of engaged learning. It is heart-warming to know that schools put in effort to implement programmes which they could call their own. This research exercise has resulted in the creation of a 'data base' of programmes of which ideas can be tapped, modified and implemented by other schools.

Responses given on the forms of assessments revealed the paucity of alternative assessments in science education. One follow-up will be to examine the causes contributing to such a phenomenon. Be it due to teachers' inadequacy in designing and carrying out alternative assessments or the lack of resources like time and materials, it is heartening to know that holistic assessment is one of the recommendations of the Primary Education Review and Implementation Committee (PERI) set up by the Ministry of Education in October 2008 to look at ways to raise the quality of primary education, and beginning with Primary 1 and Primary 2, and eventually making its way up to Primary 6, teachers are being sent in batches to undergo training in alternative assessments in all subject areas, both academic and non-academic.

5.5 LIMITATIONS OF THE STUDY

The exercise of the meta-cognitive skill of reflection is of paramount importance in all learning. A self-reflection carried out at the end of this research study, a rather long and arduous learning journey but nevertheless an intellectually challenging and enriching experience, revealed limitations which can be broadly categorized under 'sample' and 'data collection'.

5.5.1 Sample

The responses of 333 eleven-year-old students were gathered and analyzed in this study. One consideration which arose was the degree of representativeness the findings had of the entire population. Given the constraints of time and resources (the research was carried out alongside teaching duties and commitments, the availability of students as research participants being entirely dependent on the limited network of friends who hold positions of authority in schools and participation being also subjected to the consent of parents), the investigator had to make do with this pool of respondents. A concerted effort at the national level will yield findings that are undeniably more representative of the population.

5.5.2 Data Collection

In a bid to minimize disruptions to the lessons of the students and the work of the Heads of Department, data were collected solely via questionnaires. The trade-off for being considerate was the compromise on the quality of the data. Without any oral interaction, as in face-to-face interviews or interviews over the telephone, information which might substantiate those reflected in the questionnaires was not captured and as Anderson (1998) put it 'When used with care and skill, interviews are an incomparably rich source of data...' (p. 190). For example, if there were opportunities to interview the students, information on why they enjoyed science lessons or the form of shared control, which was found to be lacking as reflected in the CLES, they would like to have. Interviews with the Heads of Department would capture information like the impact the schools' programmes had on students' learning outcomes and the difficulties encountered in implementing them. It is with a tinge of regret, and to admit with objectivity, that the data collection of this research was a case of 'what you see is what you get', having no avenues for between methods triangulation, a strategy based on the rationale that 'the flaws of one method are often the strengths of another: and by combining methods, observers can achieve the best of each while overcoming their unique deficiencies' (Denzin, 1978, quoted in Mathison, 1988, p. 14).

5.6 SUGGESTIONS FOR FURTHER RESEARCH

The completion of this research study is not synonymous to the closure of the exercise. On the contrary, it may be a platform for further research, albeit with the need for some fine-tuning. The nature of research that can spring forth from the existing one can be classified under the headings of 'Extension' and 'Variation'.

5.6.1 Extension

This research can be replicated but not before making modification to the methods of data collection. It is strongly recommended that in addition to using the questionnaires, interview sessions with a random sample of students and the Heads of Department will certainly improve the completeness of the data. The scale of the research can be extended to cover a greater sample size.

5.6.2 Variation

Future research can arise from the broadening of the scope of the existing one. Currently, only students were research participants. In future, teachers could be roped in to partake of the research. The teachers' responses to the CLES (Actual and Preferred Forms) and the QTI (Ideal and Actual Form) will enable the investigator to make cross comparisons between the perception of the teachers and that of their students.

As a complement to this research which studied the associations between the constructivist learning environment and students' enjoyment of science lessons, future research could look into the associations between constructivist teaching strategies and students' enjoyment of science lessons or their learning outcomes. The Attitude Scale could be expanded to include other attitudinal dimensions like attitude towards science inquiry and leisure interest in science. A study could also be made to examine the relationships between the programmes designed to bring about greater engaged learning and students' attitude towards science.

5.7 FINAL COMMENTS

TLLM, the buzz word in the education fraternity since 2005, not only has as its central theme igniting the passion for engaged learning but has also sparked off the idea for this research study. In line with inquiry learning in science which is based on the theory of constructivism, this research exercise was centred on studying the constructivist learning environment and students' perception of their teachers' interpersonal behaviour in association with students' enjoyment of science lessons and getting a glimpse of different programmes and modes of assessments in schools.

The results of the study proved to be realistic, comprising a mixture of heartening findings (as in the case of the highly positive perceptions students had of their teachers and variety in programmes to bring about engaged learning) and grim revelations (as in the case of the low pervasiveness of constructivist classroom learning environment and the dearth of alternative assessments). Nevertheless, success should be celebrated and fault lines mended and fortified.

Though the study has shed some light on the impact of the TLLM initiative on science education so far, it is hoped that more research studies will be made to provide a more comprehensive picture of primary science education in Singapore.

REFERENCES

Aiken, L.R., & Aiken, D.R. (1969). Recent research on attitudes concerning science. *Science Education, 53*(4), 295-305.

Anderson, G. (1998). Fundamentals of educational research. London: Falmer Press.

American Association for the Advancement of Science. (1989). *Benchmarks for science literacy*. New York: Oxford University Press.

American Federation of Teachers. (1990). Standards for teacher competence in educational assessment of students. *Educational Measurement: Issues and Practice, 9*(4), 30-32.

Anderson, L.M., Stevens, D.D., Prawat, R.S., & Nickerson, J. (1998). Classroom task environments and students' task-related beliefs. *The Elementary School Journal, 88*(3), 281-295.

Arends, R.I. (2001). *Learning to teach* (5th ed.). Boston: McGraw-Hill.

Arends, R.I. (2004). *Learning to teach.* Boston: McGraw-Hill.

Bass, J.E., Constant, T.L., & Carin, A.A. (2009). *Methods for teaching science as inquiry*. Boston: Pearson.

Bell, B., & Cowie, B. (2001). *Formative assessment and science education*. Dordrecht: Kluwer Academic Publishers.

Bell, B., & Gilbert, J. (1996). *Teacher development: a model from science education*. London: Falmer Press.

Bell, R.L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction: Assessing the inquiry level of classroom activities. *The Science Teacher, 72*(7), 30-33.

Bettencourt, A. (1993). The construction of knowledge: A radical constructivist view. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 39-50). Hillsdale, NJ: Erlbaum

Bianchini, J., & Colburn, A. (2000). Teaching the nature of science through inquiry to prospective elementary teachers: A tale of two researchers. *Journal of Research in Science Teaching, 37*(2), 177-209.

Boo, H.K. (1995, November). *Teachers' and students' understandings of the nature of science and implications on learning processes and outcomes*. A paper presented at the 9th Annual Conference of the Educational Research Association, Singapore.

Boo, H.K., & Toh, K.A. (1998). Practising teachers' views of science. *Journal of Science and Mathematics Education in S.E. Asia, 21*(2), 29-36.

Brekelmans, M., den Brok, P., van Tartwijk, J., & Wubbels, T. (2005). An interpersonal perspective on teacher behaviour in the classroom. In L.V. Barnes (Ed.), Contemporary Teaching and Teacher Issues (pp. 197-226). New York: Nova Science Publishers.

Brooks, J.G., & Brooks, M.G. (1993). *In search of understanding: The case for constructivist classrooms.* Virginia: Association for Supervision and Curriculum Development.

Bybee, R.W. (2004). Scientific inquiry and science teaching. In L.B. Flick & N.G. Lederman (Eds.), *Scientific inquiry and nature of science* (pp. 1-14). Netherlands: Kluwer Academic Publishers.

Chiappetta, E.L., & Adams, A.D. (2004). Inquiry-based instruction – Understanding how content and process go hand-in-hand with school science. *The Science Teacher, 71*(2), 46-50.

Chin, C. (1993). Towards a problem-solving approach in teaching and learning science. *Journal of Science and Mathematics Education in South-east Asia, 19*(2), 21-27.

Clement, J., Brown, D.E., & Zietsman, A. (1989). Not all preconceptions are misconceptions: Finding 'anchoring conceptions' for grounding instruction on students' intuitions. *International Journal of Science Education, 11*, 554-565.

Cobern, W.W. (1993). Contextual constructivism: The impact of culture on the learning and teaching of science. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 51-69). Hillsdale, NJ: Erlbaum.

Critical Issue: Ensuring equity with alternative assessments. [Electronic database]. (1997). Oak Brook, Illinois: North Central Regional Educational Laboratory.

Curriculum Planning and Development Division (CPDD), Ministry of Education. (2001). *Science Syllabus (Primary).* Singapore: Ministry of Education.

Curriculum Planning and Development Division (CPDD), Ministry of Education. (2008). *Science Syllabus (Primary).* Singapore: Ministry of Education.

Davies, M.A., & Wavering, M. (1999). Alternative assessment: New directions in teaching and learning. *Contemporary Education, 71*(1), 39-45.

Desautels, J., & Larochelle, M. (1998). The epistemology of students: The ‘thingified’ nature of scientific knowledge. In B.J. Fraser and K.G. Tobin (Eds.), International handbook of science education (pp. 115-126). The Netherlands: Kluwer Academic Publishers.

Doyle, W., & Rutherford, B. (1984). Classroom research on matching learning and teaching styles. *Theory Into Practice, 23*(1), 20-25.

Driver, R. (1989). The construction of scientific knowledge in school classrooms. In R. Millar (Ed.), *Doing science: Images of science in science education* (pp. 83-106). London: The Falmer Press.

Driver, R. & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education, 13*, 105-122.

Duit, R., & Treagust, D.F. (1995). Students’ conceptions and constructivist teaching approaches. In B.J. Fraser and H.J. Walberg (Eds.), *Improving science education* (pp. 46-69). Chicago: National Society for the Study of Education.

Eick, C., Lee, M., & Balkcom, R. (2005). Breaking into inquiry. *The Science Teacher, 72*(7), 49-53.

Ellis, S.S. (1979). Models of teaching: a solution to the teaching style / learning style dilemma. *Educational Leadership, 36*(4), 274-277.

Falk, J.H., & Balling, J.D. (1980). The school field trip: Where you go makes the difference. *Science and Children, 17*(6), 6-8.

Fish, A.S., & Goldmark, B. (1966). Inquiry method: Three interpretations. *The Science Teacher*, *33*(2), 13-15.

Fisher, D.L., Fraser, B.J., & Cresswell, J. (1995). Using the questionnaire on teacher interaction in the professional development of teachers. *Australian Journal of Teacher Education*, 20(1), 8-18.

Fisher, D.L., Rickards, T., & Fraser, B.J. (1996). Assessing teacher-student interpersonal relationships in science classes. *Australian Science Teachers Journal, 42*(3), 28-33.

Flexer, B.K., & Borun, M. (1984). The impact of a class visit to a participatory science museum exhibit and a classroom science lesson. *Journal of Research in Science Teaching, 21*(9), 863-873.

Flick, L.B., & Lederman, N.G. (Eds.). (2004). *Scientific inquiry and nature of science: Implications for teaching, learning and teacher education.* Boston, MA: Kluwer Academic Publishers.

Fraser, B.J. (1977). Selection and validation of attitude scales for curriculum evaluation. *Science Education, 61*(3), 317-329.

Fraser, B.J. (1978). Development of a test of science-related attitudes. *Science Education, 62*(4), 509-515.

Fraser, B.J. (1981). *Test of Science-Related Attitudes (TOSRA)*. Melbourne: Australian Council for Educational Research.

Fraser, B.J. (1982a). How strongly are attitude and achievement related? *Science Review, 63*, 557-559.

Fraser, B.J. (1982b). Development of short forms of several classroom environment scales. *Journal of Educational Measurement, 19*(3), 221-227.

Fraser, B.J. (1986). *Classroom environment*. London: Croom Helm.

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

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

Fraser, B.J., & Fisher, D.L. (1983a). Development and validation of short forms of some instruments measuring student perceptions of actual and preferred classroom learning environment. *Science Education, 67*(1), 115-131.

Fraser, B.J., & Fisher, D.L. (1983b). Student achievement as a function of person-environment fit: A regression surface analysis. *British Journal of Educational Psychology, 53*, 89-99.

Fraser, B.J., & Fisher, D.L. (1983c). Use of actual and preferred classroom environment scales in person-environment fit research. *Journal of Educational Psychology, 75,* 303-313.

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

Fraser, B.J., Giddings, G.J., & McRobbie, C.J. (1995). Evolution and validation of a personal form of an instrument for assessing science laboratory classroom environments. *Journal of Research in Science Teaching, 32,* 399-422.

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

Fraser, B.J., & O'Brien, P. (1985). Student and teacher perceptions of the environment of elementary school classrooms. *The Elementary School Journal, 85*(5), 567-580.

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

Fraser, B.J., & Walberg, H.J. (Eds.). (1991). *Educational environments: Evaluation, antecedents and consequences*. London: Pergamon Press.

Gardner, P.L. (1975). Attitudes to science. *Studies in Science Education, 2*, 1-41.

Gardner, P.L. (1995). Measuring attitudes to science: Unidimensionality and consistency revisited. *Research in Science Education, 25*(3), 283-289.

Gauld, C.F., & Hukins, A.A. (1980). Scientific attitudes: A review. Studies in *Science Education, 7*, 129-161.

Germann, P.J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*(8), 689-703.

Gil-Perez, D., & Carrascosa-Alis, J. (1994). Bring pupils' learning closer to a scientific construction of knowledge: A permanent feature in innovations in science teaching. *Science Education, 78*(3), 301-315.

Ginott, H. (1971). Teacher and child. New York: Collier.

Goh, C.T. (1997). *Shaping our future: Thinking schools, learning nation.* Speech presented at the opening of the 7th International Conference on Thinking, Singapore. Retrieved January 20, 2009 from the World Wide Web: http://www.moe.gov.sg/media/speeches/1997/020697_print.htm

Goh, S.C., & Fraser, B.J. (1996). Validation of an elementary school version of the questionnaire on teacher interaction. *Psychological Reports, 79,* 515-522.

Goh, S.C., & Fraser, B.J. (1997). Adaptation of the questionnaire on teacher interaction for elementary grades. *Asia Pacific Journal of Education, 17*(2), 102-116.

Good, R.G., Wandersee, J.H., & Julien, S.J. (1993). Cautionary notes on the appeal of the new 'ism' (constructivism) in science education. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 71-87). Hillsdale, NJ: Erlbaum.

Gopinathan, S. (1997). Education and development in Singapore. In J. Tan, S.Gopinathan & W.K. Ho (Eds.), *Education in Singapore: A book of readings* (pp. 33-54). Singapore: Prentice Hall.

Gregorc, A.F. (1979). Learning / teaching styles: Potent forces behind them. *Educational Leadership, 36*(4), 234-236.

Habermas, J. (1972). Knowledge and human interests. (2nd ed.). London: Heinemann.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of student, teacher and learning environment variables to attitudes towards science. *Science Education, 66*(5), 671-687.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1983). Correlates of class attitude toward science. *Journal of Research in Science Teaching, 20*(4), 311-324.

Henderson, R.W. (1986). Self-regulated learning: Implications for the design of instructional media. *Contemporary Educational Psychology, 11*(4), 405-427.

Henson, K.T., & Borthwick, P. (1984). Matching styles: A historical look. *Theory Into Practice, 23*(1), 3-9.

Hewson, P.W. (1996). Teaching for conceptual change. In D.F. Treagust, R, Duit & B.J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 131-140). New York: Teachers College Press.

Hewson, P.W., & Thorley, N.R. (1989). The conditions of conceptual change in the classroom. *International Journal of Science Education, 11*, 541-553.

Ho, W.K. (2006). *Education in Singapore: Focusing on quality and choice in learning.* Singapore: Singapore Teachers' Union.

Ho, W.K., & Gopinathan, S. (1999). Recent developments in education in Singapore. *School Effectiveness and School Improvement, 10*(1), 99-117.

Hyman, R., & Rosoff, B. (1984). Matching learning and teaching styles: the jug and what's in it. *Theory Into Practice, 23*(1), 35-43.

Intrator, S.M. (2004). The engaged classroom. *Educational Leadership, 62*(1), 20-24.

Johnstone, A.H., & Reid, N. (1981). Towards a model for attitude change. *European Journal of Science Education, 3*(2), 205-212.

Joyce, B., Weil, M., & Calhoun, E. (2004*). Models of teaching.* Boston: Pearson Education.

Kim, H.B., Fisher, D.L., & Fraser, B.J. (1999). Assessment and investigation of constructivist science learning environments in Korea. *Research in Science and Technological Education, 17*(2), 239-249.

Klopfer, L.E. (1976). A structure for the affective domain in relation to science education. *Science Education, 60*(3), 299-312.

Koballa, Jr., T.R. (1988). Attitude and related concepts in science education. *Science Education, 72*(2), 115-126.

Krynowsky, B.A. (1988). Problems in assessing student attitude in science education: A partial solution. *Science Education, 72*(4), 575-584.

Kyle, W.C., Jr. (1980). The distinction between inquiry and scientific inquiry and why high school students should be cognizant of the distinction. *Journal of Research on Science Teaching, 17*(2), 123-130.

Lee, H.L. (2004). *Our future of opportunity and promise.* Speech delivered at the National Day Rally, Singapore 22 Aug. Retrieved January 20, 2009 from the World Wide Web: http://www.gov.sg/nd/ND04.htm

Lee, H.L. (2005). *Remaking Singapore as a vibrant global city*. Speech presented at the National Day Rally, Singapore 21 Aug. Retrieved January 20, 2009 from the World Wide Web: http://stars.nhb.gov.sg/stars/public/viewHTML.jsp?pdfno=2005082102-2

Lee, H.L. (2007). *City of possibilities; Home for all.* Speech presented at the National Day Rally, Singapore 19 Aug. Retrieved January 25, 2009 from the World Wide Web: http://stars.nhb.gov.sg/stars/public

Lee, S.S.U., Fraser, B.J., & Fisher, D.L. (2003). Teacher-student interactions in Korean high school science classrooms. *International Journal of Science and Mathematics Education, 1*, 67-85.

Lee, Y.J., Lee, K.W., Chin, L.F., & Yap, K.C. (2003). The nature of science and science education. In K.C. Yap, K.A. Toh and N.K. Goh (Eds.), *Primary science teaching* (pp. 1-5). Singapore: Prentice Hall.

Llewellyn, D. (2007). *Inquire within: Implementing inquiry-based science standards in grades 3-8*. California: Corwin Press.

Lloyd-Jones, R. & Bray, E. (1986). *Guides to assessment in education assessment.* London: Macmillan Education Ltd.

Lorsbach, A., & Tobin, K. (1992). *Constructivism as a referent for science teaching.* (Monograph No. 30). Retrieved March 19, 2009, from http://www.exploratium.edu/IFI/resources/research/constructivism.html

Low, S.H., & Yeo, K.H. (2003). Primary science education in Singapore: An overview. In K.C. Yap, K.A. Toh and N.K. Goh (Eds.), *Primary science teaching* (pp. 6-10). Singapore: Prentice Hall.

Lui, T.Y. (2007). *Gearing up for the future: Innovation in Singapore's education system.* Speech presented at the International Baccalaureate Asia Pacific Teachers Conference, Singapore 31March. Retrieved February 02, 2009 from the World Wide Web: http//stars.nhb.gov.sg/stars/public

Mallinson, G.G. (1977). A summary of research in science education – 1975. *Science Education Supplement*. New York: John Wiley & Sons.

Marks, H.M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle and high school years. *American Educational Research Journal, 37*(1), 153-184.

Marshall, H.H., & Weinstein, R.S. (1984). Classroom factors affecting students' self-evaluations: An interaction model. *Review of Educational Research, 54*(3), 301-325.

Mathison, S. (1988). Why triangulate? *Educational Researcher, 17*(2), 13-17.

McCombs, B.L. (1986). The role of the self-system in self-regulated learning. *Contemporary Educational Psychology, 11*(4), 314-332.

McRobbie, C.J., Fisher, D.L., & Wong, F.L. (1998). Personal and class forms of classroom environment instruments. In B.J. Fraser and K.G. Tobin (Eds.), *International handbook of science education* (pp. 581-594). Dordrecht, The Netherlands: Kluwer Academic Publishers.

McTighe, J., Seif, E., & Wiggins, G. (2004). You can teach for meaning. *Educational Leadership, 62*(1), 26-30.

Mergendoller, J.R., Marchman, V.A., Mitman, A.L., & Packer, M.J. (1988). Task demands and accountability in middle-grade science classes. *The Elementary School Journal, 88*(3), 251-265.

Mertler, C.A., & Charles, C.M. (1998). *Introduction to educational research* (5th ed.). Boston, MA: Pearson Education Inc.

Millar, R. (1994). What is 'scientific method' and can it be taught? In R. Levinson (Ed.), *Teaching science* (pp. 164-177). London: Routledge.

Ministry of Education. (1999). Project work (primary) teacher training booklet. Singapore: Ministry of Education.

Ministry of Education, (2005). *Teach less, learn more: Re-igniting passion and mission.* Retrieved August 26, 2007 from the World Wide Web http:www.moe.gov.sg/corporate/contactonline/2005/Issue13/big_pic/p_bigpic.htm

Ministry of Education, (2006). Primary science syllabus 2008. Retrieved August 26, 2007 from the World Wide Web http://intranet.moe.gov.sg/science/HODmeeting/Pri%20HOD%202007.htm

Ministry of Education. (2007). *The PETALS™ primer.* Singapore: Ministry of Education.

Moos, R.H. (1974). The social climate scales: An overview. Palo Alto, CA: Consultancy Psychologist Press.

Moos, R.H. (1975). Evaluating correction and community settings. New York: Wiley.

Moos, R.H. (1976). The human context: Environmental determinants of behaviour. New York: Wiley.

Moos, R.H. (1979). Evaluating educational environments: Procedures, measures, findings and policy implications. San Francisco, CA: Jossey-Bass.

National Research Council. (1996). *National science education standards.* Washington, D.C: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards.* Washington, DC: National Academy Press.

Newmann, F.M. (1988). Can depth replace coverage in the high school curriculum? *Phi Delta Kappan, 69*(5), 345-348.

Newmann, F.M., & Wehlage, G.G. (1993). Five standards of authentic instruction. *Educational Leadership, 50*(7), 8-12.

Novak, J. (1990). Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science, 19,* 29-52.

Novak, J. (1996). Concept mapping: A tool for improving science teaching and learning. In D. Treagust, R. Duit and B.J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 32-43). New York: Teachers College Press.

Oliver, P. (2003). *The student's guide to research ethics.* Berkshire: Open University Press.

Oppenheim, A.N. (1992). *Questionnaire design, interviewing and attitude measurement*. London: Pinter

Orgill, M., & Thomas, M. (2007). Analogies and the 5E model. *The Science Teacher, 74*(1), 40-45.

Orion, N. (1993). A model for the development and implementation of field trips as an integral part of the science curriculum. *School Science and Mathematics, 93*(6), 325-331.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079.

Peterson, R.W., & Carlson, G.R. (1979). A summary of research in science education – 1977. *Science Education, 63*(4), 425-553.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66, 211-227.

Punch, K. (1998). *Introduction to social research: Quantitative and qualitative approaches.* London: Sage Publications.

Rastin, T. (2003). Model for development: A case study of Singapore's economic growth. *Critique: A worldwide student journal of politics.* Retrieved January 13, 2009 from the World Wide Web: http://litl.itstu.edu/critique/Fall%202003%20ds/TaymazFinal.pdf

Rayner, S., & Riding, R. (1997). Towards a categorization of cognitive styles and learning styles. *Educational Psychology, 17*(1&2), 5-27.

Reid, N. (2006). Thoughts on attitude measurement. *Research in Science and Technological Education, 24*(1), 3-27.

Rosenshine, B. (1970). Evaluation of classroom instruction. Review of *Educational Research, 40*(2), 279-300.

Rutherford, F.J. (1964). The role of inquiry in science teaching. *Journal of Research in Science Teaching, 2*, 80-84.

Ryan, A.M., & Patrick, H. (2001). The classroom social environment and changes in adolescents' motivation and engagement during middle school. *American Educational Research Journal, 38*(2), 437-460.

Renzulli, J.S., Gentry, M., & Reis, S.M. (2004). A time and a place for authentic learning. *Educational Leadership, 62*(1), 73-77.

Sammons, P. (1989). Ethical issues and statistical work. In R.G. Burgess (Ed.), *The ethics of educational research* (pp. 31-59). London: The Falmer Press.

Schibeci, R.A (1984). Attitudes to science: An update. *Studies in Science Education, 11*, 26-59.

Shanmugaratnam, T. (2004). *To light a fire: Enabling teachers, nurturing students.* Speech presented at the MOE work plan seminar. Retrieved December 28, 2008 from the World Wide Web: http://www.moe.gov.sg/speeches/2004/sp20040929_print.htm

Shanmugaratnam, T. (2005). *Achieving quality: Bottom up initiative, top down support.* Speech presented at the MOE work plan seminar. Retrieved December 28, 2008 from the World Wide Web: http://www.moe.gov.sg/speeches/2005/sp20050922_print.htm

Shanmugaratnam, T. (2006). Speech presented at the MOE work plan seminar. Retrieved December 28, 2008 from the World Wide Web: http://www.moe.gov.sg/speeches/2006/sp20060928_print.htm

Shanmugaratnam, T. (2007). *Having every child succeed.* Speech presented at the MOE work plan seminar. Retrieved December 28, 2008 from the World Wide Web: http://www.moe.gov.sg/speeches/2007/sp20071002-short_print.htm

Sharpe, L., & Gopinathan, S. (1997). Effective island, effective schools: Repair and restructuring in the Singapore school system. In J. Tan, S.Gopinathan & W.K. Ho (Eds.), *Education in Singapore: A book of readings* (pp. 369-383). Singapore: Prentice Hall.

Sharpe, L., & Gopinathan, S. (2002). After effectiveness: New directions in the Singapore school system? *Journal of Education Policy, 17*(2), 151-166.

Singer, J., Marx, R.W., & Krajcik, J. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist, 35*(3), 165-178.

Skinner, E.A., & Belmont, M.J. (1993). Motivation in the classroom: Reciprocal effects of teacher behaviour and student engagement across the school year. *Journal of Educational Psychology, 85*(4), 571-581.

Smith, L.H., & Renzulli, J.S. (1984). Learning style preferences: A practical approach for classroom teachers. *Theory Into Practice, 23*(1), 44-50.

Taylor, P.C., Dawson, V., & Fraser, B.J. (1995, April). *A constructivist perspective on monitoring classroom learning environments under transformation.* Paper presented at the annual meeting of the National Association for Research on Science Teaching (NARST), San Francisco, CA.

Taylor, P.C., & Fraser, B.J. (1991, April). *CLES: An instrument for assessing constructivist learning environments.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (NARST), The Abbey, Fontaine, Wisconsin.

Taylor, P.C., Fraser, B.J., & Fisher, D.L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27,* 293-302.

Taylor, P.C., Fraser, B.J., & White, L.R. (1994, April). CLES*: An instrument for monitoring the development of constructivist learning environment.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Tobin, K., & Tippins, D. (1993). Constructivism as a referent for teaching and learning. In K.Tobin (Ed.), *The practice of constructivism in science education* (pp. 3-21). Hillsdale, NJ: Erlbaum.

Treagust, D.F., Duit, R., & Fraser, B.J. (1996). Overview: Research on students' preinstructional conceptions – the driving force for improving teaching and learning in science and mathematics. In D.F. Treagust, R. Duit & B.J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 1-14). New York: Teachers College Press.

Tymms, P. (1997). Science in primary schools: An investigation into differences in the attainment and attitudes of pupils across schools. *Research in Science and Technological Education, 15*(2), 149-159.

von Glasersfeld, E. (1993). Questions and answers about radical constructivism. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp.23-38). Hillsdale, NJ: Erlbaum

Watzlawick, P., Beavis, J., & Jackson, D. (1967). *The pragmatics of human communication.* New York: Norton.

Wehlage, G.G., Rutter, R.A., Smith, G.A., Lesko, N., & Fernandez, R.R. (1989). *Reducing the risk: Schools as communities of support.* Philadelphia: Falmer Press.

Welch, W.W., Klopfer, L.E., Aikenhead, G.S., & Robinson, J.T. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education, 65*(1), 33-50.

Williamson, M.F., & Watson, R.L. (2006). Learning styles research: Understanding how teaching should be impacted by the way learners learn. Part II: Understanding how learners prefer to receive information. *Christian Educational Journal, 3*(2), 343-361.

Wilson, J., & Johnson, P. (2000). Students thinking about their learning: assessment to improve learning. *Educational Research Quarterly, 24*(2), 10-20.

Windschitl, M. (1999). The challenges of sustaining a constructivist classroom culture. *Phi Delta, 80*(10), 751-755.

Wubbels, T. (1993). *Teacher-student relationships in science and mathematics classes (what research says to the science and mathematics teacher, No. 11).* Perth: Curtin University of Technology.

Wubbels, Th., Créton, H.A., & Hooymayers, H. (1985, April). *Discipline problems of beginning teachers.* Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Wubbels, Th., Créton, H.A., Levy, J., & Hooymayers, H. (1993). The model for interpersonal teacher behaviour. In T.Wubbels and J.Levy (Eds.), *Do you know what you look like? Interpersonal relationships in education* (pp. 13-28). London: The Falmer Press.

Wubbels, T., & Levy, J. (1991). A comparison of interpersonal behaviour of Dutch and American teachers. *International Journal of Intercultural Relations, 15*, 1-18.

Yager, R.E. (1991). The constructivist learning model. *The Science Teacher, 58*(6), 52-57.

Yip, John S.K. (1997). Reflections and renewal in education. In J. Tan, S. Gopinathan & W.K. Ho (Eds.), *Education in Singapore: A book of readings* (pp. 385-400). Singapore: Prentice Hall.

Yip, S.K., Eng, S.P., & Yap, Y.C. (1997). 25 years of educational reform. In J. Tan, S. Gopinathan and W.K. Ho (Eds.), *Education in Singapore: A book of readings* (pp. 3-32). Singapore: Prentice Hall.

Zimmerman, B.J. (1986). Becoming a self-regulated learner: which are the key sub-processes? *Contemporary Educational Psychology, 11*(4), 307-313.

Zimmerman, B.J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice, 41*(2), 64-71.

APPENDIX 1

CLES (Preferred)

What I wish would happen in my science classroom
(Student form)

1. Purpose of the Questionnaire

This questionnaire asks you to describe important aspects of the science classroom which you are in right now. There are no right or wrong answers. This is not a test and your answers will not affect your assessment. Your opinion is what is wanted. Your answers will enable us to improve future science classes.

2. How to Answer Each Question

On the next few pages, you will find 30 sentences. For each sentence, circle only one number corresponding to your answer. For example:

	Almost always	Often	Sometimes	Seldom	Almost never
In this class I wish that... 8. the teacher would ask me questions.	5	4	3	2	1

- If you think this teacher **almost always** asks you questions, circle the **5**.
- If you think this teacher **almost never** asks you questions, circle the **1**.
- Or you can choose the number **2, 3 or 4** if one of these seems like a more accurate answer.

3. How to Change Your Answer

If you want to change your answer, cross it out and circle a new number. For example:

	Almost always	Often	Sometimes	Seldom	Almost never
In this class I wish that... **8. the teacher would ask me questions.**	5	4	3	2	1

4. Completing the Questionnaire

Now turn the page and please give an answer for **every** question.

Learning about the world	**Almost always**	**Often**	**Sometimes**	**Seldom**	**Almost never**
In this class I wish that... **1. I learned about the world outside of school.**	5	4	3	2	1
2. my new learning would start with problems about the world outside of school.	5	4	3	2	1
3. I could learn how science can be part of my out-of-school life.	5	4	3	2	1
In this class I wish that... **4. I would get a better understanding of the world outside of school.**	5	4	3	2	1
5. I learned interesting things about the world outside of school.	5	4	3	2	1
6. what I learned had something to do with my out-of-school life.	5	4	3	2	1
Learning about science	**Almost always**	**Often**	**Sometimes**	**Seldom**	**Almost never**
In this class I wish that... **7. I learned how science cannot provide perfect answers to problems.**	5	4	3	2	1
8. I learned how science has changed over time.	5	4	3	2	1
9. I learned how science is influenced by people's values and opinions.	5	4	3	2	1

In this class I wish that... **10. I learned about the different sciences used by people in other cultures.**	5	4	3	2	1
11. I learned that modern science is different from the science of long ago.	5	4	3	2	1
12. I learned that science is about <u>inventing</u> theories.	5	4	3	2	1
Learning to speak out	Almost always	Often	Sometimes	Seldom	Almost never
In this class I wish that... **13. it was OK for me to ask the teacher 'Why do I have to learn this?'**	5	4	3	2	1
14. it was OK for me to question the way I'm being taught.	5	4	3	2	1
15. it was OK for me to complain about activities that are confusing.	5	4	3	2	1
In this class I wish that... **16. it was OK for me to complain about anything that prevents me from learning.**	5	4	3	2	1
17. it was OK for me to express my opinion.	5	4	3	2	1
18. it was OK for me to speak up for my rights.	5	4	3	2	1
Learning to learn	Almost always	Often	Sometimes	Seldom	Almost never
In this class I wish that... **19. I could help the teacher to plan what I'm going to learn.**	5	4	3	2	1
20. I could help the teacher to decide how well I am learning.	5	4	3	2	1
21. I could help the teacher to decide which activities are best for me.	5	4	3	2	1

In this class I wish that...					
22. I could help the teacher to decide how much time I spend on activities.	5	4	3	2	1
23. I could help the teacher to decide which activities I do.	5	4	3	2	1
24. I could help the teacher to assess my learning.	5	4	3	2	1
Learning to communicate	Almost always	Often	Sometimes	Seldom	Almost never
In this class I wish that... **25.** I got the chance to talk to other students.	5	4	3	2	1
26. I could talk with other students about how to solve problems.	5	4	3	2	1
27. I had the chance to explain my ideas to other students.	5	4	3	2	1
In this class I wish that... **28.** I could ask other students to explain their ideas.	5	4	3	2	1
29. other students would ask me to explain my ideas.	5	4	3	2	1
30. other students would explain their ideas to me.	5	4	3	2	1

☺ Thank you for taking part in this survey ☺

APPENDIX 2

CLES (Actual)

What happens in my science classroom? (Student form)

DIRECTIONS

1. **Purpose of the Questionnaire**
   This questionnaire asks you to describe important aspects of the science classroom which you are in right now. There are no right or wrong answers. This is not a test and your answers will not affect your assessment. Your opinion is what is wanted. Your answers will enable us to improve future science classes.

2. **How to Answer Each Question**
   On the next few pages, you will find 30 sentences. For each sentence, circle only one number corresponding to your answer. For example:

	Almost always	Often	Sometimes	Seldom	Almost never
In this class... **8. the teacher asks me questions.**	5	4	3	2	1

- If you think this teacher **almost always** asks you questions, circle the **5**.
- If you think this teacher **almost never** asks you questions, circle the **1**.
- Or you can choose the number **2, 3 or 4** if one of these seems like a more accurate answer.

3. **How to Change Your Answer**
   If you want to change your answer, cross it out and circle a new number. For example:

	Almost always	Often	Sometimes	Seldom	Almost never
In this class... **8. the teacher asks me questions.**	~~5~~	(4)	3	2	1

4. Completing the Questionnaire

Now turn the page and please give an answer for **<u>every</u>** question.

Learning about the world	**Almost always**	**Often**	**Sometimes**	**Seldom**	**Almost never**
In this class...					
1. I learn about the world outside of school.	5	4	3	2	1
2. my new learning starts with problems about the world outside of school.	5	4	3	2	1
3. I learn how science can be part of my out-of-school life.	5	4	3	2	1
In this class...					
4. I get a better understanding of the world outside of school.	5	4	3	2	1
5. I learn interesting things about the world outside of school.	5	4	3	2	1
6. what I learn has <u>nothing</u> to do with my out-of-school life.	5	4	3	2	1
Learning about science	**Almost always**	**Often**	**Sometimes**	**Seldom**	**Almost never**
In this class...					
7. I learn that science <u>cannot</u> provide perfect answers to problems.	5	4	3	2	1
8. I learn that science has changed over time.	5	4	3	2	1
9. I learn that science is influenced by people's values and opinions.	5	4	3	2	1

In this class... **10.** **I learn about the different sciences used by people in other cultures.**	5	4	3	2	1
11. **I learn that modern science is different from the science of long ago.**	5	4	3	2	1
12. **I learn that science is about <u>inventing</u> theories.**	5	4	3	2	1
Learning to speak out	Almost always	Often	Sometimes	Seldom	Almost never
In this class... **13.** **it's OK for me to ask the teacher 'Why do I have to learn this?'**	5	4	3	2	1
14. **it's OK for me to question the way I'm being taught.**	5	4	3	2	1
15. **it's OK for me to complain about activities that are confusing.**	5	4	3	2	1
In this class... **16.** **it's OK for me to complain about anything that prevents me from learning.**	5	4	3	2	1
17. **it's OK for me to express my opinion.**	5	4	3	2	1
18. **it's OK for me to speak up for my rights.**	5	4	3	2	1
Learning to learn	Almost always	Often	Sometimes	Seldom	Almost never
In this class... **19.** **I help the teacher to plan what I'm going to learn.**	5	4	3	2	1
20. **I help the teacher to decide how well I am learning.**	5	4	3	2	1
21. **I help the teacher to decide which activities are best for me.**	5	4	3	2	1

In this class...					
22. I help the teacher to decide how much time I spend on activities.	5	4	3	2	1
23. I help the teacher to decide which activities I do.	5	4	3	2	1
24. I help the teacher to assess my learning.	5	4	3	2	1
Learning to communicate	Almost always	Often	Sometimes	Seldom	Almost never
In this class...					
25. I get the chance to talk to other students.	5	4	3	2	1
26. I talk with other students about how to solve problems.	5	4	3	2	1
27. I explain my ideas to other students.	5	4	3	2	1
In this class...					
28. I ask other students to explain their ideas.	5	4	3	2	1
29. other students ask me to explain my ideas.	5	4	3	2	1
30. other students explain their ideas to me.	5	4	3	2	1

Thank you for taking part in this survey

APPENDIX 3

QUESTIONNAIRE ON TEACHER INTERACTION (QTI)

DIRECTIONS

This questionnaire is not a test.

We want to know your opinion about how your teacher works with you.

We want you to answer honestly.

Read each sentence carefully.

Show your opinion about your teacher by circling the number 1, 2, 3 or 4.

FOR EXAMPLE

This teacher has a happy smile.

NEVER	SELDOM	SOMETIMES	MOST OF THE TIME
1	2	3	4

If you think that your teacher **never** has a happy smile, you circle 1

If you think that your teacher **seldom** has a happy smile, you circle 2

If you think that your teacher **sometimes** has a happy smile, you circle 3

If you think that your teacher has a happy smile **most of the time**, you circle 4

Please answer all questions. If you want to change your answer, just cancel your original answer and circle another number.

Remember you are describing your <u>science teacher</u>.
Circle your answer 1, 2, 3 or 4.

No.	Description of your science teacher	NEVER	SELDOM	SOMETIMES	MOST OF THE TIME
1.	We all listen to this teacher.	1	2	3	4
2.	This teacher is friendly.	1	2	3	4
3.	This teacher trusts us.	1	2	3	4
4.	This teacher allows us to work on things that we like.	1	2	3	4
5.	This teacher doesn't seem sure.	1	2	3	4
6.	This teacher is unhappy.	1	2	3	4
7.	This teacher gets angry quickly.	1	2	3	4
8.	This teacher makes us work hard.	1	2	3	4
9.	We learn a lot from this teacher.	1	2	3	4
10.	This teacher likes to laugh.	1	2	3	4
11.	This teacher knows when we do not understand.	1	2	3	4
12.	We can decide some things in this teacher's class.	1	2	3	4
13.	This teacher is not sure of himself / herself.	1	2	3	4
14.	This teacher is bad-tempered.	1	2	3	4
15.	This teacher looks down on us.	1	2	3	4
16.	We have to be quiet in this teacher's class.	1	2	3	4

No.	Description of your science teacher	NEVER	SELDOM	SOMETIMES	MOST OF THE TIME
17.	This teacher gets our attention.	1	2	3	4
18.	This teacher's class is pleasant.	1	2	3	4
19.	This teacher is willing to explain things again if we don't understand.	1	2	3	4
20.	This teacher gives us a lot of free time in class.	1	2	3	4
21.	This teacher is shy.	1	2	3	4
22.	This teacher thinks that we can't do things well.	1	2	3	4
23.	This teacher makes fun of us.	1	2	3	4
24.	This teacher's tests are hard.	1	2	3	4
25.	This teacher knows everything that goes on in this classroom.	1	2	3	4
26.	We like this teacher.	1	2	3	4
27.	This teacher takes notice of what we say.	1	2	3	4
28.	This teacher allows us to choose who we work with.	1	2	3	4
29.	This teacher is not sure what to do when we fool around.	1	2	3	4
30.	This teacher thinks we cheat.	1	2	3	4
31.	This teacher shouts at us.	1	2	3	4
32.	This teacher is strict when marking our work.	1	2	3	4

No.	Description of your science teacher	NEVER	SELDOM	SOMETIMES	MOST OF THE TIME
33.	This teacher explains things clearly.	1	2	3	4
34.	This teacher helps us with our work.	1	2	3	4
35.	This teacher knows how we feel.	1	2	3	4
36.	This teacher allows us to fool around in class.	1	2	3	4
37.	This teacher allows us to tell him / her what to do.	1	2	3	4
38.	This teacher thinks that we know nothing.	1	2	3	4
39.	It is easy to make this teacher angry.	1	2	3	4
40.	We are afraid of this teacher.	1	2	3	4
41.	This teacher is sure about what he / she wants to take place in the classroom.	1	2	3	4
42.	This teacher cares about us.	1	2	3	4
43.	This teacher listens to us.	1	2	3	4
44.	This teacher allows us to choose what we want to work on.	1	2	3	4
45.	This teacher acts as if he / she does not know what to do.	1	2	3	4
46.	This teacher says that he / she will punish us.	1	2	3	4
47.	This teacher has a bad temper.	1	2	3	4
48.	This teacher is strict.	1	2	3	4

APPENDIX 4

Attitude to Science Lessons

Items 1-10 below consist of a number of statements about any science lesson you might have in this class.
You will be asked what you think about these statements.
There are no 'right' or 'wrong' answers.
Your opinion is what is wanted.

For each statement, draw a circle around

1 if you DISAGREE 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 science lessons.	1	2	3
2.	Science lessons are fun	1	2	3
3.	I enjoy the activities we do in science.	1	2	3
4.	What we do in science are among the most interesting we do at school.	1	2	3
5.	I want to find out more about the world in which we live.	1	2	3
6.	Finding out about new things is important.	1	2	3
7.	I enjoy science lessons in this class.	1	2	3
8.	I like talking to my friends about what we do in science.	1	2	3
9.	We should have more science lessons each week.	1	2	3
10.	I feel satisfied after a science lesson.	1	2	3

APPENDIX 5

Questionnaire on customized activities and forms of assessments (for Science HOD)

Customized activities

Please state in point form and describe briefly the activities carried out in your school in lieu of the 20% 'white-space' in the science curriculum. Please specify whether these activities are class-based, level-based or school-based.

Assessments

Please state the different forms of assessments used in your school.

- *Types of formative assessments:*

____

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- *Types of summative assessments:*

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Thank you for completing this questionnaire.

APPENDIX 6

Curtin University of Technology

SCIENCE AND MATHEMATICS EDUCATION CENTRE

Participant Information Sheet

My name is Evelyn Tan. I am a teacher and currently completing a piece of research for my Doctoral Degree in Science Education at Curtin University of Technology.

I am investigating the classroom learning environment and students' attitude towards science in light of the TLLM (Teach Less Learn More) initiative.

I would appreciate it very much if you would permit your child to spend some time to fill in 4 questionnaires, each taking up an average of 10 minutes.

Your child's involvement in the research is entirely voluntary. The information your child provides will be anonymous and kept confidential. Only I will have access to it and in adherence to university policy, all electronic data will be kept in a secure place and password protected in my supervisor's office in SMEC for a period of five years, after which, they will be destroyed.

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number is SMEC20080032).

If you would like further information about the study, please feel free to contact me on my mobile at 96775439 or by email: evelyn_tan_kim_choo@moe.edu.sg.

Alternatively, you can contact my supervisor, Professor Darrell L. Fisher via email: D.Fisher@curtin.edu.au

Thank you very much for your attention in this matter.

APPENDIX 7

(For Principals)

Curtin
University of Technology

CONSENT FORM

- I have been provided with the participant information sheet.
- I understand the purpose of the study.
- I understand that the procedure itself may not benefit me or my pupils.
- I understand that participation in this research exercise is voluntary and I can withdraw my pupils' participation at any time without any problem.
- I understand that no personal identifying information like my name and address or my pupils' names and their addresses will be used and that all information will be securely stored for five years before being destroyed.
- I permit my pupils to take part in this research exercise.

Name of school: ______________________

Name of principal: _____________________

Signature of principal: __________________

Date: ______________

(For Parents)

Curtin
University of Technology

CONSENT FORM

- I have been provided with the participant information sheet.
- I understand the purpose of the study.
- I understand that the procedure itself may not benefit me or my child.
- I understand that participation in this research exercise is voluntary and I can withdraw my child's participation at any time without any problem.
- I understand that no personal identifying information like my name and address or my child's name will be used and that all information will be securely stored for five years before being destroyed.
- I permit my child to participate in this research exercise.

Name of child: ______________________

Name of parent: _____________________

Signature of parent: __________________

Date: ______________

(For HODs)

Curtin
University of Technology

CONSENT FORM

- I have been provided with the participant information sheet.
- I understand the purpose of the study.
- I understand that the procedure itself may not benefit me.
- I understand that my involvement is voluntary and I can withdraw at any time without any problem.
- I understand that no personal identifying information like my name and address will be used and that all information will be securely stored for five years before being destroyed.
- I agree to participate in this research exercise.

Name of School: ______________________

Name of HOD: _______________________

Signature of HOD: ___________________

Date: ______________