Enhancing the Mathematical Achievement of Technical Education Students in Brunei Darussalam Using a Teaching and Learning Package.

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This thesis is presented for the Degree of Doctor of Philosophy of Curtin University of Technology

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DECLARATION

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

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

Signature: ........................................

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16/11/2004
ABSTRACT

Mathematics plays a key role in many of today's most secure and financially rewarding careers. In almost every sector of the economy, a substantial core of mathematics is needed to prepare students both for work and for higher education. The impact of computers and information technology in areas as diverse as manufacturing and advertising means that understanding mathematics becomes more important because it provides students with basic prerequisites in other useful areas such as problem-solving.

Technical students in Brunei are trained with the skills needed in the world of industry and commerce to become competent workers and many of them continue to pursue higher education. They need the right balance of mathematics that can prepare them for both purposes. Considered to be academically weak, and coming from the system (high schools) whose teaching approaches benefit abstract learners, these students need to be motivated and have their interest in mathematics nurtured.

This study is an attempt to improve the mathematical skills of technical students in Brunei by developing a teaching and learning package that can be used by mathematics instructors with their students. The package was designed to provide student-centred instruction and focuses on the learning environment aspects of "Teacher Support", "Innovation", "Cooperation", "Task Orientation" and "Relevance". These learning environment aspects were incorporated into each category of the ARCS motivational model (Keller, 1983b) for the purpose of enhancing motivation. It was anticipated that students' mathematical understanding and attitude would be improved when their learning environment and thus their motivation was enhanced. When the package was implemented among a group of technical students, they experienced an approach to the teaching of mathematics that shifted from instruction fostering the procedures of practice and memorisation toward instruction that emphasised mathematical inquiry and conceptual understanding. Integrated curricula and cooperative learning techniques were used to link both the mathematics understanding of materials and their composition to the application of materials in the world of work. The use of technology to pursue
mathematical investigations by way of learning aids was encouraged because the impact of technology on education today cannot be ignored.

A group of students from two classes were involved in the implementation of the package to determine its effectiveness, for a duration of eight weeks. By applying the pre-experimental design methodology to the study, pre-test and post-test were used to measure students’ cognitive and affective changes. Mathematics proficiency in the categories of procedural skills, conceptual understanding and problem solving abilities were measured and examined by comparing students’ pre- and post-test results. Other forms of assessment such as projects and graded class-work (and homework) and also the communication that took place between the students during discussions were analysed to further validate their mathematical understanding.

The learning environment and attitude factors mentioned were identified and validated through surveys, observations and interviews. A learning environment instrument called the College Classroom Environment Inventory (CCEI) was adapted for the purpose of measuring students’ perception of the learning environment. Another instrument named the Attitude Towards Mathematics survey was designed to measure students’ attitude towards mathematics. Both instruments were created, validated and then used to measure students’ affective changes (before and after package implementation) and thus evaluate the efficacy of the package. Besides the quantitative data obtained, the qualitative data from observations and interviews was used to confirm, explain and verify results.

The results obtained from this study demonstrated students’ improved cognitive outcome in all areas of mathematical proficiency measured. As for the affective outcome, there were improvements in students’ perception of the classroom environment and also in the attitude category of “Importance” where more post-test than pre-test students agreed on the importance of mathematics in everyday life. The result also indicated associations between cognitive outcomes and a number of the learning environment scales. Students who experienced the package also demonstrated better mathematical understanding compared to those who did not.

Students, instructors, curriculum developers and administrators should benefit from the results of this study. The study also provides a starting point for more research of this kind to be carried out for the benefit of technical students in Brunei in particular, and for mathematics students generally.
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Chapter 1

Introduction

"A teacher of mathematics, no matter how much he loves his subject and how strong his desire to communicate, is perpetually faced with one overwhelming difficulty: How can he keep his students awake?"

(Martin Gardner, Mathematical Carnival, Vintage, 1965.)

1.1 Background to the Problem

Business and industry reports, and remedial courses in mathematics at the post-secondary levels of education provide evidence that many students do not develop satisfactory knowledge and skills for the future use of this subject (Howe, 1988). This trend, although reported quite long ago in the United States, is global and is certainly still faced by many students (including technical education students) in Brunei.

Many of the students who come to the technical college in Brunei have problems with mathematics. To them and many other students around the world, mathematics is an intimidating subject (Miller, 1997; Schiavone, 1998). The abstract, rote-learning manner in which mathematics is presented is incompatible with the concrete nature of the Vocational and Technical Education (VTE) subjects. There are many reasons that contribute to the phenomenon that can be referred as math-phobia, and the question arises: Can teachers/instructors improve or enhance students' mathematical understanding when they are at the technical college?

I believe that most students can become proficient at mathematics if taught with the right approach. Instructors should utilise and take advantage of a number of contributing factors that are already present at technical colleges in Brunei (such as very small classes; the practical nature of the courses that students are taking, and also the maturity and reliability of the students) to enhance students' mathematics understanding. I believe that what needs to be done involves motivating these
students and encouraging their interest in learning mathematics. One of the greatest motivational influences for students is the classroom environment (Hicks & Carol, 1998; McMunn & Butler, 2000). The figure below shows my proposed model of how an improvement in the classroom environment may lead to an improvement in students’ motivation and finally leads to an improvement in the cognitive and affective performance. The details of the model will be further discussed in Chapter 2, Section 2.3.2.

![Diagram showing relationship between improved classroom environment, student motivation, and affective performance](image)

*Figure 1.1*: A proposed model showing association between classroom environment, student motivation and performance

The classroom environment includes the social, psychological and pedagogical context in which learning occurs. Concentrating on the classroom environment could make students feel special and motivated. This in turn affects student attitude and achievement. In a classroom, students derive motivation from their peers, teachers, the instructional approach and the goals that they set out to achieve. These are the factors that should be considered when dealing with students in a classroom. Juhani and Perti (2000) claimed that students who are satisfied with their environment encounter few obstacles to concentrate on their studies.

This study set out to improve the mathematical proficiency of technical students in Brunei by developing a teaching and learning package that can be used by mathematics instructors for classroom implementation. The package was designed to incorporate aspects of favourable classroom environments that will be defined later and focuses on enhancing mathematical achievement in Trigonometry. It could have been designed for any mathematics topic incorporating the features and reform ideas that are the current trend, but in this case Trigonometry was the topic of choice for the reasons mentioned in Section 1.5 (after Figure 1.2). The package was then implemented and evaluated to determine its effectiveness and power to improve students’ motivation, attitude and cognitive mathematical abilities. Introduction of the package was intended to shift the emphasis of teaching and learning of
mathematics in Brunei from instruction that fosters the procedure of practice and memorisation toward instruction that emphasises mathematical inquiry and conceptual understanding.

1.2 Overview of the Chapter

In Section 1.3 of this chapter, I will describe Brunei’s Education System including its philosophy, education policy and education objectives in order to establish an appropriate context for the study. Section 1.3.4 will briefly describe the secondary and tertiary education levels, which Bruneian students may go through after seven years of primary schooling so that readers will have a clear conception of the type of students who are the focus of this study. Section 1.3.5 describes the Technical and Vocational Training branch upon which this research study concentrates and the centres that are providing the technical and vocational training. A brief introduction to Brunei’s Department of Technical Education appears in Section 1.3.6, which also informs about the structure and function of the Department, the programme accreditation, the student population and the challenges of Vocational and Technical Education (VTE) so that readers will become familiar with the Department that is responsible for the students who are the focus in this research study.

Sections 1.4 and 1.5 explain the rationale and the objectives of the study respectively. The research questions, expected outcome and the significance of the study appear in Sections 1.6, 1.7 and 1.8 respectively, and Section 1.9 presents a summary of this chapter and that of other chapters that constitute this thesis.

1.3 Brunei's Education System

The formal education system in Brunei Darussalam involves a 7-3-2-2 pattern; representing the number of years at primary, lower secondary, upper secondary and pre-tertiary levels respectively. The University of Brunei Darussalam, the Brunei Institute of Technology, the Pengiran Anak Putri Rashidah Saadatul Bolkiah (PAPRSB) Nursing College, training centres and various technical and vocational education institutions provide education and training at the post-secondary level in both academic and professional fields. The structure of the education and education system is illustrated in Appendix 1A.
The main purpose of examining the education system in Brunei is to provide a general idea of what the Brunei Government considers important in educating its people; the link between secondary education and technical education, and the type of students who usually enrol for technical education. At the same time, a brief description of Technical and Vocational Education and Training provides an overview of that system in Brunei and the centres that provide the training in progression. The information produced in this section was obtained from a number of sources (Azaharaini Mohd Jamil, 2000; Brunei Ministry Of Education, 2003; DTE, 2003).

1.3.1 The Philosophy of Education in Brunei

Brunei Darussalam's Education Philosophy is founded on the National Philosophy of a Malay Islamic Monarchy – that is, to establish an effective, efficient and equitable system of education that will produce an educated workforce. This workforce will contribute to the development of a progressive and peaceful nation where the following are emphasized: Malay as the language and culture, Islam as the faith and values, and loyalty and allegiance to the monarchy and state (Brunei Ministry Of Education, 2003).

1.3.2 Education Policy

The following items are incorporated in the education policy of Brunei Darussalam which provides for:

1. Twelve years of education for every student – that is, seven years of primary education including a year of pre-school, three years of lower secondary and two years of upper secondary, or VTE.
2. An integrated curriculum as well as suitable and uniform public examinations administered according to the level of education, including special needs, in all schools throughout the nation.
3. Facilities for mathematics, science, technical as well as information and communications technology education in order to enable students to obtain knowledge and skills that are relevant and necessary in the constantly changing world of employment.
4. Self-development and enrichment programmes through co-curricular activities in accordance with the national philosophy.
5. Opportunities in higher education for those with appropriate qualifications and experience, such opportunities to be offered based on national needs as and when they arise.

From this policy, it can be seen that the Brunei Government emphasizes learning and consider it the main priority in educating its citizens for at least twelve years. The government also considers the integrated curriculum, mathematics, science and technology education as important, and it emphasizes self-development according to the national philosophy that values higher education and experience. The Brunei government has been providing free education at all levels to all her citizens, and in addition students at post-secondary level receive a generous allowance.

1.3.3 Educational Objectives

The educational objectives of Brunei Darussalam include:

1. Implementation of an integrated curriculum so that the spiritual, physical, intellectual, social, and aesthetic talents of each individual can be developed in a balanced way.
2. Enhancement of mathematical, scientific, technical, as well as information and communications technology skills.
3. Implementation of educational programmes for the development of self reliant and enterprising individuals.
4. Implementation of technical education programmes which are responsive, relevant and flexible and in line with global economic development in order to fulfil national development needs.
5. Implementation of educational programmes based on culture, society and nationalism for the development of Brunei citizens.
6. Provision of opportunities for skills training in professional and semi professional areas.
7. Implementation of enrichment and value added programmes and industrial placement/training for the enhancement of the quality of an individual so that he/she is able to compete at the international level.

In line with the education policy, the Brunei Government recognizes the importance of implementing an integrated curriculum that will develop a balanced
citizen; of implementing technical education programmes that are relevant in order to
fulfil the national needs and educational programmes that develop enterprising
individuals; of providing opportunities for skill training and value-added
programmes that can enhance individual quality and also enhance mathematics,
science and technology skills. These ideals suggest that Brunei is endeavouring to
equip its citizens with the necessary skills and education, especially in the technical
field, that requires mathematics, science and technology to fulfil the labour market in
its quest for building a self-reliant country.

1.3.4 The Primary, Secondary and Tertiary Levels

After seven years of primary level education, students in Brunei proceed to
three years of lower secondary level study. At the end of the third year, they sit for
the Lower Secondary Assessment (PMB), a public examination that assesses students
on a number of subjects. Based on their performance of the PMB examination
students have the option to either pursue:

1. Two or three years of upper secondary education leading to the Brunei
Cambridge General Certificate of Education (GCE 'O' Level) examination
(in the Arts or Science stream) or the GCE 'N' level examination.

2. Craft level courses at technical or vocational institutions (in the
vocational stream) or enter the employment market.

Those who are considered less academically inclined may sit for the Brunei-
Cambridge GCE 'N' level examination after two years at upper secondary level.
Students obtaining a good pass at 'N' Level are given the opportunity to transfer into
the Academic stream, and upon completion of one further academic year of study,
can sit for GCE 'O' Level while the others may pursue the technical stream or find
employment.

Those students with adequate and relevant 'O' Level passes may proceed to do
a further two-year Pre-University course leading to the Brunei-Cambridge Advanced
Level Certificate of Education examination (GCE 'A' Level). Others may decide to
opt for employment or undertake education and training programmes at the Sultan
Hassanal Bolkiah Institute of Education (Universiti Brunei Darussalam), technical
colleges, the nursing college or study abroad.
After A-levels, depending on the quality of their results, students may be admitted to the local University (University Brunei Darussalam), Brunei Institute of Technology, Technical Colleges or overseas universities. Appendix 1B shows the levels of education (including VTE) that are being offered in Brunei.

1.3.5 Technical and Vocational Education and Training (TVET)

Vocational and Technical institutions specialise in imparting to young learners the skills needed in the world of industry and commerce where programmes are offered at well-defined levels. In Brunei, VTE craft programmes are offered to students who have completed lower secondary education in order to prepare them to become semi-skilled or skilled workers (DTE, 2003). At the same time, technician programmes are offered to students who have completed upper secondary education to prepare them for work as technicians and for progression to higher-level technical studies.

The Department of Technical Education (DTE) is the major provider of technical and vocational education and training (TVET) and continuing education (CE) programmes in Brunei Darussalam. At present, DTE is responsible for seven education and training institutions and a Continuing Education Section offering a wide range of full-time VTE programmes at various certification levels that are validated by the Brunei Darussalam Technical and Vocational Council (BDTVEC). These programmes range in duration from one to three and one-half years. All full time programmes except the Pre-National Diploma programmes have a period of three to six months of industrial attachment built in. Meanwhile, ad hoc, short-term, upgrading and re-training programmes are also offered by these institutions to satisfy the needs of government departments, the private sector and individuals. Part-time programmes leading to BDTVEC awards are also available for those who are already holding in-service positions with the government or who are working with the private sector.

1.3.5.1 Vocational Schools and Centres

There are currently two vocational schools and a Mechanical Training Centre providing craft level training programmes in a variety of fields. A third vocational school is currently in the planning phase and will offer programmes in Agriculture, Forestry and Fisheries, which are not provided by the other two schools. The primary
focus of the vocational schools is to train young people for employment, including apprenticeship employment training. Craft level programmes are also offered at the technical colleges in various courses (Azaharaini Mohd Jamil, 2000; DTE, 2003).

The Mechanical Training Centre offers vocationally oriented programmes in the principles of operation, maintenance and repair of heavy construction equipment and are of one and one-half years duration.

1.3.5.2 Technical Colleges and Centres

The Sultan Saiful Rijal Technical College (MTSSR) and the Jefri Bolkiah College of Engineering (MKJB) offer career, technical and vocational programmes to those students who enter directly from the formal school system and to adults requiring upgrading and re-training. These certificate and diploma programmes at craft and technician levels relate to the current or intended occupations of students or provide the generic skills needed in a wide range of occupations and community situations. Both colleges offer programmes at the National Diploma level in a number of fields including Engineering, Construction, Computer and Business studies. There are more variations of programmes offered by MTSSR than those offered at MKJB. The colleges also offer a Pre-National Diploma in similar fields, and craft level programmes are also offered in a variety of other skills and services oriented industries. Full-time technician level diploma programmes at both colleges are offered to students who have completed Brunei-Cambridge GCE 'O' levels in relevant subjects, whilst craft level courses only require Secondary Three completion as prerequisites. Technician programmes are more theoretical and scientific in orientation (Azaharaini Mohd Jamil, 2000).

1.3.5.3 Brunei Institute of Technology (ITB)

The Brunei Institute of Technology is an autonomous institution that offers Higher National Diploma (HND) programmes. Most of the students who enrolled here are those who have completed their National Diploma and those with the A-level qualification from the sixth form centres. ITB offers studies in areas similar to those offered by the technical colleges, but at a higher level leading to the HND qualification. Many students possessing a National Diploma who wish to pursue a higher academic qualification would enrol themselves here, while some would continue their studies overseas.
1.3.5.4 Seameo Voctech

Another institution that is of importance to the Technical and Vocational Education in Brunei is the Seameo Voctech. It is a regional institution for the member countries of the Association of South-East Asian Nations (ASEAN) and was established in 1990 in Brunei Darussalam with the mandate to strengthen and improve the quality of Vocational and Technical Education and Training through human resources development. Seameo Voctech has three major roles:

1) As a catalyst and innovator: Conducts regular training programmes for TVET administrators and personnel of member countries.

2) As a clearinghouse: Handles information services related to TVET issues using state-of-the-art techniques in information technology.

3) As a resource centre: Provides consultancy services and undertakes research projects for the benefit of the regional TVET community and facilitates sharing of ideas and experiences through seminars, workshops, symposia, forum, and conferences.

1.3.6 The Department of Technical Education (DTE)

This section describes the important body responsible for the TVET in Brunei which also sets the quota for the number of students enrolled in the VTE courses - giving an idea of the importance that the country places on technical education. The challenges faced by the department and the strategies that have been documented are also presented.

The DTE was established in 1993 under the umbrella of the Ministry of Education to carry out two major aims; namely to plan, coordinate and evaluate the implementation of TVET programmes in addressing the socio-economic demands of Brunei Darussalam as well as to support and promote the development of human resources through the provision of VTE services to the community, government and private sectors.

In order to achieve the above aims, the DTE is guided by its vision, namely "to achieve excellence in technical education and training" and by its mission which is "to develop a competitive, dynamic and quality workforce through technical education and training consistent with national aspirations" (DTE, 2003).

The Department is charged, among other responsibilities, with:
1) Ensuring that VTE institutions offer programmes that are relevant to the socio-economic development of Brunei.

2) Evaluating and maintaining appropriate standards through a regular system wide review of VTE and training programmes.

3) Promoting VTE programmes which provide people with the skills needed for creating their own enterprises in order to create jobs and future economic expansion.

4) Establishing apprenticeship-training schemes to meet the skills requirements of the economy, in cooperation and collaboration with the public and private sectors.

5) Advising and cooperating in the development of secondary school curricula and subjects leading to vocational careers and further VTE.

6) Providing students with the opportunity to explore career options to help them realize their capabilities and potential for success in the world of work.

7) Promoting greater access to learning and career opportunities by bridging the gap between academic and vocational and technical education.

8) Providing a secretariat to the BDTVEC and advising the Council on areas of work to be covered, including the establishment and interpretation of Council policy in the promotion and provision of VTE and training.

9) Conducting research and providing information on manpower training issues.

While continuing education has existed since 1958 and VTE has been formally operating in the country since 1970, the DTE itself has been operating as a separate department only since 1993. Recently the DTE conducted an internal review of its operations in order to identify areas that need strengthening so that it will be better equipped to carry out its mission.

The Brunei Darussalam Technical and Vocational Education Council (BDTVEC) was established in May 1991 and since then has gradually taken over the responsibility for awarding certificates and diplomas to students from overseas awarding bodies such as the Business and Technology Education Council (BTEC) of the United Kingdom. All programmes are now localized and under the award of the Council. This localization of programme awards was prompted by the need to be
more responsive to the demands of local industry as well as to public demand for quality and varied programmes in line with the diversifying economy.

The Council has developed a unified system of approving programme submissions, assessing standards in programme development and awarding certificates and diplomas. The establishment of the accreditation system ensures a high degree of credibility and recognition, by educational and professional bodies, employers and students both locally and internationally. The schemes promote student mobility and progression to higher-level qualifications.

The total number of students studying at VTE institutions (excluding the Continuing Education Section) in 1999 was 2342, of which 1065 (45%) were female. The number of students enrolled in technician level programmes was 1315, of whom 548 (42%) were female, and 630 students were in the craft-level courses, of which 224 (36%) were female. There were a greater proportion of female students in technician level programmes than in the craft level programmes, implying that many female students have acquired good academic qualifications which make them eligible to opt for higher-level courses. This also implies that equal opportunity in VTE is not an issue in Brunei Darussalam.

The bulk of technical education graduates at diploma level in Brunei are produced by MTSSR and MKJB while the ITB has been the sole producer of graduates at higher diploma level. About 1300 VTE graduates from all disciplines and programme levels were produced yearly, from a total country population of 350,000. In the next ten years, assuming the capacity of VTE institutions does not change, the total number of graduates will be 13,000. Comparing this figure with the projected manpower requirements in the year 2011 – about 93,300 for low growth and 148,300 for high growth (Economic Planning Unit, manpower projection 1991-2011) – VTE institutions will only be able to produce 14% of the projected manpower required for low growth or 8.7% for high growth. Therefore, the HRD capacity of VTE is expected to be increased to meet the manpower demands of the country (DTE, 2003).

Some of the future challenges facing the Department include:

- Accommodating the needs of the increasing number of secondary school leavers at Lower Secondary Assessment (Penilaian Menengah Bawah) and ‘N’ level.
• Responding to the rapid changes in technology for workforce training;
• Catering to the needs of the increasing number of women participating in national development.
• Enhancing VTE (including the image).
• Promoting cooperation and collaboration with the industry in workforce training.
• Creating jobs within the private sector to supplement the limited job availability in the government sector.
• Enhancing students’ achievement in science and mathematics for technical programmes.

(DTE, 2003)

In the light of these challenges the DTE is planning a number of strategies to maximise its contribution to the achievement of Human Resource Development goals by increasing its internal and external efficiency. Such strategies include:

• Improving quality control systems to ensure marketability and wider recognition of programme awards at local and international levels.
• Implementing staff development programmes for upgrading and localisation of instructional staff.
• Developing appropriate curricula and delivery systems to maximise access to education and training.
• Strengthening the Department’s capacity in publication, documentation and marketing to improve the image of VTE among the public.

(DTE, 2003)

Having described the physical context of the study, the next section describes the rationale for undertaking the study.

1.4 The Rationale for the Study

Technical education in Brunei has been providing skills and training for students for more than thirty years, but the nature of technical education is constantly changing. Work is changing in response to evolution in both employer and employee preferences, globalisation and new technology (Forman & Steen, 1999). Changes are occurring in the organization of work, the management of human resources, the relationship between technology and skill requirements, work arrangements and non-
standard arrangements (self-employment and part-time work). The preparation of workers for entry into and advancement in the workplace of the next decade requires an educational programme that provides higher order thinking, problem solving, and collaborative work skills. Not just job skills, as career and technical education did throughout the 1900s. With the advancement of technology and the dependence of jobs on information technology there is a greater need for educators to examine the kinds of mathematics that students need. An understanding of mathematics has become more crucial than ever before because science and mathematics is a fundamental pre-requisite for the nation to be equipped with a technologically oriented workforce.

The preparation of a workforce of scientifically and technologically competent technicians now rests in large part on the foundation of a deep understanding of mathematical concepts and skills. Although technical mathematics is an essential component of science, technology and engineering technology, there is a widening disparity between the mathematics used in industry and what is taught in schools. Content and curriculum issues such as the integration of mathematics content with science and technology content; relevance to business and industry needs; pedagogy and the use of technology should be addressed (AMATYC, 2002)

Vocational and technical education in Brunei is unpopular among secondary school graduates. This situation has led to some policy changes in recent years. The Department of Vocational and Technical Education, Brunei Darussalam introduced a five-year plan in 1997 to gain more acceptance and recognition among the public of these programmes. Within the five year plan stands a vision, and the vision for one particular Technical College that I am going to focus on in this study is to:

"Build Sultan Saiful Rijal Technical College into a dynamic centre of excellence – an exemplary model of business and industrial technology training". One of the goals to achieve this vision is to provide ‘An effective training system for students, responsive and relevant to the needs of economic development’ (MTSSR, 1999).

The vision and mission stated above shows that the College realised its important role in training and educating students effectively and in a manner relevant to the need of the country. Since mathematics is considered one of the core subjects in technical studies, students’ performance in the subject should be given a priority.
However, many of the students who come to the college have problems with mathematics. To them, mathematics is an intimidating subject. They tend to shy away from mathematics as it represents unfamiliar and difficult territory. This is due to their experience in secondary schools where teaching is so much directed to testing (students are required to take public “O-level” or “N-level” examination), which results in an emphasis on their ability to memorize number facts rather than to use reason for problem solving. The difficulties that the students face are caused through their:

- Weakness in basic mathematics
- Lack of interest in mathematics
- Inability to see the benefit of learning mathematics
- Bad habits that they have acquired earlier in learning mathematics – habits that are difficult to eradicate (e.g. misconceptions).

Currently, a growing number of students enrol for further studies after they have completed their National Diploma course. Some will proceed to complete a Higher National Diploma locally or overseas, while some will advance straight to first-year or second-year degree programmes (many students have been admitted to UK and Australian institutions in this manner). Since many of them do not take the unit “Additional Mathematics” during higher secondary level (where the syllabus is more challenging and tailored for students with higher mathematical ability), they are not prepared for the rigours of higher-level mathematics, especially the unit Engineering Mathematics at degree level. But this problem is common to technical graduates in other countries as well. A recent study carried out in the United Kingdom shows that those with BTEC qualification are often unsuccessful in completing a Quantitative Methods module in the study for their first degree (Chansarkar & Michaeloudis, 2001).

These issues, along with the challenges that are facing technical education justify the need to introduce changes in mathematics instructional practices and curricula in Brunei. As was stated earlier, one of the challenges is to enhance the achievement of the mathematics and science for technical programmes, with one of the strategies aimed at developing appropriate curricula and delivery systems to maximise access to education and training. The students also need to be motivated to achieve excellence. When developing the curricula, attention should be focussed on a
classroom environment that can motivate the students to perform better in mathematics.

The current mathematics curriculum for National Diploma Year 1 was introduced in November 1999 and was implemented in early 2000. It promotes and:

- Encourages the development of thinking skills through an intuitive rather than rigorous instructional approach.
- Emphasises the integration of mathematics with other subject disciplines and learner directed application of skills
- States that learning and assessment throughout will be work related.


It is debatable whether this planned curriculum is what is actually being implemented (Van den Akker, 1998). From my observation, many teachers are still practising traditional instructional methods and students are still learning by rote and memorising. Saxe, Gearhart and Nasir (2001, p. 56) quoting Ball and Cohen stated: “to guide students in conceptual thinking and the exploration of mathematical conjectures, teachers must transform the ways they use curriculum materials with their students”. Mathematics teaching and learning should be approached from several different viewpoints since students have different ways of understanding ideas and concepts. While some of the traditional methods are still applicable today, other approaches should be at hand. As will be explained later, the presence of a mismatch between relational understanding and instrumental understanding in teaching and learning should not be allowed to occur (Skemp, 1976).

1.5 Objectives of the Study

The aim of the study was to enhance the mathematical understanding of a sample of Brunei’s technical students by focussing on the classroom environment using a teaching and learning package based on the topic of trigonometry. It was also anticipated that the package could generally improve students’ attitude and motivation to learn mathematics. The package was designed to contain, among other materials, lesson plans that would incorporate the reform ideas (such as the ARCS motivational model) and proven instructional methods that are effective for use in lessons. The package would also emphasise the preferred classroom environment
factors that was identified to have the potential to enhance students overall performance.

The research paradigm consists of four phases, namely - the identification phase, the design and development phase, the implementation phase and the evaluation phase. The main objectives of the study are stated here according to the four phases the research study went through - namely to:

1. Investigate and identify factors in the classroom environment that will improve students' mathematical understanding and their attitude towards mathematics at the initial stage,

2. Design and develop a teaching and learning package in the topic of Trigonometry, based on the features identified in (1).

3. Implement the package,

4. Evaluate the package.

The steps or phases of study mentioned above resemble the structure of the “ADDIE” model, which is a model that describes a systematic approach to instructional development (Grafinger, 1988). This model does not seem to have a single author, but appears to have evolved informally through oral tradition. It is not a specific, fully elaborated model in its own right, but rather an umbrella term that refers to a family of models that share a common underlying structure. ADDIE is an acronym referring to the major processes that comprise the generic Instructional System Design (ISD) process: Analysis, Design, Development, Implementation, and Evaluation. When used in ISD models, these processes are considered not only to be sequential but also iterative, as depicted in the left model of Figure 1.2 (Grafinger, 1988). This figure also shows the updated model used in this study. The only difference between these two models is that I have termed the analysis phase as the identification phase because analysis was only part of the process for the purpose of identifying factors that will enhance teaching and learning. I had also grouped together the design and development phases because the package was developed immediately after a suitable design was selected. Because of the set time that I had to complete my research, the process was not carried out iteratively.
Figure 1.2: ISD models featuring the ADDIE processes on the left and the model used in this study on the right.

The features and set up of the package could have been used for any mathematics topic, but in this case it was designed for the topic of trigonometry. Trigonometry was chosen because there are many real-world problems and authentic applications in this topic that could be included in the package. Since the technical students are not very strong in many areas including trigonometry, my hope was that the students would be more motivated and interested in studying them through realising that the applications were directly related to their field of study. The relevance of what they are studying was clearly visible when they carried out a project on sinusoidal waves (refer Chapter 6). The Electrical Engineering students and the Radio, Television and Electronics engineering students who worked in this project were happy that they could relate what they studied in mathematics to what they studied in their own fields.

The Mathematics Department of the college was also in the process of documenting a package of applicable exercises that could be used by teachers and students from various levels in all topics that the students studied. This gave me the opportunity to add in problems that I considered were suitable and relevant.

The final reason for the choice of trigonometry was because it is a basic topic for other courses (especially calculus), which the students will be learning later. A
sound understanding of trigonometry and knowledge of its real-world applications would certainly be of benefit to the students.

1.6 Research Questions

In order to provide a focus for the aims of the study, four research questions that correspond to the four phases of the study mentioned in section 1.5 were formulated:

a) What factors are important for the enhancement of students' mathematical understanding, attitude and motivation?

b) How can the characteristics identified in (a) and from the literature review be used to design and develop an effective teaching and learning package that will enhance students' cognitive and affective traits?

c) How should the package be implemented?

d) How effective was the package?

1.6.1 Phase 1: Identification of Factors

Corresponding to research question (a), three secondary research questions that relate to identifying the factors affecting the teaching and learning of mathematics were:

i. What were the actual and preferred learning environment situations at the technical institutions?

ii. What were the students' attitudes towards mathematics and its association with the learning environment?

iii. What other factors would enhance students' mathematical understanding and attitude?

Factors and relationships were identified through quantitative and qualitative data. Survey questionnaires were administered to determine students' perception of the learning environment and the attitude towards mathematics. Qualitative data were also utilised to confirm, explain and add to the results.
1.6.2 Phase 2: Design and Development of the Teaching and Learning Package

I believe that learning should be made enjoyable and interesting if students are to excel. In order for this to be achieved, the teacher-centred style that is common at present in Brunei was replaced with a student-centred approach, and the traditional “drill and practice” method was replaced with a problem-solving and investigative approach. The package was developed by following the guidelines set by the programme guide 1999 created for “Mathematics for National Diploma 1”, combined with proven and unproven methods that were identified through literature review and surveys. The secondary research questions that relate to research question (b) that were considered during the design and development of the package were:

i. How can the factors that enhance mathematics teaching and learning identified from phase 1 and the literature review be used in developing and designing the package?

ii. What other tools (for example graphic calculators and computers) are appropriate for inclusion in the package?

iii. What innovative methods of assessment are appropriate for inclusion?

1.6.3 Phase 3: Implementation of the Teaching and Learning Package

Once the package was developed, it was implemented with the students to determine its effectiveness. Procedures were developed to measure the changes in the learning environment and the cognitive and affective outcomes. Attention focussed on how the package was to be implemented – how students and teachers reacted to the package; the problems they faced and whether the package was suitable. The package in this study was restricted to one group of students from two classes in order to avoid disturbing of the daily routine of other classes and their usual programmes. Since I was able to gain access to the results of the phase-test (a test conducted by the Mathematics Department of MTSSR as part of their assessment requirement) for all classes taking the parallel course, I took this opportunity to compare the results between students who were administered the package and those who were not. Details of these other groups of students (non-treatment group) are presented in Chapter 3, Section 3.3.2.
The secondary research questions corresponding to research question (c) earlier that emerged for this phase were:

i.  What were the students’ and teachers’ reactions to the package?

ii. What are the problems faced by students and teachers during implementation?

iii. Were the standard and quality criteria of the research ensured?

1.6.4 Phase 4: Evaluation of the Teaching and Learning Package

A careful analysis and evaluation of the package was made during and after the implementation. Improvements on the students’ grades and attitudes were documented (students’ learning outcome were evaluated through qualitative and quantitative analysis), and teachers/educators’ views were sought regarding the whole program. Listed below are the secondary research questions that emerged from the research question (d) earlier:

i.  Did the treatment group develop a better understanding of mathematics after the implementation of the package?

ii. Did the perception of the classroom environment and the attitude towards mathematics of the treatment group improve after the study?

iii. Is there a positive correlation between cognitive achievement of the treatment group and particular aspects of the classroom environment as well as attitude?

iv. What was the overall achievement compared to other groups that were not administered the package?

1.7 Expected Outcomes

The outcomes of the study are expected to include a determination of:

1. The impact of curriculum and instruction on Brunei students’ achievement, attitudes and behaviour,

2. Classroom environment, curriculum, teacher and student variables related to student achievement, attitudes and behaviour,

3. Changes desired to improve students’ achievement, attitudes and behaviour,

4. Changes in policy, resources and practices required to help effect change.
1.8 Significance of Study

Enhancing students' mathematical achievement is a major objective of mathematics educators worldwide. Many students are unable to make connections between what they learn in the classroom and how the knowledge can be used outside. This study was designed to enhance students' achievement and make both teachers and students aware of effective teaching and learning techniques. Since the package concentrates on applications in the real world, students were expected to be able to apply mathematics in their area of work, hopefully resulting in their becoming effective problem solvers. Software available on compact discs and resources available on the Internet were introduced to assist them in honing their mathematics skills and their visualisation of abstract materials. It was intended that, as a result, they would be able to learn to value mathematics, to learn to reason mathematically, to learn to communicate mathematically, to become confident of their mathematical abilities and to become efficient mathematics problem solvers who would be able to apply mathematics in their future field of work.

The teaching and learning package also has the potential to assist teachers to create effective learning conditions and to adjust instructional strategies to foster increased learning. It is realistic to have high expectations of academic achievement from nearly all students if the learning material can be structured to match their needs. Curriculum developers and education administrators should be able to use the outcomes of this study in their curriculum planning and in the proper allocation of resources. The Department of Technical Education should strive to improve the quality of teachers throughout teacher training, so that teaching and learning methodology and curricula are always up-to-date.

1.9 Summary

This study arose from the need to improve the effectiveness of the current mathematics programme for the Technical students in Brunei Darussalam. The broad aim was to investigate how to enhance the mathematical understanding of the students. Their weakness in mathematics creates the need to examine students' attitude towards mathematics and to consider what was required to motivate and enhance their interest in mathematics. I attempted to achieve these goals by improving the learning environment of the classroom.
The study consisted of four phases. The first phase investigated the actual and preferred learning environment of the students’ mathematics classroom, where the scales in the learning environment survey were determined as being suitable and most appropriate for the students. This was achieved by taking into consideration the nature of students, their learning styles, the nature of their future jobs, their culture and also where they would be after completing their studies (that is, in further studies or employment). In the second phase, a teaching and learning package was developed from the information collected and was implemented with the students in the third phase. In the final phase, an evaluation of the package was carried out.

This chapter first described the background of the problem that initiated this study and Brunei’s education system. It then described the rationale of the study, which justified the need to introduce changes in mathematics instructional practices in Brunei’s VTE, and the purpose of the study, which described both the principal aim and the secondary aims. The “significance of the study” stressed the need to use less traditional methods of teaching mathematics in Brunei and also described the implications of the outcomes for the technical education system in Brunei.

Chapter 2 reviews the literature relevant to the study. It discusses instructional strategies and effective teaching and learning approaches for technical students, and it also establishes where this study fits into the body of literature and where the study will break new ground. The overall methodology that was used in the study is explained in Chapter 3. Chapter 4 describes the result of the evaluation of Phase One of the study that investigated and identified the factors that enhanced technical students’ mathematical understanding. Chapter 5 deals with the process of designing and developing the package using the literature review and the outcomes described in Chapter 4; the implementation phase is described in Chapter 6, and Chapter 7 describes the evaluation of the package. The discussions and conclusions as well as limitations of the study and suggestions for future research in Chapter 8 complete the thesis.
Chapter 2

Literature Review

We must reject the conception of education professed by those who say that they can put into the mind knowledge that was not there before – rather as if they could put sight into blind eyes.

Plato

2.1 Overview of the Chapter

The purpose of this chapter is to review the literature relevant to the study. It provides the basis of support for justifying the choice of topic, research questions and the research methods used. The chapter also provides evidence to establish the significance of the study.

Section 2.2 reviews literature covering the problems that students throughout the world generally experience in mathematics. The discussion then focuses on the problems in mathematics faced by Brunei technical students particularly. The changing trends in technical education highlight the needs for these students to understand mathematics in this era of globalisation and technology in order to join the work force, or to engage in further studies. These changes have resulted in reforms to mathematics teaching that are being widely introduced in many countries.

Section 2.3 begins with a list of suggested strategies that might be adopted to overcome the problems and then proceeds with a review of recommendations from the literature on what can be done to enhance technical students’ achievements in, and understanding of mathematics in Section 2.3.1. Section 2.3.2 describes the theoretical framework of the study and the components of that framework, including aspects of motivation, classroom environment, achievement variables in understanding mathematics and also attitudes towards mathematics. Sub-sections 2.3.3 and 2.3.4 review the learning environment and attitudinal literature including the instruments that have been used to measure these two entities in Brunei
respectively. They also discuss the results and implications of other related studies that have been carried out. Section 2.3 concludes with a review of the literature on the impact of the learning environment on motivation, and thus its impact on attitudes and achievement in sub-sections 2.3.5 and 2.3.6 respectively.

The teaching and learning theory described in section 2.4 traces the history of reform efforts in mathematics up to the present time and includes a brief description of constructivism. Section 2.4.1 explains the kinds of approaches that should be incorporated into a teaching and learning package, designed and developed especially to suit the technical students’ needs. Section 2.4.2 highlights the main pedagogical aspects that were identified and adopted for a preferred classroom environment, and this section also explains how the study will contribute to the literature base on technical education and mathematics teaching. Section 2.4.3 examines the literature on the evaluation of teaching and learning packages and their efficacy, in terms of cognitive and affective classification. A brief review of other related studies, including exemplary mathematics programmes that have been conducted in the technical education sector are presented in Section 2.4.4, and the chapter concludes with a summary in Section 2.5.

2.2 The Problem

For many students, school mathematics simply doesn’t make sense. Often, teachers offer fragmented information that is of little use or application to the students and convey this inadequate information in a poor fashion. Topics or areas that do not make sense cause students to lose interest and develop what has been described as an aversion or phobia towards mathematics. This leads to poor performance, and often students will develop the habit of studying by memorising formulae and facts simply to pass examinations. Much of what I learnt at school, such as dividing fractions or using algorithm-like operations in algebra, seemed mysterious to me. It only made sense for me many years later as I continued to pursue mathematics in later studies.

The questions that concern me are:

- What is the best way to convey mathematical concepts to technical students in Brunei so that they can apply and retain information through deep understanding?
• How can mathematics instructors teach effectively and motivate students when faced with those who are academically weak and who question the meaning and the relevance of what they study?

The majority of students whom I knew and taught at the college were not able to make connections between what was learnt and how the knowledge was to be used. I believe that this was due to the way mathematics was taught. The traditional lecture method is still common in Brunei – an approach that is not sufficiently motivating to create interest or assist students to understand the concepts as they relate to work and everyday life. Now, the need for higher-level academic understanding is essential as the need for workers with strong academic backgrounds increases. Previously there has been a tendency to water-down the mathematics syllabus for technical students in order to make it less challenging. However, because of the changes that we are experiencing today, I believe that standards should not be compromised, nor the syllabus, since a strong academic foundation is becoming more and more vital for the students’ future success.

In Brunei, as in many countries, the second-class status of technical education makes young people hesitant to choose this form of study as their career preparation. To make technical and vocational education more attractive, the curriculum should be designed to make possible the articulation between technical and vocational education and higher education (Saluja, 1993).

2.2.1 Students’ Difficulties with Mathematics

Problems with mathematics learning are universal. Most students in developed and developing countries encounter difficulties in their mathematics education. Students can be very good at it and others simply shy away from it. Burns (1998) stated that more than two thirds of the American population fear and loathe mathematics, and evidence from a variety of sources makes it clear that many students are not learning the mathematics they need or are expected to learn (Beaton, Mullis, Martin, Gonzalez, Kelly & Smith., 1996; Kenney & Silver, 1997; Mullis, Martin, Beaton, Gonzales, Kelly & Smith, 1997). The reasons for this phenomenon are related to the way mathematics is taught. Historically mathematics has often been presented as a subject of “absolute truths” with an emphasis on the need to determine the one correct answer to every problem, in a curriculum of disconnected items, tasks, and subtasks taught independently of the contexts (Boaler, 1994).
intimidates students when they cannot obtain the correct answer, and this experience leads to what has been described as “mathematics phobia” – fear of mathematics (Lyman, 2003; Vazsonyi, 1999).

These problems exist in Brunei. The issues in mathematics education at the secondary school level in Brunei Darussalam include concerns about deteriorating student achievement in mathematics; students’ lack of motivation for learning mathematics; the centralised system of education, and the presence of numerous external examinations that encourage teacher-centred classroom practices and a preoccupation with preparing students for examinations (Majeed, Fraser & Aldridge, 2001). These students brought those conceptions and attitudes they possessed in secondary schools to wherever they next pursued their study. In my view, there is no reason why mathematics education in Brunei cannot be improved. It requires a concerted effort and determination from a number of key players at various levels of the education hierarchy in the country to bring about the desired change.

2.2.2 Technical Students’ Problems in Mathematics

Across the international spectrum, Technical Education (or Career and Technical Education, Vocational Education, Technical and Further Education as they are known in other countries), reflects a country’s economic and social investment in education and the strategies used to enhance the skill development of workers and foster their employability (Brown, 2003a). However technical education has an image problem since parents, students and employers still hold negative stereotype ideas about it (Brown, 2003a) and as a result, it does not attract high achievers. Various studies in other countries have demonstrated that technical/vocational studies are not able to attract academically competent students, especially in mathematics and science (Hull & Souders Jr., 1999).

The same scenario exists in Brunei: The unpopularity of technical education results in few good students (higher achievers) making applications and thus choosing the better students for college admission is difficult. Many students who enrol in technical studies do not have a firm background in mathematics because they come to their programmes with only passes in Mathematics Syllabus “D” and not the “Additional Mathematics” unit that has a more rigorous and extensive syllabus. Many students’ are required to sit for a selection test in mathematics because they cannot meet the requirement of at least a credit in mathematics or English –
especially if they are applying for Diploma level courses in engineering, computing and construction. Table 1 shows the number of students who have applied for courses at a particular technical college (MTSSR), the number who sat for the mathematics selection test because of lack of requirements, and the number admitted from 1998 – 2000. From the table, it is clear that about fifty percent of the number of students who applied for courses at the college were required to sit for a selection test. After the interview, an average of approximately twenty two percent of the students who applied were admitted. Unofficial research conducted by a colleague in his own spare time has revealed that only about ten percent of those who applied met the basic requirements in mathematics, and they made up approximately forty five percent of students admitted.

Table 2.1: The number of students who applied, required to sit for selection tests, interviewed and admitted to MTSSR. Source: Registrar, MTSSR Brunei.

<table>
<thead>
<tr>
<th>No. of students \ Year</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied</td>
<td>1600</td>
<td>1949</td>
<td>1403</td>
</tr>
<tr>
<td>Sit for Selection Test</td>
<td>864</td>
<td>948</td>
<td>793</td>
</tr>
<tr>
<td>Interviewed</td>
<td>843</td>
<td>771</td>
<td>610</td>
</tr>
<tr>
<td>Admitted</td>
<td>344</td>
<td>432</td>
<td>360</td>
</tr>
</tbody>
</table>

Mathematics has traditionally been taught in a manner that benefits abstract learners, however most technical students are not abstract learners since they are more inclined to appreciate concrete experiences. In fact Kolb (1984) and others, as quoted by Hull (1999) state that less than one fourth of students are abstract learners and that most students learn best when they can connect new concepts to the real world through their own experiences, or experiences that teachers can provide for them. If academic subjects such as mathematics were properly integrated with career-focused courses, a student might be able to see practical applications of mathematics contained within the academic courses (McCaslin & Parks, 2001). According to these researchers, a student’s cognitive growth in core academic subjects should be expected to increase when technical and academic courses were featured jointly. Hull (1999) believes that it is realistic to have high expectations of academic achievement from nearly all students if we restructure our learning materials and teaching to match their learning styles.
Two questions that I kept asking myself during my tenure at the technical college were:

1. Do the students have enough mathematics knowledge to be successful at their potential jobs or for further studies?
2. If they do not, what can be done to enhance their mathematical understanding?

International and Regional institutions responsible for technical and vocational studies such as UNESCO - UNEVOC and SEAMEO - VOCTECH (which are responsible for strengthening and upgrading of technical and vocational education and training for the world of work), concentrate more on technical subjects when drawing up policies and preparing curriculum guidelines. As in the case of academic subjects such as mathematics, instructors have to prepare and design their own strategies and pedagogical approaches.

2.2.3 Changing Trends in Technical Education

Vocational and technical education (VTE) specialises in imparting to young learners the skills needed in the world of industry and commerce (DTE, 2003). In this changing world, employers are no longer looking for workers who can perform only a prescribed set of tasks or operate equipment; they want workers who can continuously grasp new information and acquire new skills; workers who can improvise, solve open ended problems and work effectively in a team (Hull, 1999). The ability to use mathematics to solve problems is no longer a job requirement only for scientists and engineers; all careers with promising futures such as technology, emerging areas of biotechnology, electronic engineering technology, information technology, semiconductors and telecommunications now require mathematical skills.

Proponents of the theory of contextual learning (Beckmann, 2002; CORD, 2001) believe that students can gain deeper understanding of academic content like mathematics when they learn it in a context that is meaningful and motivating. I believe that technical education classes provide such a context. There is a considerable amount of mathematics embedded in technical courses, from surveying to marketing, from aircraft engineering to auto-technology and from information technology to electrical/electronics engineering. Helping students in technical education to learn and understand more mathematics by teaching them in context
will benefit the students, not only when they seek full time employment, but also when they decide to go on to further studies.

Technician programmes in Brunei are pursued by students who have completed upper secondary education to prepare them for work as technicians and for progression to higher-level technical studies. In Brunei, as in other countries, VTE begins as an alternative education for the less academically inclined students to undertake courses that place strong emphasis on the development of skills.

Historically, instructional practices in vocational and technical education promoted hands-on learning and knowledge transfer although this varies from one institution to another. However, this tradition has now been expanded through the introduction of constructivist theory, which verifies that people construct knowledge based on the shaping of internal mental models using previous experience, taking into account sociological/emotional issues, and building problem-solving skills (Brandt, 1996). Constructivist approaches to pedagogy are reflected in current school-to-work initiatives. These approaches require students to be active learners where they can draw upon perceptual, cognitive, and affective learning dimensions by testing academic theories via tangible real world application (Brown, 1998). It is my opinion that to enhance mathematics in technical programmes, real world contexts and applications that are especially targeted to the workplace should be introduced. According to Lynch (2000), reformers demand tough standards – a rigorous but relevant curriculum, better teaching, safe and disciplined schools and outcomes that will enhance student’s competitiveness in workplaces while simultaneously preparing them for college level academic work.

Lynch (2000) further listed the following as the essence of ‘the latest’ technical education trends: Programmes that are;

- academically rigorous
- career relevant
- a combination of academic and career applications
- teaching student about all aspects of the industry
- teaching how to apply high-level mathematics, science, technology and languages in workplaces and communities
- preparing students with the education and technical skills needed for successful employment.
There is a growing trend across countries to forge connections between academic and technical education (Brown, 2003b). Brown further quotes Keating et al. and Sellin in stating that core competencies, soft skills (self-awareness, analytical thinking, leadership, team-building, listening, problem-solving, listening, communicating effectively, flexibility, diplomacy and creativity) and foundation skills that contribute to lifelong learning are increasingly recognised as vital. Technical and vocational education is seen as a means of human resource development, leading to social and economic progress.

2.3 Enhancing Students’ Mathematical Understanding

Earlier sections of this chapter have illustrated some of the problems generally faced by students, particularly technical students, with regard to mathematics. It would be most desired for such students to be able to apply mathematical concepts and understanding to everyday situations, manipulate patterns, understand and demonstrate number sense, solve problems effectively and communicate mathematically. This would enable them to make intelligent use of information which is essential in order for them to become a contributing member of society, and which also gives them the flexibility to enjoy a broad range of life choices.

My approach to achieving the above aims was to address the following issue: Teachers should try to motivate students and promote a positive attitude towards mathematics. They should also have an intimate knowledge of the curriculum for which they are responsible; have high expectations of students’ performance; provide students with wide variety of tools for problem solving; plan, instruct and assess effectively by relating mathematics to everyday life, create classroom environments conducive to learning, and participate in professional growth opportunities.

The role of the administration is to support teachers and students by providing a safe environment conducive to effective learning, providing materials, tools and the technology needed for effective teaching, and allocating sufficient time for planning and collaboration.

2.3.1 Suggested Remedies to the Problem

I think most teachers believe that because of the demands of rigorous learning and tight schedules, paying attention to classroom environment factors – the
classroom community's well-being, relationships, and positive emotions – must be put aside. However, relationships and the classroom climate are the foundations of teaching and learning. Student perceptions of the classroom environment such as their feelings of acceptance, care, and participation, are directly related to their motivation to learn and to academic achievement. Stepanek (2000) asserted that the classroom environment is not just the physical space; it is the entire setting for learning. It not only covers the relationships between and among students and teachers, but the expectations and norms for learning and behaviour as well. Positive classroom environments are associated with a range of important outcomes for students such as higher level of motivation and achievement.

According to Jensen (1998), cognitive scientists have found that positive emotions and relationships enhance learning and memory, while negative emotions produce the opposite effect. Ignoring the social and emotional aspects of the classroom lowers students' attention levels and hinders their ability to make meaning of what they are learning. Students' beliefs about the learning environment usually determine whether the classroom climate has a positive effect (Waxman & Huang, 1996) and yet students' perceptions and reactions to the learning environment may not match teachers' perceptions. Waxman and Huang (1996) further stated that changing the classroom environment to improve students' perceptions improves achievement as well as outcomes such as interest and motivation. This means that students' positive perceptions of the classroom environment contribute to developing a favourable attitude toward mathematics (Reynolds & Walberg, 1992).

Convinced by these ideas, I believe that in order to increase students' understanding and achievements in mathematics, their motivation to learn mathematics should be enhanced, and this could be achieved through upgrading or providing them with the conducive classroom environments that they prefer. In order to achieve this, a teaching and learning package was designed and developed for the purpose of enhancing achievements by taking careful consideration of the classroom environment. The classroom environment variables were identified from an earlier survey and were incorporated into the package designed especially to enhance motivation. Other reform ideas and approaches from the literature review that are deemed to be suitable for the technical students, as well as proven older approaches in the teaching and learning process were also part of the package.
2.3.2 The Conceptual/Theoretical Framework

Factors influencing students' academic achievements include family background, quality instruction, peer influence, school climate, teacher quality, classroom climate and socio-economic factors. The 1997 study by the Latin American Laboratory for Evaluation and Quality in Education (UNESCO Santiago, 2001) listed parental education and classroom climate as having the main impact on student achievement. School climate and socio-economic factors were listed by Bulach, Malone and Castleman (1995) as the factors influencing students' achievement. Therefore, it seems clear that educators should pay attention to the classroom environment in order to enhance students' achievement since they cannot influence socio-economic factors and parental education.

The main learning elements in any classroom are the teacher and the students. Communication between them through the teaching and learning process determines the outcomes/goals and vice versa. So, student characteristics, teacher characteristics, the teaching and learning processes as well as outcomes (with some influence from the classroom context) are all aspects of the classroom environment that determines the outcomes in terms of attitude and understanding (refer Figure 2.1 following).

2.3.2.1 The Classroom Variables

There are two perspectives of the learning elements. The first is the situational perspective that focuses on the learning context and has direct implications for the structuring of the learning environment and student experiences. The second perspective is what can be called an interpersonal or dispositional perspective. This concerns the student's general orientation to learning and is connected with the identification of student priorities and student development (Ainley & Lindsey, 1995). Figure 2.1 shows the learning elements, which are of a situational nature that would directly influence the teaching and learning process in a classroom. This model, based on one by Watkins, Carnell, Lodge and Whalley (1996) listed the teacher characteristics as teaching characteristics. I decided to change teaching characteristics to teacher characteristics because in my opinion, it is among the most important elements that influence teaching and learning in a classroom. Instead of having teaching-learning process as in the original model, I consider it more appropriate to change it to teaching/learning characteristics.
Students' individual characteristics are influenced by previous experiences and beliefs and are partly shaped by aspects of family dynamics, cultural heritage and own learning style. Teachers and peers in a classroom also play a significant role in determining these characteristics. Teacher characteristics are partly influenced by their nature (where family and cultural background also plays a great part), their conception on learning, their training as a teacher, experience and how seriously they take their responsibilities as a teacher, all of which would account for how supportive the person will be as a teacher. The curriculum, assessment and course design will impact on the outcomes and teaching/learning characteristics.

*Figure 2.1:* The key variables in a classroom. Arrows denote influence on both ways, meaning outcomes affect teaching/learning process and vice versa (Watkins et al., 1996).

Recent school effectiveness research shows, according to Bosker and Witziers (1996), that school effects account for approximately eight to ten per cent of the variation in student achievement, and the effects are greater for mathematics than for languages. It also shows that classrooms as well as schools are important and that classroom variables such as teachers' influence account for more variance than school variables (Scheerens, 1993; Scheerens, Vermeulen, & Pelgrum, 1989).

Other research on learning has shown that different kinds of learning goals are best met by different approaches to instruction (Bransford, Brown, & Cocking, 1999). Well-delivered direct instruction like that described by the process-product researchers (where researchers attempt to determine what relationship exists between
teacher behaviours (process) and student achievement (product) is best suited to accomplish goals of knowledge, skill and routine applications. Learning goals that emphasise understanding, problem solving and construction of knowledge are more likely to be met in classrooms that differ significantly from the teacher-led classes of the process-product researchers (MSU, 1997).

Teaching/learning characteristics can be considered another important variable in Figure 2.1. Curricular goals and classroom environments have been described in detail in a series of Standards documents published by National Council of Teachers of Mathematics USA, most recently Principles and Standards for School Mathematics (NCTM, 2000). In effective standards-oriented classrooms, students engage regularly and actively in tasks or activities in which they are trying to make sense of important mathematics in problematic situations. It is of utmost importance that the tasks are designed not only to involve important mathematics, but also to be accessible to students (to connect with their present levels of understanding) and to be of interest to them in the process of enhancing the technical students' understanding. Appropriate mathematical tools are available to support learning. The teachers' role is mainly to facilitate students' conceptual understanding – that is, the degree to which students see how a current task's content is related to other things that they know. The social culture of the classroom values the ideas of students, respects the methods that they attempt to develop, uses mistakes as vehicles to study errors in reasoning, and recognises that the authority for correctness lies in the logic and structure of mathematics. Finally, these classrooms make the mathematics learning accessible to all students – that is, all students are afforded the opportunity to reflect on, and communicate about, mathematics (Hiebert et al., 1997)

2.3.2.2 The Learning Environment Scales

In this section, I identify the characteristics of five classroom variables that comprised the learning environment scales in the study. In the beginning, I planned to look at eight scales altogether, namely Student Cohesiveness, Teacher Support, Involvement, Innovation, Cooperation, Task Orientation, Individualisation and Relevance. After going through the process of factor analysis, I found that students' responses overlap in the case of Student Cohesiveness, Cooperation and also Involvement. I decided to choose Cooperation as one of the scales and discarded the other two because this coincided with the theme of teaching and learning that I
emphasised during implementation – that is, Cooperative Learning. Since Individualisation didn’t produce a satisfactory factor loading, I decided to discard this scale too because I believe that students in Brunei are not familiar with the situation described in the Individualisation scale such as “Students have a say in how class time is spent” and “Students are allowed to choose activities and how they work”. It’s appropriate to explain here why the other scales, which represented the characteristics of the learning variables mentioned above, were chosen. One scale of the learning environment instrument refers to what I consider as the most important characteristics of the teacher (teacher support), another refers to the characteristics of students (cooperation) and three refer to the teaching/learning characteristics (task orientation, innovation and relevance). In the following sub-sections, I will relate the importance of each chosen scale in detail.

Teacher Support

The teacher/instructor is the most important variable in Figure 2.1. It is the teacher who acts as the medium of knowledge in a classroom and it is the teacher who is responsible in selecting the right approach to facilitate the acquisition of knowledge. The Southern Regional Education Board of USA (SREB, 2000), in their publication site mentioned that an effective teacher for technical education should remind other technical educators to continually upgrade their:

Knowledge of students: Accomplished technical educators dedicate themselves to advance the learning and well being of all students. They plan instruction and assessment to suit a diverse student population by challenging students with high expectations; they design meaningful instructional tasks and use a systematic assessment process for better student understanding. These dedicated educators are constantly alert and aware to the changing nature of the labour market and workplace. Their classroom instructions are not only centred on academic preparation but also on future vocations, workplace values and life skills. They re-configure the curriculum to align it with student needs and the changing demands of the labour market.

Knowledge of subject matter: Teachers should not only be knowledgeable about the subject matter in their field, but they should also keep abreast of its new developments and current technology. They should know what students’ need to
know and be able to do in order to demonstrate competence in the field. Outstanding technical educators are supposed to be able to infuse the core disciplines in the school curriculum – English/language arts, history and social studies, and especially mathematics and science (academic skills) – into technical education. They know that these academic skills underlie all workplace environments, and they should work with students to ensure that they will enter the workplace with these skills soundly in place. These teachers know the mathematics and science concepts fundamental to most industries – particularly those that are connected to their field. They are also knowledgeable about technology, particularly the types that are common to most workplaces. They understand that many job processes are dependent on the ability to acquire and use information well, and they are adept at gathering, storing and retrieving data needed in many work settings.

Knowledge of basic skills: Technical educators also need to be knowledgeable about the many general skills and attitudes (workplace basic skills) that students need to develop in order to succeed in employment. This knowledge includes six key areas: Interpersonal skills (such as negotiation, working on teams and leadership); creative thinking and problem solving; technology use; information acquisition and use; systems operation; and health and safety issues, which I referred to as soft skills earlier.

Learning environment: Accomplished technical educators create learning environments in which students develop knowledge, skills and confidence through real-world learning activities, independent and collaborative laboratory work, and simulated workplace experiences. They should be able to manage their classrooms efficiently, by modelling and communicating clear expectations of classroom policy, by promoting the open sharing of ideas, and by encouraging students to take the initiative for their own learning. These teachers deal with disruption expeditiously and fairly and in ways that do not create a focus on disruptive behaviour. They foster teamwork in the classroom, blending attention to individual student needs with the goals of the entire class.

Encouragement of the love of learning: Outstanding career/technical teachers are enthusiastic about their field and driven by a love of learning. They continually push themselves and their students to do their best. This work ethic, which extends from their desire to continually improve their task, results in their modelling to their students a love of learning. They also cultivate students’ enthusiasm for learning by
creating flexible assignments that encourage creativity and problem solving. These teachers foster student excellence by validating independent thinking, encouraging inquisitiveness and celebrating student competence.

*Assessment:* Accomplished career/technical educators use a variety of assessment methods for a variety of reasons: They use this information to provide themselves with a perspective on student learning, to assist students in reflecting on their own progress, and to refine their teaching. They are knowledgeable about a broad array of assessment methods and issues, and they select approaches that match their instructional goals. Furthermore, they know that the skills and understandings they gauge can seldom be captured with a single assessment, and that tracking student progress requires frequent sampling of student work and thinking.

Obviously no teacher can meet all of these standards completely upon first entering the classroom. These qualities are honed and developed over time and with experience. I identified “Teacher Support” as an important characteristic of the learning environment as any teacher with the above qualities would be effective in supporting their students.

**Cooperation**

The second variable in Figure 2.1 is the student, and the characteristic that will be emphasized here is “cooperation” because technical students should demonstrate that they are: Active, strategic and also cooperative and goal setting. Processing between learners leads to higher order skills (Wertsch, 1979), so that cooperative cultures and group investigation methods give better academic results (Slavin, 1995), as well as improved communication skills and positive multi ethnic relations (Shachar & Sharan, 1994). These effects are mediated through the quality of group interaction, and highlight the need to promote students’ interpersonal and management skills.

Cooperation was chosen as one of the important scales in the classroom environment because it prepares students for workplaces that have become less hierarchical, more cooperative and team oriented; therefore, employers value workers who are flexible enough in skills and temperament to deal with uncertainty and change and understand the need for continuous improvement (SREB, 2000).
The last three scales mentioned below (Task Orientation, Innovation and Relevance) are part of the teaching-learning characteristics shown in Figure 2.1.

**Task Orientation**

Outstanding task orientation continually pushes students to do their best. Encouraging creativity and problem solving could also cultivate students’ enthusiasm for learning. Validating independent thinking, encouraging inquisitiveness and celebrating student competence also foster excellence in students. Tasks should be designed requiring collaboration where learners allocate roles and plan a group process so that students would then reflect together on the process in a suitably structured way by examining the tasks in the group. Teachers should think of more ways and means to motivate students to be more task-oriented, and to complete given work on time because students who are task-oriented were more likely to value and use deep-processing strategies such as integrating new information with what they already know (Nolen, 1988). Using particular learning tasks, attention is focused on a learning process. That makes task orientation, among other characteristics, very important in a classroom environment.

**Innovation**

In career/technical education, tasks should engage students in wrestling with and gaining command of important ideas, concepts, theories, facts and skills. Teachers should create a marriage of both “hand and mind” learning. Their classrooms are supposed to mirror activities, projects, problems and jobs in the world beyond the classroom. A variety of materials and resources should be utilised as this creates an environment that often extends the classroom into the community, or brings the outside world inside. Teaching approaches should be innovative so those students won’t be bored. A variety of activities should be able to cater to various learning styles that students possess. Students, according to Honey and Mumford (1992), possess four kinds of learning styles, namely activist, reflector, theorist and pragmatist. Watkins et al. (1996) described the characteristics of each learning style:

- **Activists** – involve themselves fully in new experience
  - Enjoy the here and now, are open minded and not sceptical
  - Tackle problems by brainstorming
- Constantly involve themselves with others.

Reflectors – like to stand back and ponder experiences
- Observe from many different perspectives
- Value the collection and analysis of data
- Listen to others before making their own points
- Act as part of a wide picture, which includes others’ observation as well as their own.

Theorists – integrate observations into sound theories
- Think problems through in a step-by-step way
- Assimilate disparate facts into coherent theories
- Like to analyse and synthesise
- Are keen on basic assumptions, principles, theories, models and system thinking

Pragmatist – like to try out ideas to see if it works in practice
- Positively search out new ideas and theories
- Take the first chance to experiment and apply
- Like to get on with things and are impatient with ruminating discussion.

Students with different learning styles favour different teaching approaches such as fieldwork, lectures, observation and hands on learning. Innovative teaching methods are required to satisfy the four learning styles of the students and these innovations in teaching and learning should also include technologies. Knowing about the learning styles and the learning characteristics of each style helps me to include (whenever possible) some of these characteristics in designing the package. Students should stay abreast of current technologies and when it is not possible to provide the latest equipment in school, alternate ways should be sought for students to learn and understand modern technology first hand.

Relevance

Whether the focus is on academic or career/technical knowledge, it is best presented in a classroom that features experiential, real-world learning. Teaching and learning should create an environment that often extends the classroom into the community or brings the outside world in. Especially for the technical students,
where emphasis on skills is of utmost importance, lessons without relevance would not be beneficial to the students whether the students plan for immediate employment or for further studies.

Dede (1993) described learning processes to prepare students for the workplace and in society as changing from “the more traditional classroom-based, discipline-focused, learning-by listening approaches” to “just-in-time, life- and work-focused, and learning-while-doing approaches” linked to everyday situations (p. 3).

The hyphen in the phrase “teaching-learning” represents the links between conceptions of learning and conceptions of teaching: Teaching activities are constructed from a range of elements, with the educational goals being the central and cohering element (Watkins et al., 1996). In effective learning, the tasks and processes need to promote active learning, collaborative learning, learner responsibility and learning about learning so that goals such as knowledge and skills, positive emotions, learning strategies, and enhanced self are met. Hughes (1993) reported that classrooms in which students negotiate an individual action plan using a study guide show gains over high quality teacher-planned learning in terms of, for example examination scores, retention of knowledge, and student reports of enjoyment, increased motivation and additional effort.

Studies of teachers’ and pupils’ perceptions of effective classroom learning show that they prioritise among others active approaches and group/pair work (Cooper & McIntyre, 1993). A context which emphasises learning about learning leads to an increase in deep approaches and long-term improvements in academic performance (Biggs, 1988). Promoting learning about learning demands that students can discuss the tasks and processes they are involved in, and their own state in regard to learning.

All of the classroom environment scales mentioned above – namely teacher support, cooperation, task orientation, innovation and relevance – play a very crucial part in building and enhancing students’ motivation. The aspects of motivation that will be emphasised in this study were in the ARCS model of motivational design (Keller, 1983a; 1983b) (refer Figure 2.2).

2.3.2.3 The ARCS Model of Motivational Design

One of the purposes of the planned re-writing of the mathematics unit in the present study was to make it more interesting and relevant to the students. The ARCS
Model of Motivational Design was chosen when designing the package because students’ lack of confidence in mathematics has been identified as the most significant barrier to successful mathematics programs (Marshall, McLoughlin, & Hayward, 2000). The ARCS Model of Motivational Design, as developed by Keller (1983a; 1983b) incorporates the major conditions of Attention, Relevance, Confidence and Satisfaction in order to have a motivated student. It was assumed that the dimensions of the model could be used to uncover attitudes, feelings and conceptions towards mathematics. This is dealt with in more detail in Section 2.3.5, where the relationship between learning environment and motivation will be highlighted.

Main (1993, p. 37) states "we need to spend as much effort in motivating the student to learn as we do with the cognitive and psychomotor needs. Perhaps we should spend more time and attention, since it has such a powerful impact on achievement". The ARCS model was used to guide me in designing and developing the package in terms of motivational techniques such as determining teacher behaviour as mentioned in Section 2.3.5. The detail of how it was done will be in Chapter 5. The initial step in motivating students is to gain and maintain their Attention. Keller (1983b, p. 1-2) says of this condition:

"At one level, it is fairly easy to accomplish. A dramatic statement, a sharp noise, a pregnant pause, all of these and many other devices are used to get attention. However, getting attention is not enough. The real challenge is to sustain it, to produce a satisfactory level of attention throughout the course and basically, the best way to fight boredom and indifference is to stimulate their curiosities so the instructor can spend more time directing attention than in getting it."

The second condition of the model is that of Relevance. A student will not be motivated to learn if he or she cannot see any point in what they are studying. To rectify this, the content can be made relevant to students. The relevance may come from the methods of instruction, the challenges presented or the social benefits of the learning process rather than the content itself.

Confidence, an expectation of success, is the third condition. Students need to believe that if they try hard enough, they have a good likelihood of achieving their goals. They need a learning situation where they do not have to fear loss of face or embarrassment as they try to develop their skills. At the same time, a degree of risk,
or challenge, is necessary to stimulate peak performance once the student has begun to master the new skill (Keller & Kopp, 1987). The final condition, that of *Satisfaction*, refers to "the combination of extrinsic rewards and intrinsic motivation, and whether these are compatible with the student’s anticipations" (Keller, 1983a). Active, collaborative, task oriented, innovative and wide varieties, relevance, real world authentic approach are part of the strategies that could motivate a student.

Further details about these conditions will be provided in Section 2.3.5 as mentioned earlier, as well as in Chapter 5 where the package design and development that includes the aspects of ARCS motivation model is described.

2.3.2.4 *Summarising the Framework*

*Figure 2.2: Model showing the theoretical framework.*
Figure 2.2 summarises the whole theoretical framework that was mentioned earlier. All scales (components) of the classroom environment are stressed in implementing each of the motivational components during classroom lessons in order that students acquire enhanced cognitive and affective achievement.

2.3.3 The Learning Environment

The educational environment can be considered as the socio-psychological context or determinant of learning, and the source of favourable and conducive surroundings can maximise learning outcomes (Fraser & Walberg, 1991). Classroom environment assessment may provide a means of monitoring and evaluating the teaching of any subject including mathematics. The term “Learning Environment” also refers to the pedagogical contexts in which learning occurs and which affect students' achievement and attitudes. The importance of the study of classroom-learning environment has been recognised increasingly over the last thirty years. Considerable progress has been made in the conceptualisation, assessment, and investigation of the important but subtle concept of the learning environment (Aldridge, Fraser, & Huang, 1999; Fraser, 1994; 1998; Fraser & Walberg, 1991; Wubbels & Levy, 1993). The development and implementation of useful and valid instruments for assessing classroom environment, together with the use of narratives, have provided an excellent framework within which learning environments have been explored. Besides using informative survey questionnaires, the qualitative method in learning environment research is also useful in helping to explain some of the quantitative findings. The use of qualitative methods in learning environment research has provided greater depth and breadth to our understanding, particularly when qualitative and quantitative methods are combined (Nair & Fisher, 2001).

The pioneering work in learning environment was carried out by Walberg and Moos. Walberg developed the learning environment inventory (LEI) in 1979, while Moos developed the classroom environment scale, (CES) also in 1979. Since then, many other instruments to measure the learning environment have been developed. Although the majority of classroom environment studies involved western students, a significant number of non-western countries had also carried out these studies. Several have been conducted in Taiwan, Hong Kong, Indonesia, Singapore and Brunei. The association between the learning environment variables and student outcomes has provided a particular focus for learning environment research (Fraser,
1998). This field of research also provides awareness of factors that influence classroom environments. By using the discrepancies between students’ perceptions of their actual environment and their preferred environment, teachers can be provided with a basis for growth and change (Yarrow, Millwater, & Fraser, 1997).

I will recount the learning environments studies that had been conducted to demonstrate how this study complements the many studies that had been done and also the difference between this study and the others. Studies in learning environment in Brunei have been carried out mainly in science education (Alvarez, 1988, 1989; Asghar, 1994; Khine, Larwood, & Fisher, 2000; Poh, 1996; Riah, 1998; Scott & Fisher, 2000). The Brunei studies also investigated the learning environment in lower secondary school mathematics classes (Majeed, 2000). These studies validated the English version of the Individualised Classroom Environment Questionnaire (ICEQ), the What Is Happening In This Class (WHIC), the Science Laboratory Environment Inventory (SLEI), Questionnaire on Teacher Interaction (QTI) and the My Class Inventory (MCI). All have reported strong associations between learning environment and student outcomes.

Alvarez (1989) investigated involvement in science activities, classroom atmosphere and practices, and attitudes towards science and cognitive achievement test scores in Math, English, Malay and General paper. Three attitudinal measures were constructed using an 8-item classroom atmosphere and practice, 10 items on involvement in science activities and 10 items on attitude also in science activities. Results showed that relationships between the 3 independent variables and the dependent measures in the four subject areas personal attribute variables (school district, school type, age, personal aspiration) correlated positively with cognitive achievements in all four subjects except Malay. However, there was no correlation found between involvement in science activities, and students’ perceived classroom atmosphere and practices with cognitive achievement in any of the four subject areas.

The results also indicated that students’ involvement in science activities, the extent to which they perceive their classroom to be interesting and enjoyable, and their attitudes towards science as a subject in their curriculum to be interrelated. It indicated indirectly that involvement in science activities (such as science hobbies and reading books about science and scientists) partly influenced students’ interest and positive attitude towards science. I used this information to encourage
mathematics activities and reading books about mathematics and mathematicians to my students during the implementation period of the current study.

Alvarez (1988) also examined the self-perceived difficulties of teaching skills, needs assessment of teaching skills, science teaching resources and attitude towards teaching science of primary and secondary science teachers in another study. It suggested that more research into the science classroom behaviours of both students and teachers in Brunei is needed. It concluded that the analysis of a teacher’s actual behaviour in the science classroom is critical to determine if the behaviours are those intended by the science curriculum or simply the teacher’s ideal or perceived classroom behaviour, which should also be demonstrated in mathematics classrooms at the technical level.

The O-level biology lab teaching was evaluated with regards to process skills and learning environment by Poh (1995). The study found that lab activities given to students in this context gave little opportunity for practice in higher order process skills and they were often close-ended. This finding triggered me to reflect on whether mathematics problems and activities solved and performed by technical students were open-ended and induced higher order thinking skills. Otherwise action should be taken for a gradual change to occur. Poh also found that female students perceived their learning environment more favourably than male students suggesting that different treatment, attention or guidance by teachers was necessary. The study suggested that classroom practice should be more participative, more investigative and less differentiated.

Riah (1998) investigated secondary chemistry classes through the use of the WIHIC and QTI and an adapted version of the SLEI. Students perceive their learning environment favourably, and the perceptions of the learning environment were associated with students’ cognitive learning outcome. The study suggested that teachers should be cautious when introducing innovative teaching approaches, such as giving students autonomy and independence, allowing students' to do their own investigation, working cooperatively in theory classes, and giving open-ended practicals in the laboratory. This is a very valuable suggestion that I was constantly reminded of when carrying out my study.

Scott and Fisher (2000) used a translated QTI to investigate students’ perceptions of their teachers’ interpersonal behaviours and their enjoyment of science lessons in primary school. Students perceived their teachers as good leaders,
seldom uncertain or dissatisfied or seldom admonishing. They also found that students’ enjoyment of lessons was correlated with each QTI scale. Teacher’s friendly/helpful behaviour impacted students’ enjoyment. Students’ perception of more cooperative behaviour was positively correlated, while perception of submissive behaviour was negatively correlated with their cognitive achievement, which further emphasises the importance of a teachers’ role in supporting students in my study.

Khine, Larwood and Fisher (2000), in their attempt to validate the QTI suggested that when a learning environment tool is used, there was a need to ensure that many of the language difficulties were overcome.

I have located two published studies in Brunei that specifically targeted mathematics education – by Majeed et al. (2001) and Siva Das and Alias (2004). The study by Majeed et al. surveyed lower secondary mathematics learning environments using the MCI. The study showed significant associations between satisfaction and all 3 MCI scales. There were positive associations between Satisfaction and Cohesiveness but negative association between Satisfaction and Difficulty as well as Competition. Overall results suggest that boys perceived the mathematics classroom environment more favourably than girls – a finding that contradicts Poh’s findings earlier. I believe that both males and females deserve the same treatment, attention and guidance.

A study with larger sample size is needed to provide a broader picture of the overall situation in the learning environment. The MCI, SLEI, QTI and WIHIC are known to give reliable, valid and important information about classroom climate and the present study should contribute to this need to some degree.

Khine (2001) examined the science classroom environment using the QTI, WIHIC and TOSRA. He concluded that students, due to cultural reasons, might not respond genuinely or openly. The QTI shows that students enjoy science lessons more when teachers display greater leadership, understanding, helpfulness and friendliness. There was significant association between all WIHIC scales and students’ attitude to science inquiry. The study demonstrated that students’ attitude is greatly influenced by the learning environment. However, he concluded that students, due to cultural reason, might not respond genuinely or openly.

Almost all of the studies conducted in Brunei have investigated the association between students’ achievement with their learning environment. My
study would be among the first learning environment studies based on technical education students, and it will be the first study in Brunei to use the outcomes from learning environment studies to improve the teaching and learning approaches and conditions that have been identified. Despite extensive research into the relationship between educational environment and student learning outcomes, relatively little has been done to assist teachers improve the environment of their own classrooms (Yarrow et al., 1997). There have been a few studies in Australia at the primary (Fisher, Fraser, & Bassett, 1995), secondary (Thorpe, Burden, & Fraser, 1994) and University (Yarrow & Millwater, 1995) level that successfully applied methods involving:

- Using the assessment of students' perception of their actual and preferred environment to identify the actual LE and that which the students preferred, and then
- Designing and implementing strategies aimed at reducing the discrepancies between the actual and preferred environments

(Yarrow et al., 1997)

I used a similar method in my study with the technical students in Brunei.

2.3.4 Students' Attitude towards Mathematics

I used the attitude towards mathematics survey as one of the measures of enhanced affective achievement. Whether these are positive attitudes, or whether students acquire desirable values (for instance, planning to take as much mathematics for further studies, enthusiastic about learning mathematics in class), depends on the nature and quality of the students' experiences in mathematical contexts, and especially in mathematics classrooms. Reactions to such experiences are often at the level of emotions, but if the same kind of experiences occur often enough then the emotional reactions often develop into what might be termed "attitudes".

Students' attitude towards mathematics depends considerably on the nature and quality of their experiences in mathematical contexts, and especially in mathematics classrooms. Therefore the proposed changes in the classroom environment incorporated in the package written for each lesson could be measured through a student's pre and post attitude, before and after the implementation of the package. Teachers of mathematics need to take their role as agents for fostering
healthy attitudes towards mathematics and a positive appreciation of the subject seriously. However, the importance of fostering positive attitudes towards, and appropriate appreciation of, mathematics is often neglected in the concern to cover mathematical content. Teachers of mathematics therefore need to be aware of their own attitudes and beliefs about mathematics, and about how these are likely to influence the attitudes and appreciations of mathematics shown by the students in their classrooms.


Cooper (1988) provides evidence that aspects of the classroom learning environment, or climate, are positively related to mathematics attitudes. In an environment where intellectual demands, difficulty, and amount of friction or conflict is lower, students show a more positive attitude (Armstrong, 1985). A number of studies have indicated that the personality and behaviour of the teacher are very important in the formation of students' attitudes, with one notable exception by Fennema (1986). Moore (1993) found in a national sample of high school students that impressions of the teachers as "likeable" or "smart" significantly predicated students' attitudes. It is important for teachers to be enthusiastic and use more indirect teaching behaviours (Anderson, 1991). Reed (1968) found that ninth grade pupils' interest in mathematics was increased when taught by teachers who were warm and who utilised the students' intrinsic motivation. Fennema and Sherman (1995) found that students of teachers who were well-organised, achievement-oriented, and enthusiastic tended to possess more positive mathematics attitudes.

Lastly, although Thomas (1988) reported some studies which showed that curriculum and instructional variables are related to attitudes towards mathematics, a substantial amount of research suggested that these variables made little or no difference (Armstrong, 1985; Fennema & Sherman, 1987; Hyde, 1996). The relationship between enjoying mathematics and perceptions of its usefulness was assessed to confirm earlier research by Aiken (1971), which suggests that a differentiation between enjoyment and usefulness is appropriate in measuring attitudes towards mathematics. In my research I attempted to measure enjoyment
under the category of Enjoyment & Interest, and usefulness under the category of Importance.

Milne (1992), in a study of the attitude of bridging mathematics students to mathematics, defined mathematics attitude in terms of confidence, motivation, perceived usefulness of mathematics, mathematics anxiety, attitude towards success in mathematics, and causal attributes (ability level, effort, quality of teaching, application). Milne’s research, conducted with a group of mature-age students returning to study in Victoria, showed that motivation, attitude to success, and perceived usefulness of mathematics were high for students throughout their course of study. It was found that female students possessed lower confidence levels, higher anxiety, and stronger attitudes towards success than males. Students who dropped out of the course possessed less confidence, less motivation, and did not see mathematics as useful.

Attitudinal surveys may also focus on students’ needs in taking a course, how well those needs are met, student interest in or appreciation for the subject matter or field or student confidence in their ability to perform in a course (Lewis & Seymour, 1995). This motivated me to conduct attitudinal surveys in my study because at the same time, such surveys can also provide information on students’ beliefs about the nature of the discipline itself, for example:

- The nature of a discipline (chemistry, physics, mathematics, engineering)
- The nature of learning within a discipline
- Students’ ability to learn within a course
- Useful strategies for learning within a course or discipline
- Students learning style or preferences for learning

(Lewis & Seymour, 1995, p. 2)

In Brunei Darussalam, outcome-environment associations have been established for scales of the MCI with a sample of 1565 Form 2 mathematics students (Majeed et al., 2001); for science attitude and scales of both the WIHIC and QTI with a sample of 1188 Form 5 students (Khine, 2001; Khine & Fisher, 2001, 2002); achievement and attitude scales of the WIHIC, QTI, SLEI with a sample of 644 chemistry students (Riah & Fraser, 1998); and for enjoyment of science lessons with scales of a primary school version of the QTI that had been translated into Malay and administered to 3104 students in private schools (Scott & Fisher, 2001).
The present study involving technical students will be the first to examine their attitudes and associations with the learning environment before and after the implementation of an intervention aiming to address students' preferred environments.

Since attitude and performance in a subject reinforce each other, knowing how the student feels about mathematics can influence teacher behaviours during prescriptive teaching. In order to change students' attitudes positively, it is very important that instructors/teachers address the components of motivation that are suggested by the model presented earlier. Because of what has been said about attitude, measuring attitude became one of the main evaluation components in my study.

2.3.5 Motivation and the Learning Environment

Motivation has been identified to be related to later mathematics achievement and attitude (Reynolds & Walberg, 1992). Schiefele and Csikszentmihalyi (1995) claimed that there is currently a trend of decreasing achievement in mathematics due to a decline in student interest and motivation in mathematics while Gottfried (1985) claimed a general decline in students' achievement motivation in middle school, with the greatest declines in intrinsic motivation occurring in science. Eccles, Wigfield, Midgley, Reuman, Mac Iver and Feldlaufer., (1993) suggested that the characteristics of the learning environment may account for this decline, including the deterioration of relationships between teachers and students and a decrease in students' sense of choice and control. This makes me more determined to address the characteristics of the learning environment in order to enhance students' motivation.

Nolen (2003) reported that classroom climate could have a significant impact on student learning and satisfaction in science. She further said that it is likely that instructional activities, assessment and evaluation techniques and teacher-student interaction styles play a role in communicating goals to students. The package that I used with the students addressed this by improving the instructional activities and assessment in terms of trends that are more current. Using the individual as the unit of analysis, Nolen and Haladyna (1990) found a relationship between students' perceptions of their science teachers' goals and their motivation and satisfaction with learning.
Nicholls and colleagues (Nicholls, 1989; Nicholls, Cheung, Lauer, & Patashnick, 1989; Nicholls, Cobb, Wood, Yackel, & Patashnick, 1990; Thorkildsen & Nicholls, 1991) described two dimensions of achievement motivation with theoretical relationships to classroom environments. Students who are task oriented hold learning and mastery to be important goals and are likely to use and value learning strategies requiring deep processing of information. Students high in task orientation tended to report more satisfaction with learning and believe that hard work, cooperation, and trying to understand lead to success in school. Social comparison or competition in the classroom decreases intrinsic motivation or task involvement (Ames, 1992; Deci & Ryan, 1985; Nicholls, 1989). Nolen (2003) found that failing to encourage task orientation through a focus on memorisation of seemingly unrelated facts rather than on student exploration of scientific questions might mislead students to think of science as dry, uninteresting and irrelevant to larger social concerns. My package attempted to address this fault.

When a classroom is conducted in a manner that makes use of students' natural motivation, emphasis is on learning and being part of the environment, not on rewards and other external reinforcers that take away from the essentials of school. Much research has been carried out to determine which factors encourage intrinsic motivation in a classroom (Bomia, Belozo, Demeester, Elander, Johnson & Sheldon 1997; Meece & McColskey, 2001; Middleton & Spanias, 1999; Valas & Slovik, 1993). It appears that, since the main players in a classroom are the teachers and students, then teacher characteristics and behaviour play a significant role in ensuring that intrinsic motivation occurs.

The personality and teaching style of a teacher can have a powerful effect on a student. In the case of teachers' support, students' intrinsic motivation is often related to the teacher's support orientation. A study by Valas and Slovik (1993) on seventh and eighth grade mathematics students found that students who believed that their teachers allowed more student autonomy tended to have higher intrinsic motivation in mathematics than students who believed their teachers were more controlling. The students with higher motivation also perceived themselves as more competent in mathematics and gain higher achievement scores. In order to create a learning environment in which students' needs are addressed, teachers must really understand their students' interests, beliefs, and concerns – meaning motivations. Middleton (1995) found that teachers often struggle with predicting their students'
motivational constructs. Instead of asking "How motivated are my students?", it is better to start asking "How are my students motivated?" One way to encourage students to be motivated is by keeping in mind the ARCS model by John Keller (1987) as mentioned earlier in Section 2.3.2.3. I used the ARCS model in my study to guide me in the design and development of the package (refer Chapter 5) so as to motivate the students in learning mathematics. ARCS stand for Attention, Relevance, Confidence, and Satisfaction. These terms suggest the following teacher behaviours:

- **Attention.** Perceptual arousal can be increased with the use of innovative, surprising, bizarre and uncertain events. Increase inquiry arousal by stimulating information seeking behaviour; pose or have the student generate questions or a problem to solve. Maintain interest by varying the elements of instruction.

- **Relevance.** Relevance within the instruction should be emphasized to increase motivation. Use concrete language and examples with which students are familiar. Provide examples and concepts that are related to students' previous experiences and values. Present goal oriented statements and objectives. Explain the utility of instruction for both present and future uses.

- **Confidence.** Confidence should be allowed to be developed in a student by making it possible for them to succeed. However, a degree of challenge that allows for meaningful success under both learning and performance conditions need to be present. Show the student that his or her expended effort directly influences the consequences. Generate positive expectations. Provide feedback and support internal attributions for success. Help students estimate the probability of success by presenting performance requirements and evaluation criteria.

- **Satisfaction.** Opportunities should be provided to use newly acquired knowledge or skill in a real or simulated setting. Provide feedback and reinforcements that will sustain the desired behaviour. Maintain consistent standards and consequences for task accomplishments. Manage reinforcement: Keep outcomes of student's efforts consistent with expectations.
When the motivation components such as the above are included in a classroom, students should be naturally involved and driven to learn because their intrinsic motivation is heightened. Each classroom variable mentioned in Figure 2.1 of 2.3.2.1 will certainly play a large role in ensuring students' intrinsic motivation.

Establishing a caring, cooperative learning environment is essential to fostering intrinsic motivation. This is where students' characteristics play their role. When students feel safe, the need for extrinsic rewards is eliminated. By being encouraged to take risks, be independent thinkers, and be responsible, a classroom community can be developed in which students interact successfully for the sake of maintaining a harmonious classroom.

Often students' intrinsic motivation is affected by the nature of the task itself. Hence, the characteristics of the teaching/learning process and the curriculum play a valuable role in maintaining students' natural interest in school. A child will assess an activity's motivational value in determining if intrinsic interest exists. Perceived fun, arousal, and control interact to influence a student's interpretation of an academic activity as intrinsically worthwhile. Arousal is achieved through challenge, curiosity, and fantasy, while an optimum control level is obtained when a student perceives free choice in the activity while the task itself is challenging, but not too difficult (Middleton, 1995). Matthews (1991) found that students who felt they had more control with regards to decision making and the general functioning of school had higher intrinsic motivation in reading, social studies, and science.

2.3.6 Achievement and Attitude towards Mathematics

Previous research has established that attitudes toward mathematics impacted on mathematics achievement or was correlated with mathematics achievement (Gadalla, 1999; Kim & Hocevar, 1998; Lokan & Greenwood, 2000; Odell & Schumacher, 1998; Simich-Dudgeon, 1996; Weinberg, 1995). Among these researchers, Gadalla (1999) and Lokan and Greenwood (2000) studied the relationship between attitudes toward mathematics and mathematics achievement using TIMSS data and found that a relationship exists between these two variables. Thus attitude toward mathematics has been considered as an important factor in the link between participation and success in mathematics. Students' attitude could therefore be another measurement to determine students' achievement – as was
introduced in this study. This study also investigated whether a relationship exists between the two variables in the context of Bruneian technical education.

It is not easy to establish a direct causal link between positive classroom environments and academic achievement because of the many variables involved. However, the relationship between these two aspects of education mentioned has been proven. The learning environment has been demonstrated to have a significant impact on student achievement, as well as emotional and social outcomes at all grade levels from the numerous studies that I investigated (Fraser, 1994; Fraser, Giddings, & McRobbie, 1995). Such findings suggest that students' low performance on tests is not solely because of their deficient skills. In fact, what I found interesting is that positive classroom environments have been shown to improve the achievement of low-performing students (Pierce, 1994). Another interesting outcome of the research by Fraser et al. (1995) is that student achievement is higher when the actual classroom environment is consistent with students' preferred classroom environment.

The challenge here is to investigate what is happening around the world in general, and in Brunei in particular, with regard to trying to improve students' understanding in mathematics. The challenge to educators is to ensure that classrooms become supportive environments where real learning occurs (Apthorp, Bodrova, Dean, & Florian, 2001). Information from the investigation in the current study should be useful in helping to design and develop a teaching and learning package that can be used to enhance the mathematical understanding of technical students in the country. All the factors mentioned above were taken into consideration in designing the present package.

### 2.4 Teaching and Learning Theory

In the mid 20th century, ideas about new technologies in the classroom were slowly being introduced. Bloom, Mesia and Krathwohl (1964) published the Taxonomy of Educational Objectives, and developed a method for reorganising instruction to allow for more individualised learning (Mastery Learning). Bloom's belief that given the opportunity, all learners could succeed is consistent with my belief. His method of Mastery Learning called for the breaking down of skills into sub-skills with one only proceeding to the next skill upon mastery of the previous skill. He also believed that Mastery Learning could be achieved this way with
additional strategies such as tutoring, small group work, programmed instruction, games, and the use of audiovisual materials.

Bruner (1961) introduced Discovery Learning as an instructional model based on cognitive views of learning and constructivist principles. In Bruner's model, students are encouraged to learn on their own through action and experience. The teacher's role is to facilitate learning activities that arouse students' curiosity, minimise the risk of failure, and be relevant to the student.

Howard Gardner introduced his first full-length theory of multiple intelligences in 1983. He viewed intelligence as the capacity to solve problems or to fashion products that are valued in one or more cultural setting (Gardner & Hatch, 1989). He formulated the list of seven intelligences:

- **Linguistic intelligence**: Learners' ability to learn and use languages to accomplish certain goals which includes the ability to effectively use the language to express themselves and as a means to remember information.

- **Logical-mathematical intelligence**: Learners' ability to detect patterns, reason deductively and think logically; which includes analysing problems logically, carrying out mathematical operation, and investigating issues scientifically.

- **Musical intelligence**: Learners' skills in performance, composition, and appreciation of musical patterns. It includes the ability to recognize and compose musical tones, rhythms and pitches.

- **Bodily-kinesthetic intelligence**: Learners' ability to use mental abilities to coordinate bodily movements. It includes the potential to use whole or parts of the body to solve problems.

- **Spatial intelligence**: Learners’ potential to recognize and use patterns of wide space and more confined areas.

- **Interpersonal intelligence**: Learners’ ability to understand the intentions, motivations and desires of other people, which allow people to work effectively with others.

- **Intrapersonal intelligence**: Learners’ ability to understand themselves, to appreciate feelings, fears and motivations. It involves having an effective model of ourselves and able to use that information to regulate our lives.

(Gardner, 1999, p. 41-43)
Gardner's work has had a profound effect on the practice in education. It created appreciation of other intelligence rather than the first two that were typically valued in schools.

In 1983, David Kolb with Roger Fry created the Experiential Learning model out of four elements: Concrete experience, observation and reflection, the formation of abstract concepts and testing new situations (active experimentation). Both of them at the same time developed a learning style model that included four learning styles: Converger, diverger, assimilator, and accommodator. These learning styles further complement the styles by Honey and Mumford (1992) that was already mentioned in Section 2.3.2.3. Kolb (1984) define them for the teachers as follows:

- **Converger**: Learner's knowledge is focused on specific problems. The learner uses abstract conceptualisation and active experimentation in problem solving, decision-making and the practical application of ideas. They prefer to deal with technical tasks rather than social and interpersonal issues. This style characterises engineers and technical specialists.

- **Diverger**: Learner possesses opposite strengths to the converger, emphasises concrete experience and reflective observations. The learner view situations from many perspectives and organise relationships into a meaningful configuration. This style is the characteristic of counsellors and personnel managers.

- **Assimilator**: The learner combines abstract conceptualisation and reflective observations to create theoretical models and assimilate observations into an integrated explanation. Style characteristic of mathematicians and those in research and planning departments.

- **Accommodator**: Learner possesses opposite strengths to the assimilator, emphasises concrete experience and active experimentation. The learner uses intuitive trial and error approach; is action orientated and adapts well to changing circumstances. This style is the characteristic of people in the business world, especially marketing and sales.

In 1990s, constructivist theory gained recognition. Constructivism, which has its roots in ideas of discovery-learning asserts that students "construct" their own knowledge and behaviours through undirected experiences (Bruner, 1961). Constructivist theory views knowledge as constructed by the individual through
interactions with environment. In the following pages, I have listed different views of approaches to learning (design principles) by Jonassen (1991, 1994), Wilson and Cole (1991), Ernest (1995) and Honebein (1996) from which I intend to choose the appropriate approaches among the many listed for the design of my own teaching approaches to be incorporated in the package. Similar recommendations on design principles by Wilson and Cole (1991), Ernest (1995) and Honebein (1996) can be found below and they formed the core of the teaching/learning themes of the package.

Jonassen (1991) noted that many educators and cognitive psychologists have applied constructivism to the development of learning environments. From these applications, he isolated a number of design principles:

- Create real-world environments that employ the context in which learning is relevant.
- Focus on realistic approaches to solving real-world problems.
- Instructor to act as a coach and analyser of the strategies used to solve these problems.
- Conceptual interrelatedness to be stressed by providing multiple representations or perspectives on the content.
- Instructional goals and objectives to be negotiated and not imposed; Evaluation should serve as a self-analysis tool.
- Provide tools and environments that help students interpret the multiple perspectives of the world.
- Learning should be internally controlled and mediated by the student.

Jonassen (1994) then summarised what he refers to as "the implications of constructivism for instructional design". The following principles illustrate how knowledge construction can be facilitated:

- Provide multiple representations of reality.
- Represent the natural complexity of the real world.
- Focus on knowledge construction, not reproduction.
- Present authentic tasks (conceptualising rather than abstracting instruction); Provide real-world, case-based learning environments, rather than pre-determined instructional sequences.
- Foster reflective practice.
- Enable context-and content dependent knowledge construction.
- Support collaborative construction of knowledge through social negotiation.

Wilson and Cole (1991) provide a description of cognitive teaching models that "embody" constructivist concepts. From these descriptions, one can isolate some concepts central to constructivist design, teaching and learning:

- Embed learning in a rich authentic problem-solving environment.
- Provide for authentic versus academic contexts for learning.
- Provide for student control.
- Use errors as a mechanism to provide feedback on students' understanding.

Ernest (1995), in his discussion of the many schools of thought regarding constructivism, suggested the following implications of the theory derived from both the radical and social perspectives:

- Sensitivity toward and attentiveness to the student's previous constructions: Diagnostic teaching attempting to remedy student errors and misconceptions; Attention to meta-cognition and strategic self-regulation by students.
- The use of multiple representations of mathematical concepts.
- Awareness of the importance of goals for the student, and the dichotomy between student and teacher goals.
- Awareness of the importance of social contexts, such as the difference between folk or street mathematics and school mathematics (and an attempt to exploit the former for the latter).

Honebein (1996) described seven goals for the design of constructivist learning environments:

- Provide experience with the knowledge construction process.
- Provide experience and appreciation for multiple perspectives.
- Embed learning in realistic and relevant contexts.
- Encourage ownership and voice in the learning process.
• Embed learning in social experience.
• Encourage the use of multiple modes of representation.
• Encourage self-awareness in the knowledge construction process.

For students to achieve experiences of understanding and success in learning new things, they should become motivated and be able to commit themselves to problem solving. The prevailing conceptions of learning are largely based on the idea that learning is not only a process of knowledge construction but also social interaction (Steffe & Gale, 1995). From a pedagogical point of view, the students' learning activity should be directed at activating their own prior conceptions and relating it to new knowledge. Accordingly, the learning environment should therefore provide students with opportunities to test and try out their new conceptual understanding in various circumstances like problem solving and project work, which also form the main theme of the package.

I would classify the epistemology of the classroom learning recommended by the package in my study as social constructivist. According to the so called socio-constructivist viewpoint, knowledge is constructed and communicated through culture and social institutions, and therefore the dimensions of constructivist learning theories can be differentiated by examining the significance of the individual and the environment in the process of knowledge construction. Therefore, some individual factors connected with learning (like motivation and skills) or pedagogical practices (like social interactions) may be given divergent or conflicting meanings among representatives of different constructivist trends (Anderson, Reder, & Simon, 1997; Greeno, 1997).

2.4.1 A Suitable Instructional Model for Technical Students

Models for instructional design provide procedural frameworks for the systematic production of instruction. They include fundamental elements of the process such as the analysis of the students as audience or the objectives (goals).

According to Ascher (1983), the National Science Board Commission in USA found that successful mathematics instruction includes motivating techniques, sufficient time-on-task, high standards for participation and achievement, a coherent course of study with early "hands-on" experience, adequate resources, innovative use of available facilities, and extensive homework.
Ascher (1983) further listed some simple and inexpensive mathematics programs that have proven successful with students of all ages which include some of the following elements:


Although no single method has proven most effective, a variety of instructional methods do work (refer Section 2.4.4). Moreover, the opportunity to learn mathematics through sufficient coursework is fundamental. Schools need to be flexibly organised so that all students, including low-achievers, can take a variety of individually tailored mathematics programs that provide access to advanced mathematical learning.

Recent research by Kamaruddin (2002) on the learning styles of VOCTEC (Vocational and Technical) students in Brunei discovered that for technical and engineering students surveyed, their learning styles were a mix of activist, reflector, theorist and pragmatist with pragmatist being most dominant and reflector coming out second. According to Honey and Mumford (1992), pragmatists favour concrete experiences that involve them in new learning experiences, while reflectors favour reflective observation by watching others, or develop observations about experience. Kolb’s (1984) learning style can be applied to suggest that pragmatists (or “concrete experience” people according to Kolb) should be encouraged with fieldwork and to make numerous observations, while reflectors (or “reflective observers” according to Kolb) should be encouraged to use logs, journals and to always be involved in brainstorming. This suggestion agrees with the claim that I made earlier suggesting that technical students are not abstract learners (refer Section 2.2.2, after Table 2.1). Kolb’s (1984) study found that relatively few students learn by thinking and watching – the learning style commonly used in the lecture mode. Most students tend to process information through concrete experience and/or active experimentation and learn best through interpersonal communication, group learning, sharing, mutual support, team processes and positive reinforcement.

Kolb also encourages the use of teaching methods that develop all four learning styles so that students can broaden their learning abilities beyond natural
inclination. After all, hands-on learners must be able to take the conceptual information they receive in traditional teaching and learning methods and transfer it into practice (Hull, 1999). I tried to have various (innovative) activities in different lessons that develop all four learning styles encouraged by Kolb.

Hull further said that the major changes needed in today’s educational system centre around processes. We need to

- Provide students with compelling reasons to remain in school,
- Use the discoveries of cognitive science to help them achieve enhanced learning, and
- Create a learning environment that opens their minds and enables them to become more thoughtful participative members of society and the workforce.

The following is my summary of the characteristics of constructivist learning and teaching as described in the earlier sections of this chapter and suggested by constructivist theory (refer p. 57 - 58). I found the list helpful for the design of the mathematics teaching and learning package for technical students:

- Teachers to serve as guides, monitors, coaches, tutors and facilitators.
- Activities, opportunities, tools and environments are to be created to encourage meta-cognition and self-analysis (regulation, reflection and awareness).
- Student to play a central role in mediating and controlling learning.
- Learning situations, environments, skills, content and tasks to be relevant, realistic, as well as authentic and represent the natural complexities of the “real world”.
- Primary sources of data are to be used in classes in order to ensure authenticity and real-world complexity.
- Knowledge construction and not reproduction to be emphasised.
- This construction to take place in individual contexts and through social negotiation, collaboration and experience.
- The student’s previous knowledge constructions, beliefs and attitudes are to be considered in the knowledge construction process.
- Problem-solving, higher-order thinking skills and deep understanding are emphasised.
• Errors used to provide the opportunity for insight into students' previous knowledge constructions.

• Exploration to be a favoured approach in order to encourage students to seek knowledge independently and to manage the pursuit of their goals.

• Students to be provided with the opportunity for apprenticeship learning in which there is an increasing complexity of tasks, skills and knowledge acquisition.

• Collaborative and cooperative learning to be favoured in order to expose the student to alternative viewpoints.

• Assessment to be authentic and inter-woven with teaching.

• Multiple perspectives and representations of concepts and content are presented and encouraged

2.4.2 The Preferred Classroom

I will now summarise the features of the preferred classroom according to the factors indicated earlier in the literature review. The main purpose is to focus, clarify and justify the choice of classroom environment scales chosen in this study.

Mathematics is not supposed to be learnt in isolation or in passivity. It is more of a process of making sense and establishing meaning both individually and collectively. In order to create harmony in a classroom, the model of a preferred classroom could be used effectively where relationships between teachers and students are as important as the relationship between students and students. There is a range of positive outcomes associated with preferred classroom, including higher achievement, stronger motivation to learn, greater interest in class, and fewer behaviour problems (Lewis, Schaps, & Watson, 1996). In a preferred classroom, which is also a caring classroom, all students know that they are important and have something to contribute.

There are two ways that the concept of caring can be applied to learning. First, there is the sense that students are being cared for by each other and their teacher. This is important in establishing the trust, safety, and collaboration necessary for the pursuit of challenging mathematics and science (Noddings, 1993). Caring also involves the relationships that students have with the disciplines of mathematics and science. When students care about the content and ideas that they
are learning, they make an emotional investment that brings energy and excitement to the pursuit of knowledge.

In a preferred classroom, all members are important, and everyone has significant contributions to make both to learning and to the general well-being (Elias et al., 1997). Students report that a sense of being known and of being friendly with other students leads to a more congenial learning environment and increased motivation to learn and participate in school (Waxman & Huang, 1996). In the adult classroom where the research was conducted, although instructors no longer acted as nurturer or caregiver as in school, students reacted better with each other through teachers’ guidance, which led to better student perceptions. Student perceptions are important as teachers shift toward a more constructivist approach to learning. Students must also make this shift in their beliefs about the learning process, the role that they play in that process, and the role of the teacher (Roth & Roychoudhury, 1994). Another shift is that workplaces have become less hierarchical, more cooperative and team oriented; therefore, employers value workers who are flexible enough in skills and temperament to deal with uncertainty and change and understand the need for continuous improvement. Today’s workers must be problem solvers and team players. Thus, career/technical teachers must be firmly and broadly grounded in the skills, knowledge and vision to inform students about possibilities and to afford them the wherewithal to take their place in the real world of the 21st century (Bottoms, 2001). This justifies the stress on cooperation in the preferred classroom environment. Research has shown that students who have opportunities to work collaboratively, learn faster and more efficiently, have greater retention, and feel more positive about the learning experience. Cooperative Learning is one of the most thoroughly researched of all teaching strategies (Felder & Brent, 1994; Shachar & Sharan, 1994; Slavin, 199; 1995), therefore, successful examples of implementing cooperative learning can be researched.

If the intention is to change the character of teaching (mathematics classes) the aim should be to influence the teachers – at cultivating their attitudes, opinions, beliefs, teaching activities in the course of mathematics lessons, their ability to act as creators of a kindly and favourable climate and vehicles of challenges, at improving their theoretical capability as well as practical teaching competence. This justifies the emphasis on teacher support in the preferred classroom environment.
Lack of motivation that has resulted from abstract concepts is a commonly recognised feature of undergraduate mathematics instruction, as well as that in high schools and graduate schools, (Laubenbacher, Pengelley, & Siddoway, 1994). Ideas were often introduced by way of another equally abstract approach, or with some practical, often trivial, "real world" application as justification for what teachers were going to inflict upon students. As a result, most students view mathematics as a game with arbitrary rules, set by educators that is unconnected to anything meaningful. Presenting mathematics knowledge as growing and changing, rather than fixed, helps bring the topics to life. Mathematics becomes more interesting and accessible because students gain an understanding that the ideas they are learning are open to questioning and testing (Nickson, 1992).

Traditionally, mathematics is one of the subjects that is learned in solitude. Lectures are the dominant mode of teaching and homework is carried out alone at home. Group projects are few. Teaching for understanding, which is the primary goal of mathematics and science education reform, requires that students are actively engaged in the classroom, are willing and able to communicate their ideas, and are able to learn from each other. Students are supposed to be active participants in class. Active engagement is important for encouraging motivation and a key factor in learning. The extent to which students actively participate in classroom activities and discussions also has a significant impact on their perceptions of the learning environment (Stepanek, 2000). Personal involvement and learning are enhanced with opportunities to figure things out, to interpret the results of investigations, to generate hypotheses, and to create knowledge and meaning (Roth & Roychoudhury, 1994). Active participation is a necessity rather than an option or an enhancement. Students learn by doing mathematics and making sense of what they are studying rather than listening to lectures and following prescribed procedures. Thus innovation and relevance are considered important in a classroom environment.

Students are most engaged when they see that the mathematics they are learning is relevant, challenging, useful, and interesting. Teachers can encourage student motivation and engagement by orientating tasks that help them to make these connections. This includes matching tasks and themes to students and the ways that they best make sense of what they are learning (Lappan & Ferrini-Mundy, 1993). Teachers do this by connecting new ideas to students' prior learning, observing and talking to their students, and drawing on the general knowledge base about how
students learn mathematics and science. This is the reason why task orientation in a classroom environment is considered important. High expectations are also an important part of creating tasks in a favourable learning environment. Teachers' expectations influence students' beliefs about their own abilities and roles in the classroom. Students learn and feel successful when they are challenged rather than when they are completing tasks that they already know how to do and they need support for this. Students learn best and perceive the classroom favourably when there are clear expectations for their work.

Intrinsic motivation is associated with activities that are inherently enjoyable, interesting, or challenging. It can be assumed that intrinsic motivation can be maintained as long as learning activities lead to a certain level of positive emotional experience (Schiefele & Csikszentmihalyi, 1995). This does not mean that all mathematics activities must be fun, but interesting and challenging questions and problems are essential. Students learn more when teachers make mathematics problematic. This means that instead of memorising or practicing facts and procedures, students must devise and select their own methods for solving a problem or answering a question (Hiebert et al., 1997) and teachers should help them devise such methods. In addition, students are eager to be actively involved in tasks that help them solve problems from their own experiences or to answer their own questions. This helps to bring a sense of shared purpose to learning and classroom activities.

I will summarise what was said in this section with the following key areas for improving the learning environment in mathematics classrooms:

- Supportive relationships among teachers and students
- Student participation in creating classroom norms, making decisions, and setting goals
- Clear expectations and responsibilities
- Opportunities for collaboration
- Adequate time for completing tasks and for discussions
- Opportunities to work on open-ended tasks
- Interesting and meaningful activities

In mathematics and science, many of the classroom factors listed above also influenced students' positive attitudes. For example, students with favourable
attitudes toward science feel that they are involved in class and receive a great deal of academic and personal support from the teacher. These students also understand the classroom expectations and rules and report friendly and strong relationships with their classmates (Fouts & Myers, 1992). Positive emotions and intrinsic motivation are essential for success in problem solving, creativity, and conceptual understanding (Schiefele & Csikszentmihalyi, 1995).

Nolen (1988) argues that in order to foster meaningful learning and effective study strategies, teachers should reduce the emphasis on competition for grades and teacher recognition and instead encourage learning for its own sake. The importance of matching tasks to each child’s skill level cannot be over emphasised, as it is necessary for both intrinsic motivation and optimal skill learning. As difficult as this principle is to implement, it is the most important one for motivation and learning (Stipek, 1988).

Stipek (1988) also said that task-oriented motivation seems to be considered by researchers to be "healthier" than ego-oriented motivation. A student who is task-oriented is interested in learning a subject for its own sake. These students tend to evaluate their performance on an internal basis. In a given situation, they tend to ask whether their performance measures up to what they want it to be, or what they expected it to be. They tend not to make comparisons to an external norm of performance provided by a peer group. Students who are predominantly ego-oriented are only interested in how their performance looks in the eyes of others. All comparisons are therefore made to an external peer group. Task orientation and ego orientation are not necessarily fixed characteristics, as they have been influenced by conditions in school environments (Ames, 1992). Task-oriented students view ability as something incremental, so they seek to improve their competence by increasing their knowledge and understanding irrespective of the performance conditions (Dweck, 2000). Dweck then asserted that task oriented students are involved towards the development of new skills, to understand their work, to improve their level of competence or to achieve a sense of mastery based on self referenced standards (Dweck, 2000). Within this mental frame, students usually perceived ability as something that can be improved and therefore would be more confident in investing their effort (Schunk, 1996). On the other hand, ego orientation goals entailed a focus upon ability as a fixed attribute, which determined a sense of self-worth.
2.4.3 Evaluation

Evaluation is necessary in any teaching and learning reform initiative to:

- Improve the quality of the course and teaching
- Monitor innovations in teaching
- Diagnose strengths and weaknesses
- Engage students more actively in the teaching/learning process
- Investigate student difficulties
- Check out students' expectations of teaching
- Provide evidence for institutional quality audits
- Engender professional satisfaction

In the case of the evaluation of this study, my main objective was to obtain students' opinion on the two questions:

- What is it about this package – its design, delivery or assessment – that is helping you to achieve the learning? and
- What is it about this package – its design, delivery or assessment – that is hindering you from achieving the learning outcomes (as stated in the course outline) and how can that be improved?

Student learning outcomes encompass a wide range of student attributes and abilities, both cognitive and affective, which are a measure of how their experiences have supported their development as individuals. The division into cognitive and affective factors was always seen as on arbitrary classification, and no true separation of the two can meaningfully be made.

- **Cognitive outcomes** include demonstrable acquisition of specific knowledge and skills; what do students know that they didn't know before, and what can they do that they couldn't do before?
- **Affective outcomes** are also of considerable interest; how has their experience impacted students' values, goals, attitudes, self-concepts, world-views and behaviours? How has it developed their potential? How has it enhanced their value to themselves?

In the present research, the cognitive outcome (mathematics proficiency) was measured via pre and post-tests as well as on going question and answer sessions in
classrooms, together with grading of assignments, projects, homework and class-
work. According to Gill (2001) of the American Federation of Teachers, 
mathematical proficiency has five strands – conceptual understanding, procedural 
fluency, strategic competency, adaptive reasoning and productive disposition. 
Strategic competency is the ability to formulate, represent and solve mathematical 
problems; adaptive reasoning is the capacity for logical thought, reflection, 
exploration and justification, while productive disposition is the tendency to see 
mathematics as sensible, useful and worthwhile. This framework has some 
similarities to the one used by National Assessment of Educational Progress (NAEP, 
2002, September) which targeted mathematical abilities in three areas of conceptual 
understanding (knowing about), procedural fluency (knowing how) and problem 
solving abilities. Problem solving includes additional specification for reasoning, 
connections and communication. Conceptual understanding and procedural skill are 
highly correlated (Rittle-Johnson & Stiegler, 1998) such that teaching conceptual 
knowledge first, leads to the acquisition of procedural knowledge later, but the 
converse is not true (Brown, Seidelmann, & Zimmermann 2002). This means that 
students who develop conceptual understanding early perform best on procedural 
knowledge later, and students with good conceptual understanding are able to 
perform successfully on near-transfer tasks and to develop procedures and skills they 
have not been taught. Students without conceptual understanding are able to acquire 
procedural knowledge when the skill is taught, but research suggests that students 
with low levels of conceptual understanding need more practice in order to acquire 
procedural knowledge (Grouws & Cebulla, 2000a). Therefore, it seems that 
conceptual understanding is a key factor, while problem solving is essential for self-
control of the student with respect to the understanding of concepts and at the same 
time with respect to acquiring procedural skills. Teaching quantitatively oriented 
courses always should include problem-solving sessions and the trend in students’ 
achievement supports the continued emphasis on problem solving (Bay, 2000). 

In the present study the affective outcomes were measured via surveys on 
classroom environment and attitude towards mathematics. Interviews were also 
conducted to obtain the students’ and teachers’ opinions about the results from the 
survey. Observation and students’ reflective journal writing and opinion sheets 
served the purpose of measuring both outcomes.
2.4.4 Other Related Studies

A number of studies of similar nature that have been carried out in the USA have been documented by Castellano, Stringfield and Stone (2001) (refer Appendix 2). These programs were developed for high school students preparing for college or work. The difference in my study was that it involved students who had graduated from high school and were completing their Diploma level courses. I will describe in detail some of the successful programs among those listed because I have used some of the strategies from those programmes that have proven to be successful.

2.4.4.1 Tech Prep:

According to Hull (1999), Tech Prep has become the leading educational reform movement in the United States because it focuses on improving student achievement in academic subjects, particularly for the middle 60 percent. Tech Prep curricula require better understanding of how academic concepts relate to the workplace and how vocational skills connect with these academic concepts. Tech Prep introduced contextual teaching of mathematics and found that most students' interest and achievement in mathematics improve dramatically (Hull, 1999). I have used the idea of relating academic concept to workplace as was done in contextual teaching from this source, in my study.

2.4.4.2 Curriculum Integration:

Curriculum integration involved the incorporation of academic and occupational-career content, and instruction beyond what would normally be covered in the curriculum for the primary subject area. Schools deliberately created models that would support students in both high-level academic attainment through vocational studies and vocational mastery through applications of academic knowledge. Curriculum integration is theme-based, for example, teachers used the contexts of health care and manufacturing to provide both vocational and academic instruction. Special efforts have been taken to define clear and strategic connections between academic and vocational material.

Through curriculum integration, academic teachers gain new tools and strategies for teaching their subject. Academic teachers seemed excited about using students' occupational or vocational interests to teach academic theories and lessons. Vocational teachers seemed to view curriculum integration as a means for enhancing
the educational experience in a way that would benefit all the students. By working
with academic faculty to strengthen academic learning in vocational classes,
vocational teachers believed they were better able to prepare their students for the
complex problems adults face in the workplace and in their personal lives (Johnson,
Charner, & White, 2003).

The Center for Occupational Research and Development (CORD) has been a
leader in integrated curriculum development. Based on CORD’s experience in
developing Principles of Technology, Applied Physics, Applied Mathematics, and
Applied Biology and Chemistry, Hull (1990) recommends (1) using a systems
approach instead of teaching a series of discrete topics; (2) integrating mathematics
with problem solving; and (3) integrating biology and chemistry in the context of
personal, work-related, and societal issues (Lankard, 1993).

Curriculum integration has also been an unmentioned strategy in Brunei’s
technical education in the introduction of common skills. “Common skills” is the
assessment of basic skills that was introduced since 2001. Students’ competencies
were assessed according to the project that was given jointly with every department
(integrated assignment) and most of the skills are considered as necessary for
individuals to succeed in the real world, for instance management of responsibilities,
working with others, communication, managing tasks and problems and applying
numeracy, design and information technology skills (DTE, 2000).

2.4.4.3 High Schools that Work:

This program concentrates on low achieving students by implementing ten
key practices in all classrooms to enhance achievement in high schools. Its approach
in the area of mathematics is as follows.

It includes group learning and individual practice. Teachers integrate
technology into the lessons and encourage students to complete tasks that
demonstrate their learning. Almost every day, students spend time in the computer
lab where they solve problems that are related to their mathematics lessons
electronically. Students are asked to meet higher expectations by using a pre-algebra
book rather than a general mathematics textbook. Many students feel that what they
are learning is more important because it is the basis for algebra. The instructional
materials are different from the ones used during the school year. If students have
been unsuccessful with general mathematics books, it makes sense to try new materials to engage them in learning (Bottoms & Carpenter, 2003).

Students are encouraged to participate in various activities and challenges that require trust, strategy, cooperation and leadership. Many activities are simply good fun and engage students in vigorous physical activity. This program has been most successful.

My study also involved low achievers, incorporated group learning and encouraged individual practice through homework.

2.4.4.4 Career Academies:

The Career Academy is a high school model that integrates school-to-work elements in a personalised learning environment. Academies were originally designed as a lifeline for students at risk of dropping out.

Academies have three essential features:

1. A school within a school cluster of students who typically stay with the same group of teachers for 2-4 years, forming a close-knit learning community that gives students personal support.

2. Partnerships with employers who sponsor career awareness and work-based learning opportunities and provide resources and financial support.

3. Integrated academic and occupational curriculum centred on a career theme, occupation, or industry to provide focused, situated learning.

These elements are intended to result in better engagement and academic performance, students’ personal and academic development, preparation for college and work, post-secondary attainment, and successful employment (Kerka, 2000). Research and anecdotal evidence show a number of positive outcomes in terms of attendance, grades, credits earned, and graduation rates. However, Kerka (2000) noted concerns about research methods and questions the validity of the findings.

Although this study is different from mine in terms of student emphasis, it does resemble my study to a certain degree in terms of integration of school-to-work elements.
2.4.4.5 Career Magnets:

Career Magnet high schools represent an important alternative to comprehensive high schools. By combining career preparation with traditional college preparatory courses, students interested in career opportunities do not have to choose between college and an entry-level job after high school graduation. This is where the parallels between career magnet programs and my package exist. My package tries to address both groups of students ready for work and those who wish to pursue further studies. Magnet schools are similar to focus schools with a curriculum theme, course content, specific pedagogy, special allied activities, student selection policies, scheduling procedures, or school organisation that attract or "magnetise" students and teachers with interests in the school's theme and practices.

Magnet schools have been found to improve student achievement, student motivation and satisfaction with school, teacher motivation and morale, and parent satisfaction with the school. Career magnet graduates did feel that they learned more in their occupationally related classes than in their academic classes, and were more likely to attribute any positive educational (academic and career) outcomes of their high school experience to their occupational classes (Flaxman, Guerrero, & Gretchen, 1999).

2.4.4.6 Career Pathways:

Career Pathways provide a useful framework to aid both students and educators to make meaningful connections to the working world. Career Pathways System is designed to enhance student ability to reach high academic and career standards. Among the features of career pathways are that, they:

- Teach students personal skill and interest in exploration by providing them the tools they need to be successful as life-long learners.
- Help all students attain high academic and occupational standards and motivate more of them to stay in school.
- Provide contextual learning experiences to promote high academic performance for all students.
- Provide both work-based and school-based learning experiences for all students to facilitate their entry into additional training or post-secondary education.
Career pathways integrate school-based and work-based learning, academic and vocational courses, and extracurricular activities. This component provides students with real world, job-related learning experiences and lends relevancy to their school-based coursework. Ultimately, the Career Pathways system should provide students with experience in all aspects of an industry (ADE, 2003).

I endeavoured to address real world, job-related learning experience that provides relevancy for the students in my study. This is where the similarity between my study and career pathways lies.

2.4.4.7 The American Mathematical Association of Two-Year Colleges (AMATYC)

AMATYC is the only organisation exclusively devoted to providing a national forum for the improvement of the instruction of the mathematics in the first two years of college. AMATYC, which has approximately 2,800 individual members and over 100 institutional members in the United States and Canada implemented programmes that seek to analyse the role and nature of technical mathematics in advanced technology programs, recognise successful models, and develop a vision and recommendations for technical mathematics. In addition, issues of transferability for students in advanced technology programmes are addressed.

The objectives of the implemented programme are to:

- Identify issues and formulate recommendations concerning the nature and role of technical mathematics set in the larger context of science, technology, and engineering technology programs
- Select and recognise up to ten programs meeting exemplary criteria
- Promote and disseminate the recommendations and exemplary programs
- Collaborate with other professional organisations to facilitate changes in curriculum

At the association’s national conference (May 12-15, 2002), which carried the theme of creating a vision for the mathematics for the emerging technologies, it was recommended that the following features are necessary for a successful mathematics programme:

- Expected student outcome should be based less on specific content skills and more on problem solving, critical thinking and communicating mathematically.
• Content should be addressed in ways that demonstrate connections between mathematics and other areas, as well as among mathematics topics.
• Students must acquire a deeper understanding of mathematical topics.
• Students must be able to transfer the mathematics knowledge or skills to applications within their disciplines. Focusing on local businesses gives immediate relevancy to applications.
• Technology should be used as a tool for teaching and, at the same time, to develop the ability of students to use that technology to solve problems.
• The classroom environment must use all the resources possible to facilitate learning.
• Mathematics classes must be a part of equipping the student with employability skills.
• Education institutions must find ways to promote innovation, sharing, and personal growth.
• Educators need to be able to provide realistic examples that motivate content.

(AMATYC, 2002)

The recommendations above provide a guideline for educators to apply in technical mathematics classes. I consider the AMATYC project as the most similar to my study in terms of the students’ age and level, at the same time being the only study in technical education that concentrates on the improvement of mathematics instruction in the first two years of college.

2.5 Summary

This chapter has explained in detail a number of the problems in mathematics education especially in the context of Bruneian technical students. The intended strategies to tackle this problem were backed up with reviews of the literature. The proposed theoretical framework and its components and how the evaluation of the study would be carried out have been explained in detail. Included in the chapter are the learning environment scales and the motivational components that were
emphasized in the writing of the package because environment aspects and the motivational strategies are essential in enhancing students’ interest in learning. They formed part of the effective learning strategies that should shape students to be lifelong learners and so make them eager to acquire knowledge for its own sake and not just learning to pass examinations or gain necessary certificates.

A strong indicator of why so much teaching of mathematics fails could be said to come from defective philosophical and epistemological perspectives. Lessons are disconnected from the inquiry experiences and the real-world, even though such learning experiences could encourage students to lose interest in learning mathematics. In the traditional mathematics classroom weaker students are often bored and restless. Teaching is routine and monotonous and only benefits good students who excel in learning the abstract way. The “weaker” students do not have any motivation to learn and are labelled as “weak at mathematics”. This vicious cycle continues until they graduate from the college. The chapter listed a number of strategies that would make learning meaningful and enjoyable and that could be recommended for application in a preferred classroom.

In my view, a healthy learning environment should be created to enhance students’ motivation and prevent the unhealthy situation described above. By focusing on students’ feelings and their perception of their learning environment teachers might be able to change students’ attitude from a negative to a more positive feeling about mathematics, which will thus enhance their interest in studying mathematics for its’ own sake and hence will increase their understanding of the subject.

The following chapter describes the research method designed to achieve the objectives of this study.
Chapter 3

Research Methods

The newer and broader picture suggests that the child emerges into literacy by actively speaking, reading, and writing in the context of real life, not through filling out phonics worksheets or memorising words.

Thomas Armstrong

3.1 Overview of Chapter

This chapter focuses on the methodology of the study, providing a detailed explanation of the design process and methodologies adopted. The chapter also discusses the research methods of the four stages mentioned in Chapter 1, namely the:

1. Identification phase,
2. Design and development phase,
3. Implementation phase, and
4. Evaluation phase.

A mixed qualitative and quantitative methodology was adopted for the study. The qualitative components that were used included: Interviews, classroom observation, as well as content analysis of syllabus, textbooks and programme guides; whilst the quantitative components included diagnostic and achievement tests, and survey questionnaires.

The identification phase describes the design and development of a learning environment and an attitude towards mathematics survey instrument designed to investigate the students’ actual and preferred learning environment along with their views of mathematics. Interviews conducted with students and teachers further enhanced and enriched the findings from the surveys. The procedure of this phase appeared to demonstrate the benefits of applying quantitative techniques to obtain classroom information, which is so often only assessed through qualitative measures.
The second phase, titled *design and development*, concerns the teaching and learning package. It describes why a certain instructional approach was favoured and it also explains the benefits that the package was intended to achieve.

The *implementation* phase describes what would happen when the package was implemented with the students. It also describes the sample selection and the formulation of the teaching schedules.

The final stage, the *Evaluation* phase, examines the efficacy of the package and addresses the research questions along with the expected outcomes of the research. The chapter concludes with a *Summary*.

### 3.2 Introduction

Dawson (1997) mentioned that many people believe that researchers are placing too much emphasis on objectives and questions to which research should be directed, with little attention to actual research designs and methods. He further quoted Gelso (1979a, 1979b), Goldfried (1984), and Magoon and Holland (1984) as stating that more attention should be placed on the training aspects of research methodology. This is due to the importance of reliable data in any research study. Reliable data comes from correct application of research methods: An appropriate research design, appropriate instruments and correct approaches to collecting these data. I took maximum effort to adhere to correct methodology and stringent standards in collecting data for my research study so that they should be as valid and as reliable as possible.

This research employs what is called the “pre-experimental design” (Cohen, Manion, & Morrison, 2000) because there is no control group. The group involved in the implementation of the package, called the treatment group was formed non-randomly. There are three pre-experimental designs that are commonly used and I decided to apply the “one-group pre-test, post-test design” to my study. Here, the treatment group is measured on a variable of interest. The group receives the experimental treatment and then the measure is again taken. The experimenter then compares the pre-test with the post-test to see if any change has occurred. Factors that may influence this design include history and the maturation of the participants. The longer the time that elapses between the two observations, and the more the number of participants for which specific events happen collectively, then the more plausible it is that history and participants maturation would have an effect on the
study (Campbell & Stanley, 1963). But in my opinion, the intervention period of eight weeks was not long enough for the influence of history and participants maturing. The design can be represented as in Figure 3.1 (Cohen et al., 2000):

\[
\text{Experimental} \quad O_1 \quad X \quad O_2
\]

*Figure 3.1*: Representation of one group pre-test, post-test design. O refers to the process observation and measurement and X the experimental variable.

My aim to identify and contrast students' pre and post, cognitive and affective ability led to the choice of administering the pre- and post- content test to examine their cognitive ability, as well as pre- and post-survey to determine the learning environment and attitude towards mathematics for the purpose of examining any affective change.

Learning environment instruments measure students' perception, and therefore such surveys could be used to measure the affective changes and thus the cognitive changes. Walberg's (1976) perceptual model (Fig. 3.2) of the learning process shows how perceptions are thought to influence student learning. Figure 3.2 suggests that student learning involves their perceptions acting as mediators in the learning process. In addition, Walberg advocated the use of student perceptions to assess environments.

\[
\text{External and Internal Stimuli} \quad \text{Perception} \quad \text{Learning}
\]

*Figure 3.2*: Perceptual Model of the Learning Process (Walberg, 1976)

### 3.3 Research Framework

I identified the chosen research paradigm as an 'action research' study, since the purpose of this research is to plan, implement, review and evaluate an intervention designed to improve or practice/solve a particular problem (Cohen et al.,
The problems of this research occur in the teaching and learning of mathematics throughout many countries and its outcomes may be applied if found suitable in similar situations. The foci of the research would be the everyday practices in mathematics education and the outcomes of the interventions. This was a collaborative action research study since it included other teachers and it was of interest to the entire Mathematics Department staff of the technical college. Some of the characteristics include participant as researcher (since I was the person conducting the intervention), reflection on practice and interventionist – leading to the solution of 'real' problems and meeting 'real' needs. Although considerable data were collected during the period of intervention, I used my knowledge and familiarity of the Brunei education system (including the process of teaching and learning, the culture and nature of students, staff and institutions) to interpret and reflect upon the outcomes. I had taught at the college for six years and in Brunei for a total of eight years before starting with my doctoral studies full-time. I have also included a narrative in writing up this study (refer Chapter 6, Section 6.4) because by framing events in a story, it permits individuals to interpret the situation, and more importantly it provides a framework for making decisions about actions and their likely outcomes.

Guba and Lincoln's (1989) constructivist paradigm also applies to the research process in that I endeavoured to construct knowledge about students' mathematical understanding and their classroom environments following my observations and interactions over a period of time.

3.3.1 Use of Qualitative and Quantitative Data

Researchers collect data as a critical part of the process of research. Researchers in educational evaluation also claimed that there are benefits in moving beyond the traditional practice of choosing one over the other of either quantitative or qualitative approaches and instead, combining the two methods. These claims are evident in recent learning environment research that exhibits value in utilizing qualitative and quantitative methods together (Aldridge et al., 1999; Nair & Fisher, 2001). The use of quantitative methods, involving the assessment of student and teacher perceptions, in combination with qualitative data, furthers our understanding of classrooms (Fraser, 1989, 1998) while classroom environment research that involves qualitative case study methods has provided insights into classroom life.
(Rutter, Maughan, Mortimore, Ouston, & Smith, 1979; Stake & Easley, 1978). It is for these reasons that the present study included both quantitative and qualitative aspects of data collection methods as recommended by Fraser (1994, 1998).

For this particular study, the quantitative data were obtained from the survey instruments – namely the College Classroom Environment Inventory (CCEI) and the Attitude Towards Mathematics survey, as well as the pre and post-tests on mathematical understanding – while the qualitative data were obtained from students’ and teachers’ interviews (face-to-face), classroom observations, content analysis of text-books, programme guides and students’ and teachers’ journals. Qualitative design allows the researcher to focus on insight, discovery and interpretation rather than students’ achievement gauged by testing (Merriam, 1988).

Face-to-face interviews were conducted before and after the implementation of the package because of the following advantages. Interviews:

- Enable the interviewer and interviewee to establish rapport,
- Allow the interviewer to listen and observe the respondents’ actions,
- Permit more complex questions to be posed.

Besides the face-to-face interviews, interaction and exchange of ideas were on-going during the implementation stage.

Meanwhile, observations were conducted because they are useful as a means of:

- Assessing how appropriate the teaching is to the learning styles of the pupils
- Detecting learning problems as they arise
- Assessing pupils’ approaches to learning materials and resources
- On-going monitoring

The advantages of content analysis are as follows: it

- looks directly at communication via texts or transcripts, and hence gets at the central aspect of social interaction;
- allows for both quantitative and qualitative operations,
- provides valuable historical/cultural insights over time through analysis of texts,
- is an unobtrusive means of analysing interactions,
provides insight into complex models of human thought and language use.

(Writing at CSU, 1997-2004)

3.3.2 Sample Details

For Phase 1, the identification phase of the study, the entire population of 239 National Diploma Year 1 students from two technical colleges (i.e. Sultan Saiful Rijal Technical College and Jefri Bolkiah Engineering College) were surveyed via questionnaires (actual and preferred CCEI and attitude towards mathematics). All of the students were above eighteen years of age, including several mature in-service students of between twenty and thirty five years old. Eighteen students from different classes and six teachers were also interviewed to validate and clarify the responses to the questionnaires and to determine ideas on ways to improve teaching and learning.

For the phase involving the implementation of the teaching and learning package, only two classes (the first year students from National Diploma in Electrical and Electronics Engineering (ND/ELE/11), and a class from Radio, Television and Electronics Engineering (ND/RTE/08)) were involved. The number of students participating was fourteen and twelve respectively. Two teachers and a cooperative colleague who was a member of the curriculum committee were present to provide feedback and member checking (explained later in the chapter, Section 3.8.6). All three were from Sultan Saiful Rijal Technical College. As was explained in Chapter 1, Section 1.6.3, since I had access to the results of the phase-test from other classes (which was referred to as non-treatment group) as well, I conveniently utilized them to make informal comparison with the treatment group. Both groups consisted of students from the same department. Other variables that differentiate students – ability, gender, ethnic background and age – can be considered to be equivalent since both groups were selected based on similar minimum admission requirements. These groups also had about the same percentage of males and females and included students of similar ethnic backgrounds.

3.3.3 Instrumentation

The survey questionnaire for factor identification was developed based on the existing questionnaires available (CUCEI – College and University Classroom Environment Inventory and WHIC – What Is Happening In This Class) and was called the CCEI – College Classroom Environment Inventory. After a pilot study,
changes were made regarding how the statements were worded to ensure that the survey questionnaires were understandable for the Bruneian students.

For the development of the package, the curriculum was documented in detail through content analysis. Among the material examined were the “programme guide”, the “syllabus”, the “BDTVEC Certification and Assessment Policy Guidelines” and the “Common Skills User Guide”. From the literature review and outcomes of the surveys and interviews conducted in the identification phase, ideas and several recommendations for enhancing both the content and the sequences of the package were carefully examined. All of these findings and ideas were used to design and develop the package created for the ‘Trigonometry’ class.

Before the implementation of the package the students from the two classes were given a pre-test. This test served a diagnostic role: To identify misconceptions that were prevalent in certain areas of trigonometry and students’ prior knowledge in the subject. An attitude towards mathematics survey and the actual and preferred CCEI were also administered.

At the conclusion of the implementation stage, questionnaires were distributed to obtain feedback on attitudes to learning and on perceptions of the learning environment. The “Attitude towards Mathematics” survey and another actual CCEI were used to measure the difference in perception that the students might have experienced after using the package. A post-test was conducted to measure the cognitive development or increment in students’ achievement level. The above instruments were administered to the treatment group following thirty hours of instruction time.

Pre-test and the post-test scores were examined to determine students’ mathematics proficiency constituting procedural skill, conceptual understanding and problem-solving capabilities (Schoenfeld, 2002). When the tests were returned, I marked them according to the marking scheme (Appendix 3E(i) and 3E(ii)). Each student’s scores were then given a percentage and compared. Gains between the pre and post-test scores were examined by way of t-tests. The scores for the categories of procedural skill, conceptual understanding and problem-solving capabilities were also obtained and were used to compare the gains in each of these categories.

A guide from the Oregon Department of Education (1994) also provided me with the necessary tools in helping to identify their level of proficiency in each category. It appears in Appendix 3G. Table 3.1 following summarises the types of
quantitative instruments that were used in the research and to which group they were administered:

Table 3.1: List of instruments used to collect quantitative data in the research

<table>
<thead>
<tr>
<th>Instrument Used</th>
<th>Treatment Groups</th>
<th>Whole Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test (Diagnostic)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Post-test (Achievement)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pre-Attitude towards Math Survey</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Post-Attitude towards Math Survey</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pre-Actual and preferred CCEI</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Post CCEI</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Following the entry of the data collected into the SPSS programme, a manual check of all records entered was carried out to ensure the accuracy of data entry. This was followed by:

a) A check of the reliability and validity of the Learning Environment and Attitude towards Mathematics survey instrument by means of:
   - Factor Analysis: To check any questionnaire items that should be removed to improve the internal consistency, reliability and factorial validity
   - Cronbach Alpha reliability test: To check the internal consistency of each scale,
   - Calculation of the η²: To check each scale’s ability to differentiate between students in different classes

b) An examination of the associations between classroom environment and attitude survey by means of
   - Simple Correlation: which describe the bivariate association between the two entities
   - Multiple Regression Analysis: which measure the associations between each scale of the CCEI to the attitude scales, when all other CCEI scales were controlled

c) An examination of the changes in perception of LE and attitude as well as an evaluation of the effectiveness of the package using
   - paired and one-sample t-tests
The tests performed in (a) – (c) are consistent with the tradition of the learning environment study.

### 3.4 Identification Phase

The main purpose of this phase was to investigate and identify the current situation in terms of students' perception of their learning environment and their attitude towards mathematics. Information and views that the students and teachers had on the teaching and learning of mathematics were also collected. This included surveying students' actual and preferred learning environment and their current attitude via questionnaires and current classroom practice via observation. Interviews with both teachers and students were conducted to determine their views about the current instructional strategies and what aspects could be improved. The reason for doing these was as follows: Without an appropriate environmental analysis, an instruction design project may produce theoretically sound but practically unusable products. The instruction may embody the proper outcomes and strategies, but lack the means to be thoroughly or successfully utilized in its intended environments (Tessmer, 1990, p. 56).

The main research question that was associated with the aims mentioned was stated earlier (refer Chapter 1, Section 1.6) and the secondary research questions were stated in the section that followed (refer Sections 1.6.1, 1.6.2, 1.6.3 and 1.6.4). Qualitative data in the form of interview transcripts, classroom observation field notes and content analyses of instructors' record books, examination folders, teachers' guide and portfolio were collected and data were used in conjunction with the results from the quantitative data to answer these research questions.

To investigate students' learning environment and attitude towards mathematics, the first step taken was to identify the appropriate learning environment and attitude surveys instruments that were available, then to determine the extent of their suitability to the study. The existing instruments were found to be unsuitable for the target group. Therefore, a new instrument was developed. Factors that influence effective teaching and learning and important trends in the current philosophy of teaching and learning were identified and used to contribute to the design and development of the questionnaire.

From the literature review, it was concluded that current trends in technical education lean towards cooperative group learning and a constructivist style student-
centred approach (Brown, 1999; Felder & Brent, 1994). The trend is also shifting towards an authentic real world approach that is relevant to the students; one that is work related, and also one that uses a multi-faceted approach to teaching allowing for uniqueness (Boaler, 2000). Teachers play the role of facilitator and motivator in this setting. In Hong Kong (Wong, 1993), it was reported that students identified the teacher as the crucial element in a positive classroom learning environment, and this is also true elsewhere. Students prefer teachers who keep order and discipline while creating an atmosphere that is not boring, who show concern and who are friendly with students. Information on learning style can also be used to create an effective learning environment.

Since cooperative group learning is an accepted pedagogical approach, it was important to consider student cohesiveness, cooperation and involvement in the classroom. A constructivist style class calls for individualisation and innovation for the construction of knowledge to happen. Lessons should be made relevant to retain students' interest and to motivate them. Motivation also comes from teacher support as mentioned above, and from a clear task orientation.

A new questionnaire was compiled in order to determine:

1) Student Cohesiveness – Extent to which students know, help and support each other.
2) Teacher Support – Extent to which the teacher helps, cares and relates to the students.
3) Involvement – Extent to which students participate, present their work, discuss and express opinions in the classroom.
4) Innovation – Extent to which the instructor plans new, unusual activities, teaching techniques and assignments.
5) Cooperation – Extent to which students cooperate rather than compete with each other.
6) Task Orientation – Extent to which class activities are clear and well organised.
7) Individualisation – Extent to which students are allowed to make decisions and treated differently according to ability, interests and how they work
8) Relevance – Extent to which authentic, real world approaches were used in class and assessments.
Several of the items used were selected from the scales of the existing WIHIC and CUCEI questionnaires. A number of items from these questionnaires were reworded. Another scale entitled relevance was added for which I composed most of the items under this scale. The new questionnaire was given the title College Classroom Environment Inventory (CCEI) (refer Appendix 3A). Efforts to establish the validity of the instruments were carried out using the Cronbach Alpha coefficient, the factor analysis and the eta-squared coefficient after the pilot study. Initially, the ‘actual’ form of this questionnaire was designed using a four-point Likert scale from ‘strongly disagree’ to ‘strongly agree’ without the neutral/unsure option.

In developing the mathematics attitude survey, three distinct scales were taken into consideration. These three scales measure what was considered as central to attitudes, namely:

1) Enjoyment & Interest – items 1, 2, 3, 5, 6, 7, 9, 10, 13, 15, 17 and 19
2) Relevance – items 4, 8, 11 and 20
3) Importance – items 12, 14, 16 and 18

Altogether the survey contains twenty statements with the “Enjoyment & Interest” scale comprising twelve items, the “Relevance” scale and the “Importance” scale having four items each. Seven of the statements were negatively worded (Refer Appendix 3B). They are items number 2, 6, 10, 12, 14, 16 and 18. A five-point Likert scale where each item is responded to with the alternatives Strongly Disagree, Disagree, Neutral/Unsure, Agree and Strongly Agree was used. This questionnaire was piloted together with the learning environment survey.

After piloting with a class of 17 students, the validity and reliability of both questionnaires were determined using the methods described in Section 3.3.3. Not fully satisfied with the results for the CCEI, it was decided that the Likert scale for the learning environment survey should include the middle (neutral/unsure) option to allow students to answer even though they were not sure, or had no opinion. It was also decided that the questionnaire would instead use the five point Likert scale from ‘almost never’ to ‘almost always’ (refer Appendix 3A). Such a scale was thought to give participants a greater choice of response. No changes were made to the Attitude Towards Mathematics survey.

Both surveys were piloted again with a class of 24 technical students in June 2001 after being checked by an “expert” to establish the “face” validity of the
instrument. The outcomes were noted and a number of changes involving rewording were made according to the recommendations of the teacher involved in the pilot study.

Finally, a learning environment survey questionnaire containing eight scales with seven items to each scale was produced. Four of the items, numbered 26, 28, 44 and 49, were negatively worded statements. This questionnaire was used to determine students’ perception of the ‘actual’ and ‘preferred’ learning environment for the initial stage of the study. The ‘actual’ form required students to describe their actual learning environment, while the preferred form required students to describe their ideal learning environment. The instrument was then administered to 239 technical students from the two institutions in Brunei. This took place over a period two weeks in September/October 2001. For the final stage of the study only the ‘actual’ questionnaire was administered.

The statistical techniques used for the validation process of the learning environment and attitudes instruments involved calculation of the:

(a) Cronbach alpha reliability coefficient,
(b) Eta squared statistic, related to the instruments’ ability to differentiate between classes,
(c) Mean correlation coefficient, and also carrying out the
(d) Factor analysis procedure.

In exploring the associations between classroom environment and attitude, simple correlations and multiple regression analysis were used.

The results obtained from this section were considered in relation to the qualitative results obtained from interviews and content analysis in order to assist in the design and development of the package. Classroom observation and interviews with students and teachers took place after the survey questionnaire was administered.

During the interviews, the teachers were asked their opinions on what they considered to be the level of mathematics understanding of their students, what they thought of the existing classroom environment and whether authentic problems and examples should be emphasized. At the same time, students were asked whether they liked mathematics, whether they thought mathematics was important, what they thought of the present classroom environment, what needed to be improved, whether
they liked the way mathematics was taught, and finally their ideas on how to improve mathematics teaching/learning. The validity of the interview was confirmed when some events, claims or statements coincided with the findings from observation and from my experience of teaching there for almost six years. Many times, the interview agreed with the survey findings. I also used the same format and sequence of words and avoid leading questions when interviewing students and teachers to ensure a high degree of reliability (Cohen et al., 2000). I strictly conformed to the guidelines established in order to maximize reliability and reduce any bias.

Sources of bias that should be minimized to achieve greater validity according to Cohen et al. (2000) include:

- The attitudes, opinion and expectation of the interviewer
- A tendency for the interviewer to see the respondent in her own image
- A tendency for the interviewer to seek answers that support her preconceived notion
- Misperceptions of the interviewer regarding what the respondent is saying
- Misunderstandings of the respondent regarding what is being asked.

Therefore, I was careful when conducting interviews to maximise the validity.

3.5 Design and Development Phase

In this phase of study, information of students’ preferred environment gathered from the identification phase was used. In designing the tests and lesson plans, a content analysis of materials (popular text-books and resources from the web) was conducted. The programme guide and the book on syllabus content were also consulted so that the content of the package was compatible with the intended syllabus set by the Department of Technical Education. In trying to enhance students’ motivation to learn mathematics, the ARCS model of motivation by (Keller, 1979) was employed in the design of the package. The four requirements that Keller proposed as necessary to motivate learners are: Attention, relevance, confidence and satisfaction. The meanings of these requirements have been explained in Chapter 2 and will be discussed again in Chapter 5.

The main aim of this phase of study was to use the information and results of the data collected in the first phase to design a teaching and learning package that
would be suitable for the technical students: One that could enhance their cognitive and affective outcomes in mathematics. As the second main research question implied (refer Chapter 1, Section 1.6), careful consideration and skills were required for incorporating the characteristics identified in phase one into the design and development of an effective teaching and learning package. Many effective strategies and techniques needed to be incorporated into the design and development of the package, such as:

- The classroom environmental and motivational factors identified from phase 1 and the literature review,
- Tools (for example graphic calculators and computers) that would assist in the teaching and learning process
- Effective and innovative methods of assessment and teaching techniques
- Integration with other subjects that utilised real-world situations and contexts where mathematics was used.

The following components were developed to be included as part of the package:

1) An introduction to the course – including a background history of the topic, the requirements for this course, the syllabus and the timeline.
2) Recommendations for teaching the course – includes curriculum, teaching, teaching style and assessment.
3) Recommendation for students
4) Lesson plans and lesson plan checklist
5) Activity sheets
6) Worksheets for class work and homework
7) Assessment sheets – includes project work and tests
8) Notes – printed notes were available for students who needed them
9) Student opinion sheet – to enable students to express their views on cooperative learning
10) The Pre-Test and the Post-Test

The detail of each item developed appears in Chapter 5.
3.6 Implementation Phase

During implementation, the two classes (the treatment classes) involved in the use of the package were observed, interviewed, surveyed and were asked to reflect upon the teaching/learning approaches. Students' misconceptions and difficulties in understanding that were identified, and the possible sources of these problems were explained to the students according to what the package prescribed (refer Chapter 6). The teachers from these two classes passed-on their classes to me for eight weeks as I believed that it was best to implement the package myself since I had first-hand knowledge regarding the kind of reforms that were to be implemented.

The aim of this phase of study was to implement the package, to monitor students' progress and reaction to the package, to observe the teaching/learning process that resulted and to ensure that the credibility criteria were adhered to.

Qualitative data gathered were derived mostly from the classroom observation (which were recorded via field notes), students' as well as my reflections, and interviews. Students were interviewed only after classes in order to avoid unnecessary imposition and interruption. Discussions with teachers were ongoing, and the package underwent changes whenever there was a need or recommendation from the other teachers to do so. I kept a journal to record students' as well as my thoughts and experiences with the two classes. I adhered to the quality criteria mentioned by Lincoln and Guba (1985) to ensure validity and reliability regarding the data collected (refer Section 3.8). Fairness requires the constant use of the member-check process, not only for the purpose of commenting on whether the constructions have been received 'as sent' but also for the purpose of commenting on the fairness process (adapted from Lincoln and Guba (1986), pg 247). Students' work was collected and used to assess their understanding of each of the sub-topics (refer Chapter 6, Section 6.3.4.3).

As in phase one of the study, great care was taken to conform to the reliability and validity criteria when interviews and observations were carried out. I would classify the type of observation that was carried out during this phase as semi-structured (Cohen et al., 2000) because I knew what I was looking for from the checklist that was prepared specially for this purpose, (refer Appendix 3C) and also I was attempting to look for any recurrent tendencies or themes that might occur during these times. I was present in the classroom all the time as a participant and
observer as I was the instructor implementing the package to the students and at the same time observing students' reaction and patterns (Cohen et al., 2000). I kept four sets of observational data as suggested by Spradley, and Kirk and Miller as stated in Cohen et al. (2000, p. 313) which included:

- Notes made in situ.
- Expanded notes made as soon as possible after initial observation.
- Journal notes to record issues, ideas, difficulties etc. that arises during field-work.
- A developing, tentative running record of ongoing analysis and interpretation.

3.7 Evaluation Phase

The general aim of this phase of the study was to ascertain the success or otherwise of implementing the teaching and learning package which contained the traits of the reform in mathematics for first-year National Diploma students. This aim required an answer to each of the research questions stated in Chapter 1, Section 1.6 and 1.6.4.

The efficacy of the package was evaluated by determining in what ways the package was successful and if it wasn't, the reasons for this.

The secondary research questions were listed in Section 1.6.4, namely:

i. Did the treatment group develop a better understanding of mathematics after the implementation of the package?

ii. Did the perception of the classroom environment and the attitude towards mathematics of the treatment group improve after the study?

iii. Is there a positive correlation between cognitive achievement of the treatment group and particular aspects of the classroom environment as well as attitude?

iv. What was the overall achievement compared to other groups that were not administered the package?

These questions are all answered in Chapter 7, Section 7.8.

The statistical package SPSS was used extensively to analyse the quantitative data collected. The perceptions of the students' learning environments and attitudes towards mathematics, before and after the implementation of the package were also contrasted and compared using SPSS. Qualitative information was used in refining
the results from the questionnaires and in seeking explanations to patterns identified through the analysis of that data. All qualitative data was analysed on a continuous basis from the start of classroom observations and in accordance with a constructivist research paradigm (Noddings, 1990). Criteria for legitimising qualitative research (i.e. the credibility and the authenticity criteria), as suggested by Guba and Lincoln (1989) and described in Section 3.8, guided the research.

Students’ test scores that were available from the treatment groups and the non-treatment groups were analysed and compared using t-tests and the statistical significances were determined. The test scores from the pre-test and the post-test were also analysed and compared using t-tests. The t-tests were widely used in this study because t-test is a statistic that measures the difference between the means of one sample on two separate occasions or between two samples on one occasion (Cohen et al., 2000). T-tests were usually used for parametric data, when normality can be assumed. In this case, the groups involved in the implementation were from a larger group of 239 students who been surveyed before, where normality can be assumed.

Evaluation was also carried out on students’ mathematical proficiency by examining their cognitive achievement in (defined in Chapter 2, Section 2.4.3):

1. Procedural skills
2. Conceptual understanding
3. Problem-solving abilities.

The questions asked in the pre-test (refer Appendix 3D1) and the post-test (refer Appendix 3D2) were classified in terms of these three categories of fluency in procedural skills, conceptual understanding and problem-solving ability as mentioned above. An ‘expert’ opinion was sought when these classifications were completed in order to establish credibility. The pre-test and post-test were marked and graded according to the marking scheme (Appendix 3E1 and 3E2). The percentage of the overall score from each student was calculated in both tests before comparison were made. The same procedure (taking the percentage score and not the raw score) was applied to analyse and compare students’ performance in each of the mathematics proficiency categories. Paired t-tests and in some cases, one sample t-tests were used to determine the statistical significance of the changes. Results for the analysis can be found in Chapter 7, Section 7.4.1.
I also examined the results to determine associations between the cognitive and affective results by performing a one-tailed simple correlation that produced the Pearson correlation coefficient ($r$), and a linear regression that produced the regression coefficient ($\beta$). Results can be seen in Chapter 7, Section 7.5.

### 3.8 Quality Criteria

In order to draw more accurate and credible conclusions, it is important to triangulate all data collected. “Triangulation”, a term coined by Webb, Campbell, Schwartz and Sechrest (1965), support findings by showing that independent measures of data agree or at least do not contradict each other (Miles & Huberman, 1984, p. 234)

Lincoln and Guba (1985, p. 219, 301) suggest that credibility be addressed by:

- Prolonged engagement in the field.
- Persistent observation.
- Triangulation.
- Peer debriefing.
- Negative case analysis.
- Member checking.

#### 3.8.1 Prolonged Engagement

Lincoln and Guba (1985) describe the importance of prolonged engagement in terms of building rapport and getting behind “fronts” that participants may present. I was present at the college during the intervention process for eight weeks, and four months before that for two weeks to administer the questionnaire as well as to conduct interviews and observations. This was the college where I worked for almost six years before commencing my doctoral studies. I knew all of the teachers in the Mathematics Department very well and most of the other teachers at the college. The students come and go to begin their studies and after finishing their studies and I still knew many of them when I returned for the intervention studies. I immersed myself in the classroom and established rapport and built trust with the students so that they would relate to me. I am confident that they were able to voice out any grievances about teaching and learning with me.
3.8.2 Persistent Observation

The purpose of persistent observation is to identify and then focus upon particularly relevant aspects of the situation under study (Guba & Lincoln, 1989). I observed some classes taught by different teachers at the beginning of the study and I became familiar with their style because I knew all of them and had observed some of them teaching before. As for the classes used for the implementation of the package, since I was the person who taught them regularly, I was able to observe the students’ actions and reactions first hand in the classroom for three and one-half hours a week for a period of eight weeks. There were many occasions where I had the opportunity to reflect upon what had taken place in one class before teaching the same lesson to the other class. Changes were made to improve the lesson for the other class. Consequently, I believe that personally implementing the package for eight weeks was adequate to satisfy the “prolonged engagement in the field” and “persistent observation” criteria described by Lincoln and Guba (1985).

3.8.3 Triangulation

Triangulation is the application and combination of several research methodologies in a study of the same phenomenon. By combining multiple observers, theories, methods, and empirical materials, researchers can hope to overcome the weakness or intrinsic biases and the problems that come from single method, single-observer, and single-theory studies. The credibility of this research was optimised by the use of triangulation. This research used what Cohen and Manion (1994) refer as methodological triangulation because of the various methods employed in the research. It also satisfies the investigator and data triangulation.

3.8.4 Peer Debriefing

Detailed discussions with an independent peer serve both a cathartic function and a stimulus to the researcher to think through the meaning and implications of findings as they emerge (Guba & Lincoln, 1989). In this study, discussions serving this purpose did occur with a very senior teacher who was also the chairman of the Mathematics Development & Evaluation Committee of the Programme Development Section in the Department of Technical Education. This teacher also served as an observer during a number of my classes to comment and ensure that any interpretations were not biased. He also pointed out any discrepancy that was
observed between himself and me, because when I was teaching it was difficult to be aware of everything that was happening in the classroom.

3.8.5 Negative Case Analysis

Negative case analysis is the process of revising working assumptions in the light of hindsight, with an eye toward developing and refining a given assumption (or a set of them) until it account for all cases (Guba & Lincoln, 1989). I was able to refine initial assumptions when contrary findings emerged or abandon other assumptions in the absence of supporting evidence on a few occasions (refer Chapter 8, Section 8.6.4).

3.8.6 Member Checking

Guba and Lincoln (1989) described member checks as the single most crucial technique for establishing credibility. In this study, member checks with each of the original class teachers were carried out from time to time to clarify and explain any questionable perceptions that were encountered during the implementation phase. Each teacher was present during two of the classes to check what their students were doing and took notes of the class happenings. The two teachers were happy to discuss and explain any queries that I had about the class and about any conclusions that were reached. I was always in constant contact with the two teachers during the implementation both in class and in the staff room. One of them was still corresponding with me after the implementation period because he was updating me with students’ project work.

3.9 Ethical Issues

Ethical issues need to be addressed when research is conducted because it is unethical in terms of human relationships to conduct an investigation if the subject is unaware of the real purpose of the study.

The first step that I took regarding this matter was to write (and explain in detail the purpose of study) to the Department of Technical Education, Ministry of Education, Brunei Darussalam to get their permission to conduct the research. The letter allowing me to conduct research arrived promptly and can be seen in Appendix 3F. Next, I approached the Principals and the heads of Department of the colleges where my data collection took place and informed them of my intentions. They were very welcoming and consented to my request. I am fully aware that in other countries
such as Australia, written consent is required from every participant, but this is not the case in Brunei.

Since all of the students involved in the study were above eighteen years of age, I did not give out consent form to their parents to sign. I informed the students involved of my intention when I had the first chance to meet them, and told them that anyone could withdraw from the study whenever they wish if they didn’t want to participate. Nobody withdrew throughout the study period because they did not have anywhere else to go. Even though individual consent is not required in Brunei, I could not expect access to the college as a matter of right (Cohen et al., 2000). I was careful in conducting the study to conform to ethical policy.

According to Cohen et al. (2000), anonymity ensures that information provided by participants does not reveal their identity, therefore I have presented personal data in this study in an anonymous way.

Another concern that I had was whether it was ethical to select only two classes of students to go through what I considered to be a better teaching and learning process and leave the other groups to continue in their normal way. I did not want to impose myself or disturb the college too much and the package was still experimental in nature. Also, I did not have any evidence to claim that the methods and strategies of the package were better than the normal approaches, therefore in my opinion this action was not discriminatory. I discussed this with the Head of Mathematics Department of the college and he preferred that only two classes were to be involved. This worked to my advantage because I could use the other groups for informal comparison purposes (as described in Section 3.3.3).

3.10 Summary (Methodology and Data Collection)

Table 3.2 summarises the methods used at different phases of the research study. The type of data collected, the instrument used, the sample involved, the data collection strategy, the validity criteria and the type of data analysis used are all mentioned in the table. Another table, Table 3.3, was also created in a more detailed manner and describes the methodology used according to each research questions.

The next chapter describes the results and evaluation of Phase One – the investigation of the students’ perception of their learning environment and their attitude towards mathematics at the initial stage. It also includes an examination of the correlation between the learning environment and students’ attitudes scales.
<table>
<thead>
<tr>
<th>Data Collection Strategy</th>
<th>Data Collection Strategy</th>
<th>Data Collection Strategy</th>
<th>Data Collection Strategy</th>
<th>Data Collection Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1. Identifying what students and teachers favour in learning &amp; attitude towards mathematics</td>
<td>Qualitative</td>
<td>CCE, attitude survey</td>
<td>Qualitative</td>
<td>Cooperative Learning survey</td>
</tr>
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<td>P2. Designing the teaching and learning package</td>
<td>Quantitative</td>
<td>Lesson plan Activity sheets</td>
<td>Quantitative</td>
<td>Post CCE &amp; attitude survey</td>
</tr>
<tr>
<td>P3. Implementing the package</td>
<td>Quantitative</td>
<td>Post CCE &amp; attitude survey</td>
<td>Qualitative</td>
<td>Pre-test/post-test comparison</td>
</tr>
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<td>P4. Evaluation of the learning package</td>
<td>Qualitative</td>
<td>Cooperative Learning survey</td>
<td>Qualitative</td>
<td>Project report</td>
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</table>

Table 3.2: A summary of methodology used according to each phase of study conducted

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sample</th>
<th>Sample</th>
<th>Sample</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>259 ND1 students from MTSR &amp; MKB</td>
<td>ND1 /10(14) &amp; ND1/8/08</td>
<td>NDE1 /10 &amp; NDE1/8/08</td>
<td>NDE1 /10 &amp; NDE1/8/08</td>
<td>NDE1 /10 &amp; NDE1/8/08</td>
</tr>
<tr>
<td>ND1 Students and 6 teachers</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:
1. The non-treatment group are the other students taking the same course and their total is about 50. They participated in the Phase 1 of the data collection. Data of their performance for Phase 2 is available.
2. T1 and T2 are teachers from the two treatment classes and they are quite involved as they sit in the class and check the project work and the data collected. One is traditional and another is quite innovative in their teaching method.
### Table 3.3: A summary of methodology used according to the research questions

<table>
<thead>
<tr>
<th>Phase</th>
<th>Research Questions</th>
<th>Data Type</th>
<th>Data collection Strategy</th>
<th>Sample</th>
<th>Validity</th>
<th>Data Analysis</th>
</tr>
</thead>
</table>
| 1     | Q1.1: What were the actual and preferred learning environment situations at the technical institutions?  
Q1.2: What was the students’ attitude towards mathematics and its association with the learning environment?  
Q1.3: What other factors would enhance students’ mathematical understanding and attitude? | Quantitative | CCEI  
Quantitative  
Qualitative | Attitude towards mathematics survey  
CCEI survey  
Interviews, content analysis of relevant documents, observation | 239 ND1 students from MTSSR/MKJB -same-  
18 Students and 6 teachers | Statistical Test  
Statistical Test  
Prolonged engagement, Persistent observation, member check, triangulation | Statistical  
Statistical  
Descriptive |
| 2     | Q2.1 How can the factors that enhance mathematics teaching and learning identified from phase one be used in developing and designing the package?  
Q2.2 What other tools (i.e. graphic calculators, computers etc.) for teaching and learning are appropriate for inclusion in the package?  
Q2.3 What effective and innovative methods of assessment and teaching techniques are appropriate for inclusion? | Literature review  
Content Analysis of syllabus, study guide, etc. | | | Check-recheck with colleagues (member checking) | |
<table>
<thead>
<tr>
<th>Phase</th>
<th>Research Questions</th>
<th>Data Type</th>
<th>Data Collection Strategy</th>
<th>Sampling</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Q3.1 How were the students' and teachers' reactions to the package?</td>
<td>Qualitative</td>
<td>Observation, interviews</td>
<td>ND/ELE/10</td>
<td>Descriptive</td>
</tr>
<tr>
<td></td>
<td>Q3.2 What were the problems faced by students and teachers during implementation?</td>
<td>Quantitative</td>
<td>Project report</td>
<td>T1</td>
<td>Statistical</td>
</tr>
<tr>
<td></td>
<td>Q3.3 Were the standard and quality criteria of the research ensured?</td>
<td>Qualitative</td>
<td>Cooperative-learning activity report</td>
<td>ND/ELE/10</td>
<td>Descriptive</td>
</tr>
<tr>
<td>4</td>
<td>Q4.1 Did the treatment group develop a better understanding of mathematics?</td>
<td>Quantitative</td>
<td>Compare Pre-test &amp; Post-test, Interview</td>
<td>RTE and ELE class</td>
<td>Descriptive</td>
</tr>
<tr>
<td></td>
<td>Q4.2 Did the perception of the classroom environment and the attitude towards mathematics of the treatment group improve after the study?</td>
<td>Quantitative</td>
<td>Post CCEI &amp; attitude survey</td>
<td>ND/ELE/10 &amp; same</td>
<td>Descriptive</td>
</tr>
<tr>
<td></td>
<td>Q4.3 Is there a positive correlation between cognitive achievement of the treatment group and the classroom environment as well as attitude?</td>
<td>Quantitative</td>
<td>Observations &amp; Interviews</td>
<td>ND/ELE/10 &amp; RTE/08</td>
<td>Statistical</td>
</tr>
<tr>
<td></td>
<td>Q4.4 What was the overall change compared to other groups that were not administered the package?</td>
<td>Quantitative</td>
<td>Phase Test result comparison</td>
<td>Others</td>
<td>Statistical</td>
</tr>
</tbody>
</table>
Chapter 4

Phase 1: Identification of Factors

"Educators worldwide often pay too much attention to
students' achievement and too little attention to learning
environments. Having a positive learning environment is
valuable in its own right. Research also reported that
positive learning environments also lead to valuable
improvements in student achievement and attitudes."

Herbert Walberg
University of Illinois at Chicago, USA

4.1 Overview of the Chapter

This chapter focuses on the results and analysis of the first phase of the study,
the identification phase, where investigations were carried out to determine the
classroom environment factors that could enhance the teaching and learning of
mathematics. Students' attitudes towards mathematics and their associations with
each of the learning environment scales were also investigated. The chapter
commences with an introduction in Section 4.2 where the importance of the learning
environment is highlighted. Analyses of the surveys are presented in Section 4.3,
starting with the quantitative data in Section 4.3.1 followed by the qualitative data in
Section 4.3.2. The quantitative data were collected through administering the
learning environment and the attitude towards mathematics survey, and the
validation of both survey questionnaires were carried out using the SPSS package.
The qualitative data collected were from interviews, classroom observations, as well
as content analysis of examination folders, instructor's record book, and teachers'
portfolio, which were analysed and used to explain and support the quantitative
findings.

Section 4.4 presents the interpretation of the results, including those of the
learning environment survey, the attitude towards mathematics survey and also the
association between the results of both surveys. Discussion and conclusions are presented in Section 4.5. This second last section, Section 4.6 revisits the research questions that guided this phase of study and which were listed in Chapter 1 and a summary in Section 4.7 concludes the chapter.

4.2 Introduction

It has been shown in many research studies that motivation is highly related to both academic achievement and the learning environment (Cheng, 1994; Uguroglu & Walberg, 1986). Students' beliefs about the learning environment determine whether or not the classroom climate has a positive effect on their attitude and achievements. Changing the classroom environment to improve students' perceptions improves achievement as well as outcomes such as interest and motivation (Waxman & Huang, 1996). For example, students' positive perceptions of the classroom environment contribute to their developing a favourable attitude toward mathematics (Reynolds & Walberg, 1992). This fact therefore highlights the importance of the analyses of the learning environment and attitudes described in this chapter.

The decision to provide students with their preferred environment was made in an attempt to improve motivation and interest that would hopefully lead to better grades and understanding in mathematics. As one teacher pointed out in an interview:

"We should provide the students with the classroom environment preferred by them. Make an effort to find out what kind of environment they want and try to teach them accordingly. This will definitely see an improvement in students’ motivation and interest in learning mathematics." (Refer Appendix 4B, page 286)

Quantitative data were collected and analysed to determine students' perception of the classroom environment factors that were important for the enhancement of their mathematical understanding and their attitude towards mathematics. Analyses were also performed to find any relationship between attitude and the learning environment. The qualitative data gathered were used to collect more information about factors that could improve students’ cognitive and affective achievement and to explain the results. The results of the analysis of both types of data are presented in Sections 4.3.1 and 4.3.2 respectively.
The following pages describe my efforts to:

1. Validate the survey questionnaires for both the learning environment and attitude.
2. Investigate how students perceive their "actual" and their "preferred" learning environment.
3. Investigate students' attitude towards mathematics in terms of enjoyment/interest, relevance and importance component.
4. Investigate the associations between the learning environment and students' attitudes.
5. Obtain information to assist in the design and development phase of the package and to compare this result with the post-implementation result later.

As mentioned in Chapter 3, the survey questionnaire for both the learning environment and attitude towards mathematics were administered at the same time. The learning environment survey consisted of fifty-six items, made up of eight scales, namely Student Cohesiveness, Teacher Support, Involvement, Innovation, Cooperation, Task Orientation, Individualisation and Relevance. The attitude survey consisted of twenty items designed to probe students' attitude in the three different scales of Enjoyment/Interest, Relevance and Importance. The results and analysis of the survey are given below.

4.3 **Analysis of the Survey**

The analysis of the survey examines the qualitative and the quantitative data components, with the quantitative instruments being validated first.

4.3.1 **Quantitative Data**

4.3.1.1 **Validation of the CCEI Questionnaire**

This study reports the first use and validation of the College Classroom Environment Inventory (CCEI) and its use to compare the actual and preferred responses of technical students in Brunei. Data collected from 23 different classes at the two colleges were analysed in various ways (refer Chapter 3, after Table 3.1) to investigate the reliability and validity of the 56-item survey questionnaire.
Table 4.1: Factor loadings from five refined CCEI scales. N = 233, (Factor loadings less than 0.33 have been omitted).

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Teacher Support</th>
<th>Cooperation</th>
<th>Relevance</th>
<th>Task Orientation</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>.653</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>9</td>
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<td>.671</td>
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<td>56</td>
<td></td>
<td></td>
<td>.564</td>
<td></td>
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</tr>
</tbody>
</table>

Factor and item analyses were conducted in order to identify questionnaire items that should be removed to improve the instrument’s internal consistency, reliability and factorial validity of the eight scales in the CCEI. As shown in Table 4.1, the Student Cohesiveness, Involvement and Individualisation scales were
omitted from these analyses because of the overlap they shared, thus the study was restricted to only five scales, namely Teacher Support, Innovation, Cooperation, Task Orientation and Relevance. The overlap between Student Cohesiveness, Cooperation and Involvement was evident since students appeared to perceive them as concerning the same concept. This I believe was due to the similarity of the statements and because English was the second language of these students. As for Individualisation, students were unfamiliar with this concept, and this made them unsure of their responses to the statements, therefore rendering the scale irrelevant. Several principal component analyses with varimax rotation eventually resulted in the factor loadings as shown in Table 4.1. Item 22, which belongs to the Innovation scale should have been reworded, as were items 24 and 25, which seemed to overlap with the teacher support scale. These three statements escaped detection when the analysis for the pilot study was carried out.

Referring to Table 4.2, the Cronbach alpha reliability index measures the internal consistency of the scale, and here it ranged from 0.73 to 0.84 for the “actual”, and from 0.62 to 0.83 for the “preferred” scales. These results indicate that the scales were satisfactory in terms of their internal consistency, for an acceptable alpha value is 0.7 or greater, but 0.6 is occasionally acceptable (Nunnally, 1978).

The mean correlation of the scale with other scales is the measure of discriminant validity (which measures whether the scales are unique in what they are measuring). The discriminant validity shows an acceptable figure of 0.39 to 0.49 for the “actual” version, and of 0.43 to 0.51 for the “preferred” version. The lower the figure, the better the discriminant validity, and in this case the CCEI appeared to measure distinct, although somewhat overlapping, aspects of classroom environment but maintained a distinction between each scale in each of the five categories in the instrument. The factor analysis results support the independence of the factor scores on the five scales. Similar results can be found in Newby and Fisher (1997), Majeed et al. (2001) as well as Nair and Fisher (2001).

The $\eta^2$ statistic is used to investigate each scale's ability to differentiate between the perceptions of students in different classrooms for the “actual” version. Actually, it is not necessary to find the $\eta^2$ for the “preferred” version because it can be safely assumed that little difference will exist between each classroom in the preferred version since students normally circle the high preference. That little difference existed between each classroom was also due to the classes being made-up.
of students having similar academic background and culture. Regardless of the reason, it can be clearly seen from Table 4.2 that the $\eta^2$ value ranged from 0.15 to 0.20 in the "actual" version, indicating that each scale of the CCEI is able to differentiate between classrooms, whereas the $\eta^2$ value for the "preferred" version that ranged from 0.10 to 0.12 (not significant) shows that the CCEI was not able to differentiate between classes.

Table 4.2: The Cronbach alpha coefficients, mean correlation coefficients and the $\eta^2$ statistics of the CCEI

<table>
<thead>
<tr>
<th>Scale</th>
<th>Alpha Reliability</th>
<th>Mean Correlation</th>
<th>ANOVA ($\eta^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Support</td>
<td>&quot;actual&quot;</td>
<td>0.84</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>&quot;preferred&quot;</td>
<td>0.83</td>
<td>0.46</td>
</tr>
<tr>
<td>Innovation</td>
<td>&quot;actual&quot;</td>
<td>0.73</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>&quot;preferred&quot;</td>
<td>0.62</td>
<td>0.46</td>
</tr>
<tr>
<td>Cooperation</td>
<td>&quot;actual&quot;</td>
<td>0.85</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>&quot;preferred&quot;</td>
<td>0.81</td>
<td>0.47</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>&quot;actual&quot;</td>
<td>0.74</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>&quot;preferred&quot;</td>
<td>0.78</td>
<td>0.51</td>
</tr>
<tr>
<td>Relevance</td>
<td>&quot;actual&quot;</td>
<td>0.76</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>&quot;preferred&quot;</td>
<td>0.78</td>
<td>0.43</td>
</tr>
</tbody>
</table>

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

4.3.1.2 Validation of the Attitude Survey

Factor analyses were also conducted to determine the internal consistency, reliability and factorial validity of the items in each scale of the attitude survey. The factor loadings are as shown in Table 4.3. The scales measured by the attitude survey were Enjoyment/Interest, Relevance and Importance. Three statements were omitted from the original questionnaire due to overlapping.
Table 4.3: Factor loadings from three refined attitudes scales. N = 233, (Factor loadings less than 0.44 have been omitted).

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Enjoyment &amp; Interest</th>
<th>Relevance</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.710</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>.508</td>
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<td>.644</td>
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<td>9</td>
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</tr>
<tr>
<td>18</td>
<td></td>
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<td>.484</td>
</tr>
</tbody>
</table>

Table 4.4 shows the statistical information derived from the attitude survey when the items were analysed into three different categories.

Table 4.4: The Cronbach alpha coefficients, mean correlation coefficients and $\eta^2$ statistics of the Attitude Towards Mathematics survey

<table>
<thead>
<tr>
<th>Scale</th>
<th>Alpha Reliability</th>
<th>Mean Correlation</th>
<th>ANOVA $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>0.83</td>
<td>0.46</td>
<td>.25***</td>
</tr>
<tr>
<td>Relevance</td>
<td>0.70</td>
<td>0.43</td>
<td>.22***</td>
</tr>
<tr>
<td>Importance</td>
<td>0.60</td>
<td>0.34</td>
<td>.13</td>
</tr>
</tbody>
</table>

*** p < 0.001

The Cronbach alpha reliability index ranges from 0.60 to 0.83, indicating that the scales were satisfactory in terms of their internal consistency. The mean correlation of the scale with other scales (measuring whether the scales are unique in what they are measuring) shows an acceptable figure of 0.34 to 0.46. The $\eta^2$ statistics ranged from 0.13 to 0.25 as seen in Table 4.4, indicating that the two scales of Enjoyment & Interest and Relevance are able to differentiate between classrooms,
however the “Importance” scale is not able to do so. The interpretations of these results and their implication will be discussed further in section 4.5.

4.3.2 Qualitative Data

There were two main sources of the qualitative data collected during this phase. One was the interview feedback and the other the classroom observations. Other minor recordings of information come from content analysis of the assessment folders and instructors’ record book. The interview transcript will be considered first.

4.3.2.1 Interview

Six instructors and eighteen students were interviewed during this period. The teachers were interviewed on a one-to-one basis while the students were interviewed in groups of three (refer transcripts – Appendix 4B and 4C).

Teachers

The teachers were asked what they thought of the students’ level of understanding in mathematics when they started their courses. They were also asked what they thought of the students’ learning environment, particularly emphasizing aspects of the authentic instruction provided. The following are comments by various teachers during the interviews:

“They are below average since they came in with C6, D7 or D8 in N-level examinations and we must remember that their syllabus is not as elaborate as the O-level math” – Teacher 1 (Appendix 4B, p. 286)

“Students are weak in basic starting from arithmetic, their knowledge is disconnected, there is no continuity in the syllabus, no attempt to connect things together, no reasoning and understanding, just memorising – rote learning.” – Teacher 3 (Appendix 4B, p. 286-287)

“Students are generally weak when they came, but they improve as they progress because classes are smaller. They are doing better now, depending on attitude. They can succeed, they are not hopeless because they can still do the procedural skill” – Teacher 4 (Appendix 4B, p. 287)

“Students are weak. They don’t usually understand” – Teacher 5 (Appendix 4B, p. 287)
“From the diagnostic test that I conducted, I found that five out of ten students are very weak. Students learn math just to pass exams. After going for holidays and coming back the next year, they cannot remember any more. Mathematics is linked (hierarchical). They should remember what they have learnt. Then there’s the language problem too. From one problem that I gave, they don’t consider the word ‘less’ as discount. Maybe the problems started from kindergarten. Then there’s the big gap between PND and ND1 syllabi. PND syllabus is too simple.” – Teacher 6 (Appendix 4B, p. 287-288)

From the comments on students’ level of mathematical understanding, it is obvious that the students were weak.

Teacher 2 suggested that to avoid having weak students, the entry requirements should be upgraded.

“Entry qualification (entry requirements) should be upgraded so that we have better students” – Teacher 2 (Appendix 4B, p. 286)

This is unlikely to occur because the class enrolments need to be maximised. Therefore, the most effective way is to try and upgrade the students’ performance when they are at the college.

All teachers interviewed agreed that they had to move away from the traditional approach when asked about the learning environment. They recommended more discussion, more collaborative and peer learning:

“Move away from the traditional approach. There should be more investigative kind of problems where we teachers provide the background and students find out (research) how to solve. There should be more discussion, collaborative and peer learning.” – Teacher 1 (Appendix 4B, p. 286)

Teacher 3 believed that the enthusiasm and passion of teachers was most important for instilling interest in mathematics.

“Teachers should show passion while talking mathematics with the students to create interest in mathematics. Through history, this interest can be instilled. Emphasis should be on how to think.” – Teacher 3 (Appendix 4B, p. 287)
According to teacher 6, there was insufficient time available in the school day to consider the classroom environment.

"Classroom environment is very important. Unfortunately, time is not enough. There should be a mathematics lab where we can have charts, project etc. Approach should be more student-centred. Instructors should learn teaching skills by themselves." – Teacher 6 (Appendix 4B, p. 288)

"Move away from the traditional form of teaching, which is teacher centred. Provide more investigative type of activities, which will improve students' understanding of maths. Rote learning is something that should be shelved." – Teacher 4 (Appendix 4B, p. 287)

Through my observations during more than five years of teaching at the college, I believe that although the teachers mention student-centred learning and other reform approaches, their teaching methods were still traditional. Teacher development courses to expose reform approaches are needed in addition to teachers' own research to upgrade their teaching skills.

Instructors seemed to be aware that technical studies should emphasize relevance and authentic problems but they found it difficult to locate materials for these kinds of problems.

"The main focus of math curriculum at MTSSR is application of maths concept to work related problems. This will definitely help students see how math theorem/concept/skills that they learn can be applied or related to work. By doing this, their interest and understanding of maths will definitely improve." – Teacher 1 (Appendix 4B, p. 286)

"Real authentic problem should be encouraged. It can apply to economics, personal problems etc." – Teacher 3 (Appendix 4B, p. 287)

"I don't know where we can find those kinds of problems. Students should first understand maths before they solve real life problems. There is no short-cut otherwise students will lose interest. A good example is in solving simultaneous equations. Oh yes, trigonometric graphs can be fully applied to electrical and electronics engineering but not all the time we can show relevance to them. Some
topics that might not be relevant now still need to be taught for higher studies.” – Teacher 4 (Appendix 4B, p. 287)

“Authentic problems should be introduced from small (meaning from young). They are even more crucial for technical studies.” – Teacher 6 (Appendix 4B, p. 288)

“We have to move to real life problems but there is no resources for these kind of problems.” – Teacher 4 (Appendix 4B, p. 287)

Students

The students were asked whether they liked mathematics and whether they thought mathematics was important. They were also asked about their classroom environment, whether they liked the way mathematics was being taught and whether they saw the relevance of what they are learning. Finally, they were asked to provide their suggestions for a better mathematics classroom.

All students described mathematics as being important but they could not give a good authentic example of an application for their course of study. Most of them did not mind if the teacher did all the talking. My conclusion is that many of the students did not know of other methods of learning mathematics since they were not exposed to them. Some students referred to classes as boring with many formulae to memorize, which shouldn’t have been the case as formulae books were always distributed to them during examinations. Here’s what they had to say:

On whether they like mathematics:

“I quite like mathematics because I don’t have to write a lot in mathematics. What we learn is about the same every time. It has a lot of application and there is always an exact answer. Specific.” – Student 1 (Appendix 4C, p. 289)

“Yes, I like it because it stimulate your mind” – Student 3 (Appendix 4C, p. 289)

“Yes, I love it. It makes my mind active. Even when it is difficult, we could solve it via teamwork.” – Student 5 (Appendix 4C, p. 290)

“It is interesting. It’s playing with numbers and uses a lot of thinking too.” – Student 6 (Appendix 4C, p. 291)
"Yes, it's quite fun. Challenging. I can do math well. It test your mind." – Student 8 (Appendix 4C, p. 291)

"Yes, I like it since primary school. My sister instils that in me." – Student 10 (Appendix 4C, p. 292)

One student liked mathematics because of the specific nature of the subject and because she did not have to write much in this subject. According to her, she was continually learning the same things repeatedly in mathematics. Students also seemed to like mathematics because of the challenge it provided. Others were not as enthusiastic about mathematics:

"I like math when the question is easy and I don't like it when it is hard." – Student 11 (Appendix 4C, p. 292)

"Sometimes. It depends on the topic. I don't like algebra. But what we are learning now is okay." – Student 9 (Appendix 4C, p. 292)

"I just accept it as something we have to do. I have no particular liking or dislike to it. But I know it is important in everyday life" – Student 2 (Appendix 4C, p. 289)

"I like it when the teacher makes it interesting, otherwise I don't, especially when it is hard" – Student 7 (Appendix 4C, p. 291)

"There are a lot of formulae to remember. The way problems are worded is hard to understand too. I hate word problems.” – Student 4 (Appendix 4C, p. 290)

None of the students said they hated mathematics. They seemed to imply that they like mathematics – with conditions. The way mathematics was taught had a great influence on the their interest, as was mentioned by two of the students. Memorizing formulae and word problems made one student hate the problems and therefore he found it difficult to understand.

The teachers' role is very important in creating interest among students or in making them perceive that learning is good in class:

"Our math class now is better than last year. It depends on the teacher." – Student 8 (Appendix 4C p. 291)
“Our teacher now is okay. It is very easy to communicate with him and others in the class.” – Student 9 (Appendix 4C p. 292)

“Teacher shouldn’t just sit. He must attract our attention. Task orientation must be clear. There should be a balance. Teacher teaches and we should also find out.” – Student 7 (Appendix 4C p. 291)

“More detailed explanation from the teacher. The class must be fun. I like the way teacher X taught last year. He taught about history behind mathematics and he makes us laugh too.” – Student 6 (Appendix 4C p. 291)

“Some instructors are boring. They should elaborate more when explaining and they should bring in models.” – Student 5 (Appendix 4C p. 290)

“A teacher cannot be boring. They need to be more friendly.” – Student 9 (Appendix 4C p. 292)

In all of the quotes above, we can see that the teacher played a significant role in creating a favourable learning environment.

On how they like mathematics to be taught, students’ commented:

“Investigation and group work would make us understand better and please concentrate on simple mathematics that is applicable to everyday life.” – This comment from Student 1 (Appendix 4C p. 289) shows the importance of relevance of subject matter and cooperation in class. It also shows the importance of making simple examples/problems but with application that can be seen in everyday life.

“Show more application. Although we were given formulae, I don’t know how to use it. During lessons we should group ourselves and discuss among ourselves” – comment from Student 5 (Appendix 4C p. 291) shows the importance of teaching mathematics in context and cooperative learning.

“Students should show working in front of the class. Then the teacher can correct the mistake that the student made” – comment from Student 6 (Appendix 4C p. 291) shows that students want involvement.
“Team work is better than working individually. If a teacher knows that a student is not good, approach him/her” – comment from Student 7 (Appendix 4C p. 291) shows they prefer cooperative learning.

“There should be more mathematics activities that stimulate thinking” – comment from Student 4 (Appendix 4C p. 290) shows importance of variety in challenging activities.

“Teachers should relate school work and working life. I expect more relevant problems.” – comment from Student 2 (Appendix 4C p. 289) shows importance of relevance.

“A balance of everything. Group work, individual and teacher explanation” – comment from Student 10 (Appendix 4C p. 292) shows the importance of varieties in teaching approaches.

In all of the above transcriptions, we can see that students do look for features that are reform-oriented although they don’t always realise it. Relevance, Cooperation, Task Orientation, Innovation seems to be genuine and important classroom features to them.

4.3.2.2 Classroom Observation

Three classrooms were observed during this period (refer Appendix 4D). Generally, the students were very polite and they listened attentively to the instructors. Most students worked very quietly on their exercises. They could be heard talking very softly to each other and would raise their hands if they had anything to ask the teacher. Almost all classroom teaching was conducted in a very traditional approach – lectures, examples, note taking by the students and practice exercises. Instructors seldom related the subject to the real world, and applications were limited to textbook examples. The nature of classroom instruction confirmed my earlier suspicion that it is still traditional in nature. I had observed some classes before (a year before I started my PhD) when I was helping with the regular classroom observation that was conducted by the Head of the Mathematics Department, and the nature of teaching had not changed significantly since then.

The first class that I observed consisted of six students. The rapport between the instructor and the students was very good and the students seemed to bond very well with each other and the instructor. When asked what they thought of their
mathematics class, most of them said that their instructor was very friendly and was very concerned about their well-being. The students appeared happy to do their own work and conferred with each other and referred questions to the instructor. Despite this, I would still describe the instructional approach as traditional.

I attended the second class during the last period of the day. The class was very quiet and ten students were quietly dealing with a work sheet of mathematics problems. Some students worked individually while others formed groups of two or three. The instructor sat in his chair doing his own work and would only approach the students when they called him. The sheet that they were working on consisted of exercises taken from a textbook used widely for that level of teaching. Although most students seemed to concentrate on their work, it was obvious that their enthusiasm and interest in the task was lacking.

The third class that I observed consisted of fourteen students. The teacher was very lively and went to considerable trouble to try to explain concepts. The students looked amused with the teacher’s antics and seemed to like the lesson very much as he moved around the class helping students during the problem solving activity. When I was teaching at the college and had to attend a meeting, this particular teacher stood in for me. When I returned, my students (who were mature in-service students) told me that they “did not go” for that kind of teaching. According to them, the teacher “over-acted”. But many other students in different classes preferred his way of teaching.

I am able to draw several conclusions from the observation of classroom teaching at the college. Having taught at other institutions in Brunei before, I could say that some of the conclusions made are common in any teaching and learning of mathematics whilst some are unique to technical institutions only:

1. Students were very obliging and would not say anything negative about their teachers.
2. The teaching and learning of mathematics was very traditional.
3. More could be done to motivate and interest the students in learning mathematics.
4. Students cooperate better in classes where teachers show support and willingness to listen to them. Since the students were all above eighteen
years old, they respond better to friendly teachers, although respect
towards teachers is still maintained.

5. Changes in teaching approaches should be carried out slowly and
carefully in consideration of the students’ culture and age.

4.3.2.3 Examination Folders, Instructors’ Record Books and Portfolio

There was a consensus among the teachers that all courses running parallel
(that is those classes taking the same syllabus) would have common phase tests that
were to be set by teachers in turn. There were three phase tests altogether in a year
and they carried 25% each of the total assessment. The tests usually focussed on
procedures and rote learning. Teachers were free to choose any kind of assessment to
make up for another 25% of the whole mark, and many teachers/instructors set
quizzes (another form of assessment of rote learning nature) or marked and gave
grades to the exercises that were solved from worksheets. Homework was seldom
given to students. Another form of assessment used was the integrated project (called
the common skills project) that attempted to integrate almost all subjects taken by the
students in that year. This form of project was introduced in 2001 and could be
considered to be more authentic in nature but only given once a year.

The instructor’s record book was used to record everything that happened in
the class – for example students’ attendance; a detailed scheme of the work given;
the scheme of work assessment and examination marks. This book was sent to the
Head of Department for checking every month and to the Principal every semester.

The teachers’ portfolio contained the syllabus for each course that the teacher
was responsible for – all the tests that were given with the marking scheme, together
with the course outline.

The mathematics department of MTSSR continues to run competitions (as it
did then) such as mathematics quizzes and crossword puzzles to involve more
students and encourage them to be more interested in mathematics. It also conducts
the Mathematics Improvement Programme (MIP) for weak students. The weaker
students are given extra tuition every week so that they might improve their
performances.
4.4 Interpretation of the Results and Their Implication

4.4.1 The Classroom Environment

From the graph shown in Figure 4.4.1, it can be observed that overall, the actual learning environment was favourable (because all scale scores are greater than 3, and 3 is the neutral/unsure response) but that students still preferred an enhanced environment.

![Graph showing actual and preferred learning environment]

*Figure 4.1*: Graph of the actual and preferred learning environment. The x-axis shows the scales while the y-axis shows the mean of each scale.

That the students perceived a favourable environment was, in my opinion, due to the culture of the students in thinking highly of their teachers and being very respectful to them so that they refrained from criticizing the actual classroom environment. Another reason might also be because students had not been exposed to any other environment and thought that what they were experiencing was the norm. The lowest score among the five scales was in the “Innovation” scale (IN) (3.36) and the highest was in the “Cooperation” scale (CO) (3.85). The largest difference between preferred and actual scores was shown in the “Task Orientation” scale (TO), while the other scales showed quite significant differences. This was interpreted to mean that students preferred to be clearer on task orientation than they currently were. The least difference between the actual and the preferred scales came from the
Relevance scale (REL). Students seemed to think that the level of relevance of the lessons they were receiving were adequate.

From the t-test (Table 4.5), it can be seen that there was a significant difference between the means for “preferred” and “actual” version for all of the scales. Therefore, there remained a need to improve on all of the categories.

Table 4.5 also showed the values of the effect size, which describe the practical significance of research finding – that is, whether they are meaningful or important educationally. According to the guideline provided by (Cohen, 1988) effect sizes of 0.2 are regarded as small, 0.5 as moderate and 0.8 as large. The value of the effect size shown in the table can be regarded as moderate for all scales, which means they are not small enough to be ignored and support the significance of the t-values. Therefore, something can be done to address the difference and reduce them.

Table 4.5: Mean, standard deviations, paired t-test value and the effect size for difference between preferred and each actual learning environment scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>SD</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Pref</td>
<td>Actual</td>
</tr>
<tr>
<td>Teacher Support</td>
<td>3.80</td>
<td>4.40</td>
<td>0.69</td>
</tr>
<tr>
<td>Innovation</td>
<td>3.36</td>
<td>3.98</td>
<td>0.52</td>
</tr>
<tr>
<td>Cooperation</td>
<td>3.85</td>
<td>4.47</td>
<td>0.72</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>3.46</td>
<td>4.30</td>
<td>0.60</td>
</tr>
<tr>
<td>Relevance</td>
<td>3.71</td>
<td>4.17</td>
<td>0.62</td>
</tr>
</tbody>
</table>

*** p < 0.001

The highest actual mean score from all the scales was in the cooperation category (3.85) and the lowest value score is the Innovation category (3.36). Overall, students considered that they cooperated well in class and this was reflected in the score for this scale (CO). As for the score on Innovation (IN), it can be assumed that students perceived that they were carrying out the same activities most of the time. Therefore there was a need to vary the instructional method occasionally.

4.4.2 Attitude Towards Mathematics

Table 4.6 indicates that the attitude survey produced positive results (all mean scores are above 3.74 and two are above 4). A relatively high percentage of students (60.27%) seemed to enjoy mathematics and were interested in it although there still existed a small percentage of students (5.78%) who were not interested and did not
enjoy the subject. Since the mean is lowest for the “Enjoyment/Interest” category, more could be done to make the score higher. The relevance scale is even higher at 79.48%, which shows that the students could see the relevance of mathematics in the courses they are taking but there still were a small percentage (3.98%) of students who thought that mathematics was not relevant. The Importance scale is also high (76.98%) which meant that students agreed that mathematics is important to them. This category also produced the highest mean among the three categories.

Table 4.6: Mean, variance and percentage of strongly disagree and disagree (1&2) and percentage of agree and strongly agree (4&5)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D.</th>
<th>1&amp;2</th>
<th>4&amp;5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>3.74</td>
<td>.5477</td>
<td>5.78%</td>
<td>60.27%</td>
</tr>
<tr>
<td>Relevance</td>
<td>4.04</td>
<td>.5912</td>
<td>3.98%</td>
<td>79.48%</td>
</tr>
<tr>
<td>Importance</td>
<td>4.10</td>
<td>.4682</td>
<td>0%</td>
<td>76.98%</td>
</tr>
</tbody>
</table>

4.4.3 Associations Between Attitude and Learning Environment

Associations were explored between the learning environment and attitude towards mathematics (in terms of enjoyment & interest, relevance and importance categories). To accomplish this, both a simple correlation (r, which describes the bivariate associations between an attitudinal measure with each CCEI scale), and the standardised regression weight (β which characterises the association between a measure and a particular environment scale when all other CCEI scales are controlled) were used (Nair & Fisher, 2001). Table 4.7 reveals the outcome.

From the simple correlation (r) value shown in Table 4.7, it can be concluded that all except Cooperation in the CCEI scales were significantly related to the attitudinal measure of Enjoyment & Interest. This implies that students do not seem to associate cooperation with enjoyment and interest. All five scales of CCEI were significantly related to the attitudinal measure of Relevance, and all except Task Orientation in the CCEI scales were significantly related to the attitudinal measure of Importance.

The β weights show that Teacher Support and Relevance were also significantly related to the attitude measure of Enjoyment/Interest and Relevance; only Relevance from the CCEI scales was significantly related to the attitude measure of Importance. This means that the scales Teacher Support and Relevance
are independent predictors of students’ Enjoyment/Interest and Relevance, and the Relevance scale is an independent predictor of students’ perceived importance of mathematics.

Table 4.7: Correlation between learning environment scales and attitude categories in terms of simple correlation (r) and standardised regression coefficient (β)

<table>
<thead>
<tr>
<th>Scale\Coefficient</th>
<th>Enjoyment/Interest</th>
<th>Relevance</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>β</td>
<td>r</td>
</tr>
<tr>
<td>Teacher Support</td>
<td>0.25**</td>
<td>0.19*</td>
<td>0.27**</td>
</tr>
<tr>
<td>Innovation</td>
<td>0.17**</td>
<td>-0.01</td>
<td>0.16*</td>
</tr>
<tr>
<td>Cooperation</td>
<td>0.04</td>
<td>-0.1</td>
<td>0.18**</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>0.14*</td>
<td>0.02</td>
<td>0.15*</td>
</tr>
<tr>
<td>Relevance</td>
<td>0.25**</td>
<td>0.21**</td>
<td>0.28**</td>
</tr>
<tr>
<td>Multiple R Correlation</td>
<td>0.31**</td>
<td></td>
<td>0.35**</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.10</td>
<td>0.12</td>
<td>0.08</td>
</tr>
</tbody>
</table>

** p<0.01, * p < 0.05

The multiple regression correlation coefficients $R$ indicated a significant association between the classroom environment and the three attitudinal outcomes. This strongly supports the conclusion that the nature of the classroom environment influences students’ attitude towards mathematics. The $R^2$ value, which indicates the proportion of variance in attitude towards mathematics that can be attributed to students’ perception of classroom environment was 10%, 12% and 8% of each of the three attitudinal scales respectively. This implies that “Teacher Support” and “Relevance” explain 10% of the variability in the Enjoyment/Interest category and 12% of the variability in the relevance category. “Relevance” was found to explain 8% of the variability in the importance category.

4.4.4 Emerging Themes from the Observations and Interviews

Data collected from the qualitative component of the analyses brought out emerging themes of the actual classroom environment. From the interviews and classroom observations, I concluded that the following were significant:

Students’ Weakness: Most teachers agree that students were generally weak. They have a weak basic knowledge but are willing to work hard.
Instructional approach: All teachers said that there needed to be a change in teaching methods. The traditional approach should be complemented with the recent trends that are more student-centred. Students also suggested many ways that aligned to the current reform methods of teaching.

Motivation to learn: Reforms to motivate students to be interested and to encourage them to have better understanding in mathematics were considered necessary. What should be stressed is relevance and connecting mathematics to everyday life. Abstract academic education not connected to specific career can be satisfying only to academically inclined students.

The teacher factor: The teacher plays an important role in encouraging students to learn in a classroom. There are certain traits of a teacher that students prefer – for example, teachers should try to be likable.

Area of improvement: I could see significant areas of improvement that could be achieved considering the favourable factors existing in terms of small number of students per class, the nature of their course where considerable connection with the real world can be made.

The student factor: Because of Bruneian students’ natural tendency to be a closely knit group, effort could be made to take advantage of this and to make cooperative learning a teaching/learning theme.

4.5 Discussion and Conclusion

The outcomes of the study have demonstrated the versatility of the learning environment instrument to gather information on certain aspects of the classroom. With the correct use and selection of instruments, the information drawn from these kinds of studies can assist in designing the appropriate teaching/learning model for a teaching intervention. Using the instrument again, the effectiveness of this intervention study could then be validated. The qualitative data might then be used to explain part of the results derived from the quantitative investigation.

From the outcomes of this study it can be concluded that the difference between the preferred and actual learning environment is both statistically and educationally significant. (In general, an effect size of +0.25 or more is considered to
be educationally significant (Cohen, 1988)). However there is a greater difference in the "Task Orientation" scale. It is apparent that students preferred to be clearer about what should be done when certain tasks were given. They wanted to be productive in class, to be in a well-organised classroom and to be clear on what to do in terms of assignments and class activities.

The lowest mean score of the five scales measured came from the "Innovation" scale. This could mean that more should be done to vary the activities that students do in class. From my observations of classroom teaching, I noticed that traditional methods were still prevalent. It is still "chalk and paper" in classes, with the students simply working on numbers of problems after a few examples have been demonstrated for them.

It was of interest to see a high mean score for "Relevance" and a small difference between the actual and preferred responses on this scale. I did not observe real world applications and authentic problems taught in classes during my observation of classroom teaching. Students might have a different understanding of relevance and were satisfied with the level of relevance taught.

The information from this survey was taken into consideration and was applied to the design and development of the teaching and learning package. The outcomes were also used later as a preliminary measure and reference for comparison with the results from the other phases of the study.

The attitude survey produced an interesting result. Knowing that the students were generally weak in mathematics, the observation of a very favourable attitude towards mathematics appears to be a contradiction. A number of researchers have commented on such a phenomenon (Gadalla, 1999; Kim & Hocevar, 1998; Lokan & Greenwood, 2000; Odell & Schumacher, 1998; Simich-Dudgeon, 1996; Weinberg, 1995). What could be said here is that the students were aware of the importance of mathematics in the real world and especially in their field of technical education. Bearing in mind that most of the students surveyed were enrolled in courses requiring a strong mathematics background (such as engineering, computer science and construction), they knew that they were expected to do (and still had to do) a considerable amount of mathematics in the course of study of their chosen career. They were also constantly reminded that mathematics is important and that they needed to do well in the subject. This may have led them to answer the survey favourably. This view was confirmed during classroom observations and also during
the interview that was conducted with the students. Being apparently weak in mathematics (as was evident from teachers’ interviews and my almost six year association with the students) doesn’t necessarily make students view mathematics unfavourably. Other studies on attitudes that have been conducted in Brunei confirm this outcome (Khine, 2002; Majeed et al., 2001).

The “Relevance” scale also showed a positive response. Students appear to believe that having a few examples on the application of mathematics in the classroom is what is meant by an authentic, real world application despite the fact that observations of classroom teaching showed very little authentic teaching happening. The teachers only dealt with applications from text-books examples and even that was only “on the surface”. Teachers didn’t go as far as taking a real case and presenting it as an example. From the inspection of the assessment folders, it was found that even the assessment given was not authentic in nature. The assessment system still relied considerably on the exams: The students had continuous assessment in the form of three phase-tests that relied principally on procedural knowledge and rote-learning. The Importance scale also showed a very positive response. Students realised the importance of mathematics in everyday life and to them all because they had been constantly reminded of this since they were in primary school. Despite this, they could not produce a good example of the subject’s importance when asked.

Many students in the interviews considered that they enjoyed learning mathematics since coming to the college because the teachers were more supportive compared to their teachers at high school. The smaller classes (average of 10 students each class, maximum number of students in a class is 20) made them closer and more open to the teachers and they could always gain the teachers’ attention. The teachers are also “friendlier over here”, they said. They also said that the anxiety factor was less here than in the earlier school days. This was due to the secondary school teachers’ determination to “complete” the syllabus because of the end of year public exam. Many students were not aware of other reform approaches to the teaching/learning of mathematics, while many still considered that doing more exercises and problems from worksheets was the most important way to improve mathematics performance.

Some of the suggestions from students on how to improve the classroom learning environments were as follows:
1) Student Cohesiveness – a) More activities should be done in groups
   b) Change members of groups every now and then for different class activities and projects
   c) Change the seating arrangement
2) Teacher Support – a) Teachers should be more helpful and friendly
   b) Teacher should be the source of motivation
   c) Teachers should pay more attention to weaker students
3) Involvement – a) Students should get involved in discussion and not be shy
   b) Teachers try to encourage students to get involved
   c) Students ideas should be heard
4) Innovation – a) more variety in class activities
   b) Not just exercises and tests in classrooms
5) Cooperation – a) Teachers should allot marks for group cooperation
   b) Discourage unhealthy competition
6) Task Orientation – a) Teachers should state clearly what is expected from activities and assignments.
7) Individualisation – a) Allow time for each individual student
   b) Try to listen to each student’s opinion
   c) Don’t differentiate between weak and bright students
8) Relevance – a) Examples should be relevant and appropriate
   b) More real-world examples
   c) More everyday use of mathematics.

Many teachers interviewed believed that students were generally weak in mathematics but were willing to work hard for better grades (Appendix 4B). They believed that they had a good relationship with their students, and because of the small size of the classes, they could provide them with individual attention. They also said that the instructional approach should be towards a more student-centred real world approach, but one teacher particularly said that changes should be gradual. From classroom observations, it could be concluded that rote learning was very popular, while teaching for conceptual understanding was paid only with lip-service.
4.6. Answering the Research Questions of Phase 1

The main purpose of this phase of study as stated earlier was to determine the factors that are important for the enhancement of students' cognitive and affective development. Since the determination of factors can be satisfied by answering all three of the secondary research questions, I will now answer the first secondary research question, that is:

*What were the current classroom environment situations at the technical institutions?*

I concluded from the quantitative and qualitative findings that the current situation of teaching and learning in Brunei technical colleges is still traditional in nature and is in need of changes for better development of students and for the future of technical education itself. As can be seen in Section 4.4.1, although the students rated their current learning environment very highly, they still prefer a more enhanced environment and the difference between the “actual” and the “preferred” environment was statistically significant. This suggests the need for a shift in the learning environment conditions at the technical institutions to ones that are more preferred by the students. It can also be concluded that for the purpose of developing the teaching and learning package, Teacher Support, Innovation, Cooperation, Task Orientation and Relevance should be stressed because students seem to identify these categories as important. Observations showed that some of these features were not present in classrooms. Also, since “Innovation” produced the lowest mean compared to other scales, I think it is important that the package also emphasize this in its instructional approaches.

The second secondary research question was:

*What were the students' attitudes towards mathematics and its association with learning environment?*

It is clear from the survey conducted that students' attitudes towards mathematics were positive and that there exist associations between attitudes and the learning environment. Although students exhibited positive attitudes in almost all of the attitude categories that were determined, as shown in Section 4.4.2, the question arises whether improving the learning environment would further improve students' attitude.
I detected significant association between Enjoyment/Interest, Relevance and Importance with almost all scales in the CCEI when statistical tests were performed (refer Section 4.4.3). This shows the importance of improving classroom environment in order to improve students’ attitude. A closer examination indicates that there was no significant association between Relevance and Cooperation and Importance with Task Orientation scale of the CCEI.

The other secondary research question for this phase was:

*What other factors would enhance students’ mathematical understanding and attitude?*

The answer to this question can be obtained from the emerging themes arising from the classroom observation and interviews in Section 4.4.4, especially in terms of the instructional approach. The traditional approach should be complemented with the recent trends that are more student-centred. The literature review of Chapter 2, Sections 2.3 and 2.4 listed the appropriate model for the technical students in Brunei as well as the preferred classroom respectively. The sections suggested a cooperative classroom that is constructivist in nature as well as encouraged a variety of innovative teaching methods to motivate and to address students’ various learning styles. Students’ suggestions on how to improve the learning environment in Section 4.5 are also valuable considerations for the enhancement of the classroom environment.

Other features that students considered were important in the further understanding of mathematics were: More problem-solving, a balanced approach and fun-loving teachers. These considerations were evident from the interviews that were conducted.

With the three secondary research questions answered, I have listed all the factors that are deemed important in the enhancement of students’ cognitive and affective ability, and together with the recommendations from Sections 2.4.1 and 2.4.2 (refer Chapter 2, Literature Review), have thus answered the main research question for phase 1:

*What factors are important for the enhancement of student’s mathematical understanding, attitude and motivation?*
4.7 Summary

From the results of this phase, it is obvious that more could be done for the improvement of mathematics teaching and learning at Bruneian technical colleges in terms of classroom environment. Teachers and students all seemed to agree that something ought to be done to improve certain aspects of teaching and learning in order to enhance mathematical understanding and attitude.

In the next chapter, I will describe how the information from this chapter was used to design and develop the teaching and learning package that was introduced to enhance the mathematical understanding of the technical students in Brunei.
Phase 2: Package Design and Development

The aim of education should be to teach us rather how to think, than what to think - rather to improve our minds, so as to enable us to think for ourselves, than to load the memory with thoughts of other men.

-Bill Beattie

5.1 Overview of the Chapter

This chapter focuses on the second phase of the study during which the teaching and learning package was designed and developed. The chapter will examine why certain designs were favoured based on certain findings that were described in the previous chapter. The design assisted in the development of the package for the enhancement of mathematical understanding of the first year Diploma Technical students in Brunei. The chapter also discusses a number of models on which the instructional design was based. The learning environment factors that foster motivation, and the aspects of motivation that the teaching/instructional methods of selected topics attempted to address are also discussed. Another topic addressed is the issues in mathematics education that especially affect technical students, for example, curriculum and assessment, the use of teaching resources, appropriate use of technological tools and the provision of appropriate environments for learning mathematics. This chapter would also answer the main research question for this phase of study:

How can the characteristics identified in (a) and from the literature review be used to design and develop an effective teaching and learning package that will enhance students' cognitive and affective traits?
5.2 Introduction

A programme designed for elementary students would not be suitable for secondary students and vice versa – for instance, the needs of technical students might not be the same as the needs of A-level students. Understanding the learning needs of particular groups was an essential part of the design process, for example, if teachers are concerned about preparing students for a final grade test, they are likely to be less amenable to learning about innovative approaches or content that is not included in those tests. That is why the identification phase is very important.

The purpose of instruction is to enable people to learn, and the goal of instructional designers is to make learning more successful (easier, quicker and more enjoyable) (Reigeluth, 1999). The manner in which students encounter mathematical ideas can contribute significantly to the quality of their learning and the depth of their understanding. The most important thing to consider when designing instruction is to know what and when to use particular methods of instruction. Again, according to Reigeluth (1999), methods of instructions are usually designed around the learner, content, goals, learning environment, teacher and resources.

Reigeluth’s (1999) three guiding principles that were considered during the design and development phase of the package were:

1) There must be a change involved in both students and teachers
   - Students must learn and understand more about learning and themselves.
   - Teachers must learn and understand more about learning, teaching, themselves, students and subject content.

2) Learning with understanding involves aspects of cognition (thoughts), affect (feeling) and behaviour.
   - Learning with understanding results from a process of purposeful inquiry leading to an outcome of adequate meta-cognition comprising two components, reflection and action. Reflection is thinking and feeling. Asking “why am I doing this?”; “what am I doing”; selecting procedures to answer these questions, evaluating the results of applied procedures and making decisions of what to do next.
   - Action is doing. Action involves observing, manipulating, applying procedures and enacting decisions
(The purpose of any meta-cognitive strategy is to generate information that will help people to be knowledgeable about, aware of and in control of what they are doing.)

3) Change must provide for cognitive and affective growth.

- The academic benefits that accrue from enhanced meta-cognition — improved performance and understanding — are matched by affective benefits such as greater satisfaction, fulfilment, a sense of purpose, control and self worth. It is unlikely that strategies learned algorithmically and implemented mechanically will enhance learners’ level of meta-cognition. What is needed is for the person undergoing change to be sufficiently intellectually and emotionally challenged by the activity to direct a process of purposeful inquiry.

- Four major conditions for successful and purposeful inquiry are — time, opportunity, guidance and support.

I dwelt and seriously reflected on this matter during the process of designing and developing the package. For students to learn and understand more about learning and themselves, I encouraged them to gain understanding of the processes necessary to become effective learners — such as trying to identify their learning style. A teacher should also be knowledgeable in many areas of learning, especially learning styles, in order for students’ acquisition of knowledge to be effective. A teacher should talk about study skills and learning styles now and then in between delivering lesson content.

As was mentioned earlier, since learning with understanding involves all aspects of thoughts, feelings and behaviour, the package needed to stress the learning environment and motivation besides content and delivery methods.

5.3 Designing the Package

This section answers the first secondary research question that was asked in this phase of study:

How can the factors that enhance mathematics teaching and learning identified from phase 1 and the literature review be used in designing and developing the package?
The purpose of the design phase was to outline lessons in complete detail before actually developing the material. It was a process of specifying how certain subjects or topics are to be learned. The package was designed according to the guiding principles that were established through understanding what the students preferred (from the interviews and surveys in phase one), what the literature declared as the current trends in education (including technical aspects), and the approaches that had been tried successfully in the past. Before designing the package, I analysed and also considered what was to be achieved, what the teaching objectives were, the students’ needs, qualifications and entry skills. I specifically asked myself:

1. For whom is the package designed? (analysis of the learner)
2. What goals are to be achieved? (writing performance objectives)
3. What contents are to be learned? (analysis of content and context in which learner will learn it – instructional analysis)
4. What teaching methods and aids are to be used? (developing instructional strategy)
5. How are the results to be tested? (developing assessment instruments)

Five scales (components) had been identified from the preferred classroom environment survey in phase one of the study (refer Chapter 4, Section 4.5.1) as those that students preferred to be more enhanced: Teacher support, cooperation, innovation, task orientation and relevance. These scales were considered so that they could be part of the environment to trigger each of the motivation components. Each classroom environment scale was incorporated into each motivational component of the ARCS (attention, relevance, confidence and satisfaction) that was discussed in Chapter 2, Section 2.3.2.3):

a) Attention: Keller recommends that instructors vary the instructional presentation to attract attention and to keep the students interest from waning (Driscoll, 2000). One of the effective methods of gaining attention is through active and collaborative learning methods.

b) Relevance: When something is familiar to the student, the more relevant it becomes. It is the instructor’s task to provide various options to assist in connecting the students especially for students who do not immediately see relevance (Driscoll, 2000).
c) Confidence: Confidence is gained as students are successful. Beliefs in one’s capabilities can motivate students in particular ways. People with strong beliefs in their capability will choose to engage in a task while those who do not have such strong beliefs tend to avoid the tasks. It is important that tasks are sequenced from easy to hard to assist students to gain confidence.

d) Satisfaction: Learners should have the opportunity to apply new skills, be recognized for acquiring the new skills and gain satisfaction knowing that the outcomes are based on materials that were consistently delivered (Driscoll, 2000). A teacher should provide challenges that the students can tackle for satisfaction to occur.

Design recommendations discussed in the literature review of Chapter 2 (Sections 2.4 and 2.4.1) were referred to frequently to determine their suitability to the students’ culture and disposition. Table 5.1 shows the strategies recommended by Driscoll (2000) in order to address each of the motivational components mentioned. I have extended Driscoll’s table by adding in the third column, to include the learning environment components that were emphasized.

Table 5.1: Instructional strategies for stimulating motivation as suggested by the ARCS model.

<table>
<thead>
<tr>
<th>Component of Motivation</th>
<th>Corresponding Strategies</th>
<th>Learning environment component emphasised</th>
</tr>
</thead>
</table>
| Gaining and sustaining attention | • Capture students' attention by using novel or unexpected approaches to instruction.  
• Stimulate lasting curiosity with problems that invoke mystery.  
• Maintain students' attention by varying the instructional presentation | • Teacher Support  
• Cooperation  
• Innovation  
• Task orientation  
• Relevance |
<table>
<thead>
<tr>
<th>Enhancing relevance</th>
<th>Teacher Support</th>
<th>Cooperation</th>
<th>Innovation</th>
<th>Task orientation</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase the perception of utility by stating (or having the learners determine) how instruction relates to personal goals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Provide opportunities for matching learners' motives and values with occasions for self-study, leadership, and cooperation.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase familiarity by building on learners' previous experiences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building confidence</th>
<th>Teacher Support</th>
<th>Cooperation</th>
<th>Innovation</th>
<th>Task orientation</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a positive expectation for success by making clear instructional goals and objectives. Alternatively, allow learners to set their own goals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide opportunities for students to successfully attain challenging goals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide learners with a reasonable degree of control over their own learning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generating satisfaction</th>
<th>Teacher Support</th>
<th>Cooperation</th>
<th>Innovation</th>
<th>Task orientation</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create natural consequences by providing learners with opportunities to use newly acquired skills.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the absence of natural consequences, use positive consequences, such as verbal praise, real or symbolic rewards.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure equity by maintaining consistent standards and matching outcomes to expectations.</td>
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<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The five-phase cycle of classroom activities which were used in lessons on each sub-topic were:
• Launch: Gaining attention

Lessons began with an intriguing question, the main purpose of which was to gain attention and hold the interest of the students (refer example in Lesson Plan 1 and 2, Appendix 5C1 and 5C2). The type of question was of a very basic, real-world kind that the students were familiar with but would not usually think about in depth. It also provided an opportunity for the teacher to assess student knowledge and to clarify directions. All five learning environment components were addressed; the teacher acted as director and moderator; the students would work cooperatively via discussion; the question asked was relevant; the task orientation was clear, and the methods of questioning was innovative.

• Explore: Gaining and sustaining attention and emphasis on relevance

Classroom activity then shifted to investigating relevant focused problems and questions related to the launching phase by gathering data, looking for patterns, constructing models and meanings, and making and verifying conjectures. As students collaborated in small groups, the instructor circulated from group to group providing guidance and support, clarifying or asking questions, giving hints, providing encouragement, and drawing group members into the discussion to help groups work more cooperatively. The unit materials and related questions posed by students focused the learning: The instructor acted as a facilitator; the students worked cooperatively exploring; innovative activities were carried out; activities were relevant, and tasks were clear and carefully planned.

• Checkpoint: Gaining and sustaining attention and relevance

In this phase students were expected to summarise important ideas or to further explore a topic if competing perspectives remained. Varying approaches and differing conclusions that could be justified were encouraged. The instructor was to be a moderator; cooperation was still emphasized; the task was clear; innovative ideas were encouraged and relevance was emphasized.

• Apply: Relevant, building confidence and generating satisfaction

Students were given relevant tasks related to lesson objectives to complete in groups. The instructor circulated in the room assessing levels of student
understanding. The instructor was to be an intellectual coach. Each group was then asked to send a representative to present their solution to the whole class (cooperation to be very important here), the task was clearly defined, the applications were all relevant, and innovative ideas of solving problem were encouraged.

- Practice: Building confidence and generating satisfaction

This phase was designed to further actively engage students in investigating and making sense of problem situations; in constructing important mathematical concepts and methods; in generalizing and proving mathematical relationships and in communicating students' thinking and the results of their efforts. Students were also expected to consolidate their understanding and new skills through practice. Again, the instructor acted as facilitator; students could still work cooperatively whether in class or at home (they could take unfinished problems as homework); relevant problems were still emphasized, tasks were clearly defined and students could use innovative methods in solving problems.

Recommendations from Chapter 2 (Section 2.4.1) provided the model for the instructional strategies incorporated into the package. Many classroom activities were designed to be completed by students working together collaboratively in heterogeneous groupings – in pairs or in groups of three or four. Following are a number of the design questions that I posed and examples of the supporting strategies that I developed which were used in designing the package (refer Table 5.2).

**Table 5.2: Design questions and the examples of supporting strategies**

<table>
<thead>
<tr>
<th>Design Questions</th>
<th>Examples of Supporting Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attention:</strong></td>
<td></td>
</tr>
<tr>
<td>1. How students' attitude of inquiry be stimulated?</td>
<td>• Launch with an intriguing question that increases curiosity about the topic</td>
</tr>
<tr>
<td>2. What can be done to capture student attention for this topic or content area?</td>
<td>• Create student curiosity by making lessons interesting and relevant • Use technology (computer, calculator) especially interactive website</td>
</tr>
<tr>
<td>Design Questions</td>
<td>Examples of Supporting Strategies</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>Attention:</strong></td>
<td></td>
</tr>
</tbody>
</table>
| 3. Once attention is captured, how can students’ interest be maintained? | • Teacher should be supportive and maintain a cordial relationship with the students  
• Have varieties of activities/teaching methods to prevent boredom  
• Task should be well organised and systematically presented so that students know exactly what to do |
| **Relevance:**   |                                   |
| 1. What existing knowledge or experiences do students have related to this topic? | • Make an effort to diagnose students’ prior knowledge and problems  
• Integrate mathematics with other subjects as much as possible  
• Try as far as possible to teach contextually  
• Source out material that are related |
| 2. How can students’ present knowledge or experience be related to the topics? | • Find out their career goals  
• Create intentional connections between mathematics and their intended profession |
| 3. How can students’ future profession or goals be related to the topic? | • Give explicit guidance on the expected outcomes as well as how projects/activities will be evaluated  
• Let students know the likelihood of success given varying amount of effort |
| **Confidence:**  |                                   |
| 1. Do students fully understand my expectation and course requirements? | • Give explicit guidance on the expected outcomes as well as how projects/activities will be evaluated  
• Let students know the likelihood of success given varying amount of effort |
<table>
<thead>
<tr>
<th>Design Questions</th>
<th>Examples of Supporting Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Confidence:</strong></td>
<td></td>
</tr>
</tbody>
</table>
| 2. Was student composition and course level considered when designing the classroom activities? | • Evaluate whether assignments are challenging enough for the course level.  
• Assess level of instructor support at each level |
| 3. Were students appropriately supported in unstructured activities so that they are challenged to achieve the objective, but not overwhelmed by the activity? | • Give enough guidance to remove unnecessary anxiety, at the same time achieve challenging learning objectives |
| **Satisfaction**                                                                |                                   |
| 1. Were students provided with sufficient and appropriate opportunities to demonstrate their achievement of course objective? | • Review the quantity of examinations, activities and projects.  
• Discuss strategies with other instructors who has had the same experience |
| 2. Was students’ achievement in ways other than course grades?                   | • Always give encouragement to the students  
• Exhibit quality student work  
• Be generous with praises |
| 3. Were culminating exercises considered to help students understand how their course experience relates to other courses of their work environment? | • Always try to give projects and exercise that can be integrated with other courses.  
• Always show application exercise as part of the students’ revision strategy |

### 5.4 Developing the Package

The development phase built on the design phase and the analysis of appropriate strategies that was mentioned and explained earlier. The purpose was then to generate the lesson plans and materials. The instructional methods, along with all media that would be used in the instructions and any supporting documentations, were developed during this stage. The development involved matching learning goals to appropriate activities, determining the best methods for
formative and summative evaluation of each sub topic, content development (writing content to be delivered in specified format), developing support materials (for example lecture notes) and developing assessments. The instructional materials that were developed for this package included:

1. An introduction to the course – including a background history of the topic, the requirements for this course, the syllabus and the timeline. (Refer Appendix 5A)

2. Recommendations for teaching the course – addressing curriculum, teaching, teaching style and assessment matters. (Refer Appendix 5B)

3. Lesson plans ((Refer Appendix 5C1 – 5C11)

4. Activity/Exploration sheets (Refer Appendix 5C1 – 5C11)

5. Worksheets for class work and homework (Refer Appendix 5C1 – 5C11)

6. Assessment sheets – includes project work and tests (Refer Appendix 5C1 – 5C11)

7. Extra Activities (Refer Appendix 5C1 – 5C11)

8. Support material – notes if they are needed by the students as reference

9. Student opinion sheet. (Refer Appendix 7C)

Once the package was developed, it was checked and then revised with the improvements that were made according to the recommendations of the instructors involved in its trialling. More refinements were made during the implementation stage based on the feedback from instructors and students.

5.4.1 The Pre-Test and Post-Test

During the design stage of the study, communication with several mathematics instructors at Sultan Saiful Rijal Technical College was ongoing. Their opinions were sought in order to determine the suitability of the items in the pre-test and the post-test. This was the face validity check.

The pre-test and post-test were developed concurrently and I endeavoured to make them as parallel in nature as possible. The pre-test was designed to act as a diagnostic test, the purpose of which to investigate students’ pre-understanding of the subject (prior knowledge) and also to detect students’ misconceptions, if they existed. Any recurring error patterns were to be noted and explained in class. The
pre-test was also used to compare students' achievement after implementation of the package. The post-test was constructed to about the same level of difficulty as the pre-test with one extra question in Section B, in order to allow for the expectation that students would perform better after the topic was taught (this eventuated as a fact because after about one and a half months of instruction, many students certainly knew more than they knew before). There was also the possibility of students maturing significantly (as stated in Chapter 3 (Section 3.2) and by giving them an extra thinking question these factors were addressed. The results from this test were used to determine any significant improvements that occurred.

The two tests were analysed on the basis of gained score in three crucial categories that were considered sound measures of students' mathematics proficiency, namely:
   a) procedural skills,
   b) conceptual understanding,
   c) problem solving abilities.

### 5.4.2 The Lesson Plans

A search of the literature revealed some interesting ideas for teaching a number of content areas – for instance, proof for the Pythagoras' theorem. These ideas were combined with my own and other local instructors' ideas in each of the following content areas:

- Radian Measure
- Trigonometric ratio & graphs
- Trigonometric identities, Sine Rule & Cosine Rule & the area formula

Details of the syllabus appear in Appendix 5D

Each lesson was characterised by five phases: *Launch, explore, checkpoint, apply and practice*. The lesson started with *launch* where the teacher would pose a question or problem for the students to think about, a strategy designed to stimulate or trigger interest among the students. The next stage, *explore*, saw the students working through student centred activities from activity sheets, with each topic taught in groups of three and four students. After finishing this work, students would then present their group’s work to the class and make a summary of their findings in
a stage referred to as checkpoint. In the apply stage, students were given work-sheets with numerous questions connected to the real world. They were encouraged to carry out several practical work exercises outside of class to assist in obtaining the answers to these questions. Later, they were again asked to present their solution to the whole class. Any unfinished problems and additional exercises were given as homework for practice.

The features of each lesson included:

- Real life Problem Solving

Each lesson emphasized the application of mathematics to real world situations that were relevant to the students’ course of study and everyday life.

- Balanced Instruction

Besides emphasizing conceptual and contextual approaches, some proven traditional instructional approaches were still used. Practice was stressed here because I strongly believe that procedural fluency is important. It sometimes led to improved conceptual understanding and problem solving ability because all three skills are interconnected. Paper and pencil skills are practical in certain situations, are not necessarily hard to acquire and are widely expected. The only drawback is when procedural proficiency is overemphasized with inadequate attention given by teachers to the conceptual basis for the procedures (Isaacs, 2001)

- Appropriate Use of Technology

This sub-section answers the second secondary research question posed in Chapter 1, Section 1.6.2:

What other tools (for example graphic calculators and computers) are appropriate for inclusion in the package?

Lessons included many activities where learning was enhanced through the use of a scientific calculator. Graphic calculators have not been adopted in Bruneian schools. Computers were also used when looking for reference material and completing the given project, and links to interesting mathematics sites were given occasionally with students being encouraged to visit these sites. The interactive activities found at the sites helped students to
have a better understanding of certain topics. Microsoft Excel and PowerPoint were also used by students to complete their projects.

- **Cooperative Learning**

  Students were divided into groups of four. Several activities were assigned to the students to be completed within the group. Besides this, lessons included time for whole group instruction as well as for individual learning.

- **Varieties of Activities**

  I attempted to create variation in the activities that the students did in order to avoid boredom. Having interesting and motivating studies was something I considered very important.

- **Non-Traditional Assessment**

  In line with my resolve to vary the assessment methods, the type of assessment used to test the students understanding of each topic was unique each time.

A typical lesson plan contained the following information:

```
Lesson XX

Approximate time:

Title:

Overview:

Aim (Objective):

Key skills emphasized:

Approach (Activities/Procedures):

  1) Launch:
  2) Explore:
  3) Checkpoint:
  4) Apply:
  5) Practice/Homework:

Figure 5.3: A typical lesson plan
```
5.4.3 Activity and Exploration Sheets

The activity sheets were developed to accompany the lesson plans. Each activity was designed for a student-centred, constructivist style of learning (refer Appendix 5C1 – 5C11).

5.4.4 Worksheets

The worksheets that were developed consisted of introductory exercises (simple problems), moderate exercises of medium level difficulty, advanced exercises (harder problems) and investigative type of problems that are applicable and connected to everyday, real world situations. Some of the questions from the worksheet were solved in class while many of them were for the students to attempt on their own for practice and as homework (refer Appendix 5C1 – 5C11).

5.4.5 Assessment Sheets

This section and the non-traditional assessment mentioned in Section 5.4.2 will answer the third secondary research question:

What innovative methods of assessment are appropriate for inclusion?

Assessing what students know and are able to do is an integral part of the teaching and learning process. To test students understanding of the material that they had learnt, they were given different types of assessments tasks for different topics, as shown in Table 5.4.

Table 5.4: The assessment types according to the topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Assessment type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radian Measure</td>
<td>Concept map</td>
</tr>
<tr>
<td>Trigonometric ratio and graph</td>
<td>Project – “Trigonometric Waveforms Around Us.”</td>
</tr>
<tr>
<td>Trigonometric Identities, Sine and Cosine Rule</td>
<td>Graded application problems</td>
</tr>
</tbody>
</table>
The project was what could be termed as an authentic assessment task because of the nature of data that they were expected to collect, and the authentic situation they were placed in when carrying out the project.

Besides the formal assessments administered as mentioned above, students were also assessed informally in terms of process, content understanding and disposition towards certain topics. Group and individual assessments were carried out as students shared their findings and as they worked individually on certain problems and activities. As mentioned earlier, they were given a post-test and they also sat for the phase test at the end of the unit.

5.4.6 Other Materials Developed

Other materials that were also developed were:

- An introduction to the course – the introduction was developed to provide the students with an overall picture of what the topic involved, the syllabus that would be covered, the objectives, the timeline, the course strategy and the assessment, plus a brief history and introduction to trigonometry (refer Appendix 5A).
- Recommendations for teachers on how to deliver the course and for students on how best to learn from the course (refer Appendix 5B).
- Student opinion sheets – forms were provided for feedback from students on how they felt about certain activities conducted and as a source of data for this research (refer Appendix 5D).
- Notes for reference – these notes were available for students who felt that they needed to read more on the topics discussed and taught in class.
- Opinion Sheets – Examples of completed opinion sheets can be viewed in Appendix 7C.

5.5 Summary

This chapter has examined how the learning environment factors identified in the previous chapter were incorporated into the design and development of the teaching and learning package. The teaching and learning strategies stressed were those that were expected to enhance the motivation of the students according to the four components of the ARCS model. I endeavoured to enhance attention, relevance,
confidence and satisfaction by concentrating on what could be done via teacher support, cooperation, innovation, task orientation and relevance to the learning environment variables.

I also endeavoured to include computer use into lessons wherever appropriate, and tried to make the lessons as enjoyable and authentic as possible by connecting problems to real world situations. I strove to make lessons as hands-on and as contextualized as possible because I believe that contextual learning motivates students to make connection between knowledge and its application to their lives. The materials used were designed with the intention of encouraging students to explore, conjecture and test ideas. Cooperative learning was the main feature of most lessons since it provides rich and varied opportunities for the developing and sharing of learning skills. Assessments were also made more authentic and non-traditional: Besides the normal tests that the students were given at the end of each topic, they were assessed via project work, assignments, class presentations and concept mapping. The project work given to the students was of an integrated kind: Students were required to incorporate science, engineering, English, mathematics and technology in order to produce a satisfactory product.

The next chapter will describe and discuss the implementation of the package.
Chapter 6

Phase 3: Package Implementation

'What we want... is for students to get more interested in things, more involved in them, more engaged in wanting to know; to have projects that they can get excited about and work on over long periods of time, to be stimulated to find things out on their own.'

Howard Gardner

6.1 Overview of the Chapter

This chapter reports the implementation stage of the package that was designed and developed in the manner described in Chapter 5. The Chapter also answers the main research question posed for this phase of study, namely:

How should the package be implemented?

The implementation phase took place over a period of eight weeks at Sultan Saiful Rijal Technical College, Brunei, commencing on the 3rd of January 2002. The chapter commences with an introduction that discusses some basic mistaken assumptions about how people learn (Berryman & Bailey, 1992). I considered these assumptions as underlying traditional pedagogical practices that are still widely adopted by mathematics instructors in Brunei.

The chapter then discusses the teaching and learning process that took place during the implementation of the package. I have divided the description of the process according to the sequence of topics that were taught. There were three main topics and each of them incorporated a different assessment mode. The three topics were:

- Radian measure
- Trigonometric ratio including graphs
- Identity, sine and cosine rule and the area formula
After describing each lesson, I also describe what happened in the classroom from the perspective of my observation of students' reactions and also from my reflections and interpretations of events during the lessons after the topics were completed. I would look at my reflection again after each topic was completed and add in any other comments and entries so that I did not neglect anything important. Students' responses gathered from student opinion sheets are also discussed. In addition, I also report on the formal and informal types of assessments that were conducted to gauge students' understanding.

This chapter also deals with formative evaluation, which is a method of judging the worth of a program concurrently with the conduct of the program. The description focuses on the processes involved. Section 6.4 presents a view of a lesson by way of a narrative followed by an interpretive commentary on the narrative. Finally, a summary concludes the chapter in Section 6.5.

6.2 Introduction

In my experience in Brunei (which might also be true in other places), I observed that many educators tend to manipulate the learning environment according to their own experience as students. They teach the way they have been taught, usually through a traditional norm – the lecture method. The teaching method normally used by instructors in mathematics is "chalk and paper" (for instance, the instructor usually explains the topic and how formulae are derived, provides examples by showing how to solve a few problems, and then sets exercises where students are asked to complete). This kind of teaching seemed to benefit only abstract learners, and because not many Bruneian technical students are abstract learners, the teaching and learning of mathematics needs to be reformed.

According to Berryman and Bailey (1992), learning situations become ineffective because of some mistaken assumptions about how people learn. Those assumptions are:

1) Learners are passive receivers of knowledge.
2) What is learned should be broken down into separate pieces
3) Getting the right answer is the purpose of learning
4) Skills and knowledge should be acquired independently of their context.
Constructivist approaches differ from these traditional approaches to teaching and learning. Constructivism is a learning theory about which every mathematics instructor should know. To increase their teaching effectiveness in the classroom, many teachers need to change their views on some of the basic assumptions about how people learn. I avoided making these erroneous assumptions during the implementation period and allowed students to construct their own knowledge; allowed them to learn by looking at the whole picture and by integrating mathematics with other subjects; allowed them to learn by considering all possible answers, and assisted them to learn new topics in context.

Berryman and Bailey's list of erroneous assumptions leads to learning characterized by:

1) A lecture mode and not an active engagement of learning
2) Control over learning in the hands of the teacher
3) A curriculum of disconnected items, tasks, and subtasks taught independently of the contexts
4) A focus on correct responses rather than processes by which responses are generated

Berryman and Bailey (1992) further suggested that this kind of education and training creates learners who:

1) Are overly dependent on their teachers, lack confidence in their ability to function independently, and lack the skills possessed by people who know how to learn.
2) Can come up with (or play back) correct answers but do not know how to approach problems, don't understand the principles involved in their answers, and revert to their own naive conceptions as soon as they are out of the classroom.
3) Are passive, bored, inattentive, and uninvolved in their learning.

To enhance the learning capacity of students (especially technical students in Brunei), instructors should create an environment that requires them to be creative, make decisions, solve problems and know how to learn and reason. The emphasis on collaborative learning that requires students to work in teams, teach others, negotiate and work well with people of other backgrounds is encouraged since this not only
assists students to "get along well" with each other, it also assists them to learn mathematics content more effectively. In my opinion, collaborative learning also provides students with rich and varied opportunities for developing and sharing their learning skills.

Students acquire thinking skills best in a learning environment that requires them to be creative, make decisions, solve problems and decide for themselves how to work and reason (CORD, 1999). This kind of environment facilitates the learning of the course content, which is the environment that I planned to achieve.

Teachers who themselves possess only procedural knowledge of mathematics will be unable to assist their students develop conceptual understanding (Ma, 1999). Teachers not only need comprehensive knowledge, they also need to understand students' thinking and how they learn. As the teacher implementing the package, I believed that I satisfied this requirement. As compared to the typical pedagogy of 25 years ago, explanations and demonstrations by the teacher are relatively less important than using questions to probe students' thinking. This shift implies that teachers have the burden in making sense of what students say in their explanations of their thinking. Making sense requires understanding, not only of the relevant mathematics that might underlie an explanation, but also of the path of development of students' undergo in understanding mathematics. Therefore, understanding every student's mathematical development becomes vital to a teacher.

Teachers can obtain information about students' thinking in a variety of ways – for example, through questioning, observing, analysing students' writing, as well as giving tests and project work. These are the actions that I took in the classroom. Probably the most significant of these activities is questioning, since that is the most interactive of these techniques. Recent curriculum projects at the college have also attempted to assist teachers understand students' thinking, and these project materials can be an effective vehicle for conducting professional development. Other examples of material that can be adapted such as the Investigations material (Kliman, Tierney, Russell, Murray, & Akers, 1996), contain:

1) Dialogue boxes, which illustrate how children might respond to particular questions,
2) Lists of questions that teachers can use to probe students' thinking, and
3) Suggestions for what to look for during observations.
Applying some ideas from the *Connected Mathematics Project* materials (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1998) – into my classroom, a launch/explore/summarize/apply/practice strategy was suggested for the lessons. Within these strategies, there were numerous suggestions for ways to assess what students know and can do. These aids were designed to assist teachers to use classroom interactions to deepen their understanding of children's thinking, with the hope that teachers will then use this information to make better decisions on instructional approaches. The process of understanding students' thinking is what has been called *classroom assessment* (Bright & Joyner, 1998). Making teachers becoming better at their classroom assessment will improve planning of their teaching methods, which in turn should lead to enhanced student learning. The following points described what teachers/instructors should do in preparing for their lessons:

- **Understand how students learn and think**
  An assessment of students' work is a particularly valuable tool for understanding their thinking.

- **Select appropriate instructional materials**
  The textbook is the backbone of the instructional program in many mathematics and science classes, so professional development that results in the selection of high quality textbooks/instructional materials has great potential for improving instruction.

- **Use appropriate instruction to promote learning for all students**
  The most content-knowledgeable teacher is not necessarily the most effective one. Teachers need to also have expertise in instructional strategies, including knowing when to use a particular strategy and how to use it well. Most importantly, teachers need to ensure that their instruction provides opportunities for all students to learn key mathematics and science content.

- **Assess student performance**
  Tests that require students to simply insert numbers into formulae or recall algorithms will not provide evidence of in-depth understanding. A variety of tools that can be used for evaluating hands-on science teaching and learning, include the use of drawings, concept maps, notebooks, folders, portfolios, work stations, and individual experiments to assess student understanding.
Mathematics assessment tasks that focus on thoughtful work and provided opportunities for a variety of solution strategies should be stressed but those that focus recitation of procedures should not.

Based on (TE-MAT, 2003)

6.3 Implementation Sequence

The implementation of this study package commenced on the 3rd of January, 2002. The students had just returned from a month long holiday and, since they were in their second semester of the first year of their courses, the teaching and learning process continued immediately. Some students had completed the topic of trigonometry prior to their holidays the semester before. Altogether there were six classes studying trigonometry at the same time. However, the paces and spread of the topics covered varied from class to class. They were all using the same syllabus, with different groups placing different emphasis and different scheduling in the subtopics to be learnt – a process that was carried out according to the different courses that the students were taking. For example, electrical and electronics engineering students did not do three-dimensional trigonometry because it was considered irrelevant to them, but to other groups of students taking construction and surveying courses, three-dimensional trigonometry was considered as relevant and important, therefore more time was spent on these topics. The trigonometry needed by technicians falls primarily into three categories: Right triangle trigonometry, sine graphs, and vectors. Students need to be able to use these concepts to solve problems or model phenomena. In order to use right triangle trigonometry, students have to know how to work with degrees-minutes-seconds. Because of their use in graphing (and calculus), students also need to be taught to convert radians to degrees-minutes-seconds and vice-versa. They also need to use inverse trigonometric functions (AMATYC, 2002).

I requested the Head of Mathematics Department of the College to provide at least two classes so that I could administer and trial the package to these classes. The Head of Department allowed me to choose from the six groups of students in varying courses, but I decided to work with the two classes from the electrical and electronics engineering group. This selection was made because these two classes had almost completed their syllabus on this particular topic while others are in the middle of studying them. The two classes were ND/ELE/10 (National Diploma in Electrical and Electronic Engineering) and ND/RTE/08 (National Diploma in Radio,
Television and Electronics Engineering), with 14 and 12 students in each class respectively. Students enrolled in these two courses were subject to the same minimum admission requirement, but information on whether they were of the same ability was unavailable.

During each lesson, I observed the students and completed the lesson checklist sheet (refer Appendix 3C) to ensure that the lessons ran as expected and according to the criteria that I had established. At the same time, since I had planned for semi-structured observation, I also noted down positive and negative behaviour reactions that the students exhibited. I took great care to conform to the quality criteria of both quantitative and qualitative research stated in Guba and Lincoln (1989) and Cohen, Manion and Morrison (2000) (described in Chapter 3).

6.3.1 Preliminary Lesson

I attended both classes for an initial meeting on the 3rd of January, 2002. Students had been informed that I would be taking their classes as their mathematics instructor for two months as part of my research project towards a PhD degree. The students listened attentively as I explained in detail about how classes were to be conducted and the purpose of my taking over the classes from their instructors. The course requirement sheet was distributed which described the course objectives, the course strategy, the syllabus, the kind of assessment that would be carried out, a timeline and a lesson scheme (refer Appendix 5A). At the same time, I also distributed notes on the historical background of trigonometry and how trigonometry was applied and can be applied in areas such as astronomy and geography, engineering and physics, including other applications in mathematics. Eight examples of real life everyday problems (such as using trigonometry to arrange items on a supermarket shelf that enables customers to have a good view of the items; determining the time ideal for fishing by considering the water depth; measuring mountain heights and river widths (Refer Appendix 5A, p. 308 - 310)) were included to show the considerable application that trigonometry possesses in the real world. I also prepared a “recommendation for teaching trigonometry to National Diploma Year 1” sheet (refer Appendix 5B) intended for any teacher who would conduct this course in future. It included recommendations on curriculum, teaching emphasis, teaching style and assessment.
The ELE class had completed the topic of trigonometry before the holidays, but the RTE class still had the sine and cosine rules yet to be completed. I decided to teach the sine and cosine rules to the RTE class first so that they would be at the same level of completion as the ELE class. I started revision on the trigonometric topics before both classes sat for their phase test – the common test concerning trigonometry given to the students after the completion of one or two topics. The scores from the test contributed to 25% of the whole assessment for the entire year. I conducted the pre-test to the ELE group on the next day, whereas this test was given to the RTE group in the following week. The brief introduction about history of trigonometry as well as an insight on how trigonometry can be used to answer real life questions mentioned before, was given to improve motivation so that students realized the relevance of what they were learning. The time-tabling of the two classes was as follows:

<table>
<thead>
<tr>
<th>Day</th>
<th>8.00 – 9.00</th>
<th>10.30-12.00</th>
<th>2.00-3.00</th>
<th>3.00-4.40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>RTE</td>
<td>ELE</td>
<td></td>
<td></td>
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<tr>
<td>Tuesday</td>
<td>ELE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td></td>
<td>RTE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday</td>
<td></td>
<td></td>
<td>RTE</td>
<td>ELE</td>
</tr>
</tbody>
</table>

6.3.2 Topic 1: Radian Measure

Three lessons were needed to introduce and assist students to understand this topic. Lesson 1 (refer Appendix 5C1) was launched with a question on what students thought was meant by an angle of π/4. In keeping with the recommendations of the ARCS motivational model by Keller (refer Chapter 5), this question was introduced to gain attention. Other questions posed that created considerable discussion were:

"Why is 1 degree 1/360th of a circle? What other unit of angle measurement do you know?"

This was a particularly useful tool because it created an opportunity for me to explain to the students that angle measurement in degrees was introduced during the Babylonian era. The reason that there is 360 degrees in a circle appeared to have originated because the Babylonians used a base 60 numerical system. They also
believed that the earth moves around the sun in a circle and that it takes the earth 360 days to do this. I stressed that, in fact, anybody could create one's own unit of measurement as long as it is well accepted. Those units still in use are the gradian (400 in a circle) and the radian (2 Pi in a circle). It is convenient to define an angle based on the circumference of a circle of radius 1 because measuring arc length is equivalent to measuring the angle, thus the reason for learning radian.

The activity sheet then dealt with the relationship between degrees and radians and students were expected to discover for themselves how to convert degrees to radians and vice versa in the phase that was referred to as "exploration". This was in line with the intention of developing new concepts through student-led activities. It also served to provide students with the relevance and confidence aspects of the ARCS model. At the end of the activity, they were required to summarise their findings. Later, students were given the application work-sheet to practice the skills and understanding that was expected to enhance their confidence and satisfaction with what they had learnt. The exercises included many real, authentic problem-solving situations. Before that, numerous examples that provided models for solving problems and clarified concepts were shown to the students.

Lesson 2 (refer Appendix 5C2) concerned arc length and area of sectors. After a brief review of the previous lesson, the second lesson was launched with two questions to gain attention.

Q1: You are given a choice of running one of the two tracks available today. One track is a quarter of a circle whose radius is 20 m and the other is one third of a circle whose radius is 15 m. You are feeling tired today and would like to choose the shortest possible route. Which one would you choose?

Q2: A whole pizza with radius 8 cm is cut into six pieces. A piece of that pizza costs $2.00. Another whole pizza with radius 10 cm is cut into eight pieces and a piece of that pizza costs $2.50. Assuming that the ingredients are the same, which one is more value for money?

Students then started on the activity sheet where they were to discover for themselves how to obtain the arc lengths and the area of sectors. After working with the activity (exploration) sheet, they were required to summarise their discoveries (which include obtaining formulae for finding arc-lengths, area of sector and area of
segments) and then return to the two initial questions. A question similar to Q2 was
given at the end of the activity sheet to allow the students to practice on the spot.
Other problems were also given for further practise to enhance confidence and
satisfaction.

In Lesson 3 (refer Appendix 5C3), students were required to apply arc length
and sector area formula to solve a range of work-related problems. An application
work-sheet of four problems was distributed and each group was asked to provide the
solution to one problem and present it to the class (in an approach called “Jigsaw”).
This strategy encourages students to share their knowledge and provides them with
responsibility and confidence to present their solution to their group members. Two
examples were given, but students considered the one where Eratosthenes (240 B.C)
measured the radius of the earth as particularly interesting. This example assists
students to realise how useful radian measure is. Students were encouraged to work
on further problems on their own in order to hone their skill and understanding. All
the remaining problems that could not be solved in class were given as homework
and a homework sheet was also given out for this purpose. This sheet referred to the
practice phase of the design to address the motivational aspects of relevance,
confidence and hence satisfaction in the ARCS model.

All of the problems distributed were real-life contextual problems. By
featuring mathematics in common contexts, a meaningful curriculum can motivate
students to link meaning with mathematics. Such contexts invite variations that can
propel students to deep understanding and stimulate mathematical habits of mind. An
infusion of practice into school mathematics can overcome what Shulman (1997)
identifies as major deficiencies of theoretical learning: Loss of learning (“I forgot
it”), illusion of learning (“I thought I understood it”), and uselessness of learning (“I
understand it but I can’t use it”). Freudenthal, quoted by (Romberg, 2001) argued that
instruction should begin with activities that contribute to matematization and that,
when students learn mathematics divorced from experiential reality, it is quickly
forgotten, or they are unable to apply it. Students make sense of a situation by seeing
and extracting the mathematics imbedded in activities and solving problems that they
can relate to. This motivates them to read and think about mathematics on their own.

At the end of the lesson the students were asked to prepare a concept map of
what they had learnt for this radian measure topic (described in Section 6.3.2.3).
6.3.2.1 Students’ Reactions (My Observations)

I observed that the seating arrangements in the classroom were unsuitable for student discussion and for cooperative learning, especially for the ELE class (refer sample field notes in Appendix 6A). This classroom had long tables that were heavy to move around. The students had to turn around to face their classmates in the row behind for discussions and cooperative learning. The students in the RTE class were able to move their tables around and their seating arrangements were more suitable. For the second and third lessons, students were prepared to move their tables and be in the required seating arrangement immediately, so a quick revision of the previous lesson was carried out before commencing the lesson. When new concepts were introduced, background information and relevant examples were first provided. Students were especially keen to learn about the Babylonians, Eratosthenes and the earth’s radius and other relevant problems in the worksheet. Any mistakes that students made were immediately pointed out in the class. I observed that the whole class was on task and progressed quite well, although they needed to be guided to complete the activity sheets. In lesson 3, students were asked to present their solution to the whole class. In one class students were eager to present their work while in the other, several students were not very enthusiastic about this in the beginning and this affected the pace of their work. I attempted to increase the pace of the lesson by encouraging students with a few words of advice. Calculators were used correctly and the main points of the lesson were summarised at the checkpoint phase. Homework was given, commencing with lesson 2.

6.3.2.2 My Reflections

Although the students had encountered this topic prior to going on a month-long holiday, my first impression was that they were learning this topic for the first time. Reactions of the students varied: Some were reserved while others were welcoming. One particular student showed his disdain of the exploration activities by not cooperating fully in the activities and refusing to participate in discussions. Another female student was honest when she commented that she thought the activities they were doing were a waste of time. According to her, she preferred the approach where the instructor would explain by examples, show the formula and allow the students to try to solve a similar problem. I explained the reasons for what I was doing to her and she seemed to be willing to participate in the lesson. According
to her, "It's not a permanent feature anyway. Measuring the arc length with a string is an activity for school kids". Because of these comments, I decided from then on to make future exploration activities befit the age of the students involved. The female student was an "in-service" student (mature age student who came back to study for their Diploma while still attached to the Department where she worked). Her responses to the lessons reminded me of Knowles's (1990) six assumptions about adult learners.

1. Adults need to know why they need to learn something before undertaking to learn it.
2. Adults have a self-concept of being responsible for their own lives.
3. Adults come into an educational activity with both a greater and different quality of experience from youths.
4. Adults come ready to learn those things they need to know.
5. Adults are life-centred (or task-centred or problem-centred) in their orientation to learning.
6. While adults are responsive to some extrinsic motivators, the more potent motivators are intrinsic motivators.

These assumptions about how adults learn need to be considered when one is designing a curriculum and preparing lessons. They also need to be considered since technical students can be regarded as adult students because, while most are school leavers (over 18 years old), some are in-service students (around 30 years of age).

The eagerness of the groups' representatives to present their solution to their group members was unexpected, knowing that this was the first time students were involved in this kind of activity. I noted that this could be a regular feature of future lessons, most probably because the students were used to, and trusted each other. It may also have been because students were confident with their solutions after they had discussed them among themselves. From then onwards, I decided to utilise the "Jigsaw" as one of the regular activities since it emphasized cooperation, responsibility and also saved students' time.

Questions like "why is one degree \( \frac{1}{360} \) th of a circle?" caused students to question certain accepted phenomena (refer Appendix 6A). It also created inquisitiveness among the students and made them research the topic to find out the
truth. They listen more attentively to me and admitted that mathematics lessons were not as dry and boring as they used to be.

6.3.2.3 How This Topic was Assessed

I used the concept map to assess student understanding of this topic. A concept map is a graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts. Concept mapping can be used for the following purposes:

- To generate ideas (brainstorming).
- To design complex structures (long texts, hypermedia, large web sites).
- To communicate complex ideas.
- To aid learning by explicitly integrating new and old knowledge.
- To assess understanding or diagnose misunderstanding.

(Plotnick, 1997)

The concept maps produced by the students were then analysed and compared. I used the concept-map scoring rubric shown in Table 6.2 to grade the concept maps that the students submitted. Each group was asked to produce a concept map to show how much they have understood the topic (samples of concept maps can be seen in Appendix 6B).

Table 6.2: The scoring rubric of concept map used for grading purposes. Source:

http://tiger.coe.missouri.edu/~vlib/matthew.html

<table>
<thead>
<tr>
<th>Level of Adherence Criteria</th>
<th>V. Poor (1)</th>
<th>Poor (2)</th>
<th>Fair (3)</th>
<th>Good (4)</th>
<th>V. Good (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts (Too few v. only major)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focal Concepts (Misses major foci v. hierarchically indicates it)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Validity of Linkages (Accurate formed proposition v inaccurate)</td>
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<td></td>
<td></td>
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<tr>
<td>Horizontal v Vertical Flow (Extend in one direction v. fairly evenly)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semantic Categories of Links (Vague prepositional links v. explicit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From the criteria in Table 6.2, and after comparing the concept maps produced by each class, I concluded that the students had developed a sound understanding of the topic with greater understanding being shown by the RTE group since the concept maps produced by groups from this class possessed more accurate linkages.

Two concept maps in Appendix 6B were from the ELE class while two are from the RTE class. I have analysed them according to the rubric above and classified the two from the RTE class as “good” while the other two from the ELE class as “fair”. I did not teach the students how to draw the concept maps since they were familiar with them. The two classes had different ways of drawing concept maps and I considered that those produced by the ELE class as “uncommon”. The second map by the ELE students did not mention the conversion of degrees to radians and radians to degrees at all although the students spent a considerable time learning this concept. The first map contained a reasonable number of concepts, while the second one again did not mention the concept of conversion. Both have valid linkages, fairly even horizontal and vertical flow and quite explicit links.

The concept maps produced by the RTE class also had valid linkages, explicit links and even horizontal and vertical flows in one of them. The other map also displayed a fairly good effort by the students in terms of the criteria mentioned. The maps produced by this class had a “regular” appearance.

6.3.3 Topic 2: Trigonometric Ratios and Graphs

This topic started with Lesson 4 (refer Appendix 5C4), which included revision on Pythagoras’ theorem, especially on identification of opposite, adjacent and hypotenuse. To demonstrate and prove the Pythagoras’ theorem, I logged on to the website constructed by Andrew Wiles (2000), produced by PBS using the computer in the college’s staff-room and also asked students to prove the theorem on their own computer. At the site, students were able to move unit squares associated with right-angled triangle ABC, from sides “a” and “b” to side “c” – the hypotenuse (Figure 6.3), in order to prove the theorem interactively. Later, the trigonometric functions were defined. For revision and homework, students were asked to calculate various unknown variables in a Trigonometric puzzle (refer Appendix 5C4, pp. 327 - 330).
Figure 6.3: The Pythagoras' theorem: Proved by inserting squares a and b into square c

A new lesson was then launched by posing a question to the students on how to measure heights of buildings, trees and hills without having to climb them, and how to measure the width of a river without having to cross it. A real life problem was demonstrated by measuring the height of the classroom wall using the tangent function.

The exploration sheet was distributed and was to be completed by the students working in groups as usual. At the checkpoint, students were asked to consolidate on how to use the trigonometric function as well as Pythagoras' theorem to solve any unknown side of a triangle given the other sides. As a practice, a very practical problem about a roof was given (refer Appendix 5C4, pp. 331 – 334) as homework. Although this problem is more suited for students majoring in Building and Construction courses, the electrical students were able to see the benefits of trigonometric function to their course of study first hand, when they saw the relevance of the last problem on the sheet. It concerned wiring and was relevant to this particular group of students. In this lesson, I also addressed the common inability of students to use one particular rule of operation. An example of students’ error of this nature is when they were trying to find a side x, given that \( \tan 50^\circ = \frac{20}{x} \). Many would say that, \( x = 20 \tan 50^\circ \).
Any unfinished problems were to be considered as homework. Students were expected to submit them during the next lesson where they would be discussed.

Lesson 5 (refer Appendix 5C5) dealt with solving various real life problems. Before that, I attempted to correct a common misconception that students have concerning $\sin^{-1} x$ being equal to $1/\sin x$. Addressing another common mistake that the students made, I emphasized that, given $\sin x$ equals a certain value, $x$ would not be unique and explained again why this is so. Some real life examples were given and then students were asked to solve problems from a work-sheet.

Lesson 6 (refer Appendix 5C6) deals with trigonometric graphs. Trigonometric graphs are very important to electrical and electronic students since they encountered sinusoidal wave almost daily in their field of study. I decided to use Ciancone's (1988) model as shown in Figure 6.4 as a guide for me to teach this particular topic.

Posing a question concerning whether they knew the equations of any trigonometric graph from the real world launched the lesson. Following Ciancone’s model (Figure 6.4), the students were shown real graphs representing real world phenomena.

![Figure 6.4](image_url)

*Figure 6.4*: Model of real, abstract and concrete worlds being connected by motivation, explanation, practice and application.

The purpose of this was also to focus students' attention on the topic. I explained the benefit of knowing the equation and showed them more examples of graphs for heartbeats, sound waves and radio frequencies. These examples attracted their attention since they were relevant to them. In the exploration part of the lesson, they were then shown how to draw sine and cosine graphs that simulated the graphs
formed when a person runs in a circle, seen from left side and from the top respectively (refer Figure 6.5).

*Figure 6.5: Graph of sine and cosine obtained by tracing the path of a person running around a circle*
Then the students were given a group activity to draw trigonometric graphs with different amplitudes, frequencies, periods and phase shifts. They were required to draw the graphs manually since graphic calculators were not used in any lessons at the college. To overcome the difficulty of not having a graphic calculator, and also to complement the activity of manually drawing the graph, I demonstrated simulations of graphs on the computer using the graph simulator available on the Internet. I provided students with the URLs of a few graphing simulation sites such as that produced by Zona Land and written by Edward A. Zobel (2001); another written by M. Bourne (2001), produced by Interactive Mathematics, and also a website by Explore Learning (1999-2004). Students were encouraged to try to access the sites as soon as they got home, as most of them owned a computer.

At the checkpoint, I asked them to define amplitude, frequency, period and phase shift. Each group of students was also asked to complete the cooperative Learning Activity sheet at the end of the lesson in order to find out if they were working cooperatively and fulfilling their responsibilities; what they thought were the strengths and weaknesses of the activity and what could be done to make interaction more effective. They were then expected to apply their knowledge to the questions that followed the activity.

Lesson 7 (refer Appendix 5C7) involved the application of trigonometric graphs to the real world and work-related problems. Two examples of problems in the real world were given before students commenced the problems in the worksheet. Trigonometric graphs are probably the most commonly used graphs in all areas of science and engineering. They are used for modelling many different natural and mechanical phenomena (e.g. populations, waves, engines, acoustics, electronics, UV intensity and the growth of plants and animals), and they are an important part of learning trigonometry. Students of electronic and electrical engineering at the technical college in Brunei encountered sinusoidal graphs almost daily in their course of study (such as sound waves and radio frequencies) and they were required to know about amplitude, phase differences, frequency, period and how to apply them in problems. They were also required to know how to obtain the equation of the graph from data, and vice versa.

At the conclusion of the lesson, students were given a project entitled “Trigonometric Waveforms around us” (refer Appendix 5C7, pp. 350 – 351). This project was given only to the ELE students since I could not obtain the cooperation
of the RTE class teacher to help me with the project later on. Project-based learning is oriented to the “real” world and has value and meaning beyond the teacher and learner (Bruner, 1990; Carbonell, 2002; Rogers, 1969). It encourages the building of relationships, communication skills, and the use of higher order thinking skills, such as critical thinking to define and solve problems. Project-based learning includes using and manipulating technology; promoting creativity and meaningful learning, and connecting new learning to past performance or learning; incorporating authentic self and outside reflection and assessment, and instilling lifelong learning patterns (Kraft, 1999; Taylor, 1998; Wankat & Oregovicz, 2000).

Although the lecture-discussion method has been around for centuries, and despite all the calls to replace it with other methods, it will undoubtedly continue to be an appropriate way to provide information in many circumstances. However, lectures should be supplemented with a variety of student-centered methods such as computer simulations, web-assisted activities, collaborative learning activities, and projects (CRAFTY, 2002). Projects require a student or group of students to design, plan, organize, research, calculate, model, and/or present their work. They differ from other activities in that they require more than a class period to complete and often require students to meet or communicate outside of the classroom. Projects provide opportunities for teachers to engage faculty from other disciplines. These are the reasons that justify projects as a way of learning, which also incorporates the assessment of students’ understanding of the topic.

6.3.3.1 Students’ Reaction (My observations):

Students were unable to complete the activity sheet in Lesson 4, so uncompleted problems were given as homework. A number of students complained because I gave them too much homework that day, including the puzzle and the Roof problem mentioned in Lesson 4 (refer Appendix 5C4). Only half of them brought back the completed homework the following day. I asked those who did not complete the work to try their best to do so because it would benefit them. Those who did the homework said that the problems were interesting and worth solving. We also discussed the wiring problem from the Roof worksheet so that every student could benefit from it.

Addressing students’ tendency to think of $\sin^{-1} x$ as $1/\sin x$, I found that immediately after the lesson, (when the students were working on problems in the
worksheet), all of them understood what was meant. Students appeared eager to start immediately on the real life problems in the accompanying worksheet.

Although students were asked to sketch the graphs in Lesson 6, they tended to draw them very elaborately, and thus spent too much time on them. Two groups could not complete all the tasks and had to take them as homework.

As for the project given in Lesson 7, the ELE students were at first given three weeks to complete it. This dateline was extended due to a number of reasons, one of which was that many students were unfamiliar with the Power-Point/Front-page software in which form they were supposed to present their project.

A group of three female students (Group 1) chose to record the temperature in one particular area over 48 hours at two hours intervals. They managed to gather the data very quickly but were not quite sure of what to do next. After asking for help from instructors, they derived the equation of the resultant graph of best fit. Their next problem concerned the Power-Point presentation because none of them had used it before. They managed to learn how to use Power-Point quickly enough to finally be able to complete and present the project satisfactorily.

Another group of four male students (Group 2) decided to be practical and chose a topic on ‘Sinusoidal AC Voltage Waveforms’. They considered this as more relevant to their course of study. They examined several different phenomena (such as the movement of a piston and also the waveform produced by an electronic guitar) before deciding that the topic was the correct one for them. They held many meetings and discussions (about ten meetings altogether) before being able to produce a satisfactory product. The major hindrance that they faced was the unavailability of the electronics laboratory.

Group 3, which consisted of another four males, decided to examine variation in tide as their topic. They took measurements of the tide over a period of forty-eight hours at fifteen different times and decided to obtain a line of best fit from all these results. They chose this topic because one of their members had basic knowledge of tides and had access to the appropriate resources to carry out the study.

Group 4, also comprising four male members, chose a topic on Islamic prayer time. They tried to calculate the changes in the “Ishyak” prayer time in Brunei over a period of one year, at 10 days intervals. They encountered some difficulties in completing this project because of limited resources, unfamiliarity with Power-Point and also limited meeting opportunities among members. They also found it hard to
derive an equation for their graph because it was of a combined sinusoidal waveform that did not have a fixed amplitude and phase shift.

6.3.3.2 My Reflections

I needed to plan my lessons carefully because of the limited time available. Ideally, explorations would have been appropriate and beneficial if adequate time was allowed and if instructors were not pressured to complete the syllabus. This is another reason why mathematics instructors were not very keen on dealing with explorations and discovery learning lessons.

According to Blackett and Tall (1991), the early stages of learning trigonometry are fraught with difficulty because students need to relate pictures of triangles to numerical relationships, to cope with ratios and to manipulate the symbols involved in such relationships. Hart, as quoted by Blackett and Tall (1991), believed that ratios prove to be difficult for students to comprehend therefore sine should be introduced as opposite side length in the right angle triangle in relation to a unit hypotenuse. Students should also be able to recognize the hypotenuse even if the triangle had been rotated through many positions. Activity sheet 3 (refer Appendix 5C4) tried to address this problem.

Students' confusion about $\sin^{-1} x$ and $1/\sin x$ appeared to originate from their prior knowledge about $n^{-1} = 1/n$. One way to overcome this was for instructors to stress the fact, every time they encountered this kind of problems, that in this case the notation referred to the inverse and not the reciprocal.

Teaching trigonometric graphs can be made more effective through the use of technology (either a graphics calculator or a computer). Technology enhances mathematics learning, supports effective mathematics teaching and influences what mathematics is taught (NCTM, 2000). It furnishes visual images of mathematical ideas, facilitates organizing and analysing vast amount of data, allows students to compute efficiently and accurately, and makes information readily available. Without the use of technology, understanding may take longer time. Whenever there is a chance, computers should be used to familiarise the students with the latest technology. These views agree with Drier, Dawson and Garofalo's (1999, p. 3) statement that "the graphics calculator, spreadsheets and the Internet offer the capability to create and use simulations that allow students to explore and visualize important mathematical concepts as well as real world and interdisciplinary
connections”. Unfortunately, use of the graphic calculator was not possible during this study, though computers were used whenever possible.

Overall, the students enjoyed carrying out the project although they faced difficulties at commencement. Most of them had difficulties with choosing a task; with familiarizing themselves with power point, (nobody in the class chose to present their project in Front Page); in deriving the equation of the graph (although they had been taught how to do this before); in setting a timetable of work for themselves, and in finding the right resources. Since projects were not a regular feature of the academic work students had been involved in before, they didn’t know where and how to start. However, because project-base learning enhances students’ contextual understanding and have been proven to succeed in creating deeper understanding of a subject (Mills, 2002; Wheeler et al., 1999), it should be encouraged as part of teaching and learning programme.

From interviews, all students said that the project made them more knowledgeable and more skilled in using the internet, Power-Point; in working as a group; in time management; in drawing graphs using Microsoft Excel; in writing reports, and even with their interaction with instructors (refer Appendix 6E, Student 1,2,3, p. 416). One student mentioned that, besides an obvious increase in understanding, he liked mathematics more now, which implies that his attitude towards mathematics became more favourable. Also, from interviews with the students and with another teacher involved with the project, it was clear that real world applications increased students’ interest and motivation in learning mathematics and that they were gratified to know that so many real world phenomena were connected to sinusoidal graphs in particular, and to mathematics in general (refer Appendix 6E, p. 416).

Students mentioned that they felt more knowledgeable in many areas because of this project. Although the class pace was too slow at first, they became more cooperative and more systematic with their work later on. Asked if they would go through it again, most of them said that they would because of the benefits that the project had brought them (such as cooperation, knowledge of using power-point and the internet, realization that many real-world phenomena are related to mathematics) (refer Appendix 6E, Student 3, p. 416).

The standard of work submitted was generally good (refer Appendix 6C). Some students made many mistakes with the English (e.g. grammatical,
inappropriate use of words and sentence structure) but this was expected since English was not their first language. As for the students’ levels of motivation, it increased as they began to see and understand the phenomenon that they were researching. I observed that students’ enthusiasm increased as they progressed since they became more excited about handing in the project. Students’ eagerness to research the material and complete the project satisfactorily replaced their poor motivation at the beginning.

6.3.3.3 How This Topic was Assessed

Students’ understanding of this topic was assessed by using the rubric that appears in Appendix 6D. The final gradings for the project were:

Group 1: Good Completion
Group 2: Good Completion
Group 3: Good Completion
Group 4: Fair completion

Examples of students work submitted can be found in Appendix 6C.

6.3.3.4 Assessing Cooperative Learning

While students were carrying out activities on graph sketching, an opinion sheet called “Cooperative Learning Activity Report”, (refer Appendix 5D) was also distributed to each group of students. The leaders were asked to record the distribution of jobs to each student: Whether each member of the group participated in the activity, contributed to the discussion and fulfilled his/her responsibility. They were also asked to record whether their group complete all assigned activities. They were required to state what concept the activity tried to address, what the strengths and weaknesses of the activity were and what could be done to make their group interaction more effective. The results of this assessment are presented in Chapter 7, Section 7.7.

6.3.4 Topic 3: Identity, Sine and Cosine Rule

Trigonometric Identities was taught in Lesson 8 (refer Appendix 5C8), where students were told why identities are extremely helpful, if not absolutely necessary, in order to solve problems. The lesson was launched with a question whether students knew that \( \cos^2 \theta + \sin^2 \theta = 1 \) and why this was so. The students found out about this once they proceed to complete activity #5. At the checkpoint, students were asked to list down the identities they have derived from the activity. They then
proceeded to solve a few identity problems. They were also required to complete the "identities investigation" (refer Appendix 5C8 p. 354).

Lesson 9 (refer Appendix 5C9) introduces the law of sines. The lesson was launched with a question asking whether students knew what to do if they had to solve a non-right angle triangle given a side and an opposite angle together with another side or angle. For the exploration phase, activity #6 sheet required students to draw different triangles and to measure the length of the sides and their corresponding angles. They then had to compare the ratio of each side with the corresponding angle and arrive at the required formula. By following through the instruction in the activity sheet students could formally prove the law of sine. Then, a number of problems on solving triangles were given, including the ambiguous case, and an extra puzzle activity was set as homework (refer Appendix 5C9, p. 358 – 559) where students were expected to solve for an unknown side using the sine rule.

The laws of cosine were introduced in Lesson 10 (refer Appendix 5C10). In the activity #7 sheet, the students explored the laws by proving them using what they already knew from the identity laws and law of sines. The lesson was launched with a question asking how to solve a triangle if the law of sine fails (cannot be used) – for example when all three sides or two sides and an included angle were given. At the checkpoint, the students were asked to list down all the six different forms of the cosine rule – that is all the following angle formulae and all the different side formulae, namely: \[ \cos A = \left( \frac{b^2 + c^2 - a^2}{2bc} \right), \quad \cos B = \left( \frac{a^2 + c^2 - b^2}{2ac} \right), \]
\[ \cos C = \left( \frac{a^2 + b^2 - c^2}{2ab} \right), \quad \text{and} \]
\[ a = \sqrt{b^2 + c^2 - 2bc \cos A}, \quad b = \sqrt{a^2 + c^2 - 2ac \cos B}, \quad c = \sqrt{a^2 + b^2 - 2ab \cos C} \]
given triangle ABC with sides a, b and c.

Then students were asked to solve related problems, which included real life situations from a worksheet provided (refer Appendix 5C10, p. 363-364). Students were asked to complete any unfinished problems as homework. An extra activity was also given out, to be completed in the students’ own time.

Lesson 11 (refer Appendix 5C11) introduced and proved two area formulae – the SAS (side-angle-side) formula \( \text{Area} = \frac{1}{2} \ ab \ \sin C \): And the Heron formula \( \text{Area} = \sqrt{s(s-a)(s-b)(s-c)} \) where \( s = \frac{1}{2} \ (a + b + c) \) given triangle ABC with sides
a, b, and c). The activity sheet led the students to the derivation of both formulae. Since finding the area of land or property is one of the surveyor’s main jobs, an assignment was given to find the area of part of the school ground.

6.3.4.1 Students’ Reactions (My Observations)

Students asked about the relevance of identities. I tried to find as many examples as possible where identities could be used by electrical and electronics students.

Students need to be reminded of the non-uniqueness of the solutions of some of the problems using the sine rule. I sensed that they enjoyed solving problems on the sine and cosine rules because of the real world problems that were relevant to their everyday life. The extra activity sheet was simple enough for the students to take away as homework. Several of the better students in each class couldn’t wait to try and get the answer to “What is a stupid ant” problem (refer Appendix 5C10, p. 365), and they started on the problem as soon as the sheets were distributed.

It was necessary to move rapidly through the topic of area formula because the students’ phase test was forthcoming. Although the area formulae were not the topic included in the coming phase test, they were part of the syllabus. Since finding measurements of angles and the area of the school yard (mini project on finding the area of an irregular shaped quadrilateral) would take a considerable time, I provided the students with the measurements required for four different areas to be calculated by each group.

6.3.4.2 My Reflections

From my experience before, I realised that students always have problems understanding and manipulating identities. Many of them could not see the relevance of identities at all. I remember proving identities to be one of my favourite activities because I could do them well and derived such satisfaction at being able to prove that the left hand side equaled the right hand side. In my opinion, one of the ways to interest students is by explaining why they need to study this and give them as much practice as possible using problems like those in the worksheets.

I stressed both the importance of the non-uniqueness of $\sin^{-1}$ of $x$ when the students were confronted with the ambiguous problems in applying the sine rule, and
also the importance and relevance of Lesson 5 which dealt with relevant real-world examples and exercises.

I believe that the mini project would have benefited the students if I had more time with them. The practicality and the relevance of the problem would have held students' interest. I did inform the students and gave them examples of the real world – every day problems that made use of the sine and cosine law, and also the area formula, to make students aware of the role of mathematics in real life (although they did not always try to solve them).

6.3.4.3 How This Topic was Assessed

This topic was assessed by grading class-work and students’ homework to determine their understanding of this topic. I used the lesson checklist to record whether students appeared to understand the topics as they solved problems in groups. I regularly checked their work thoroughly and also required them to submit their work so that it could be checked.

A problem-based learning situation with scenarios or case studies would provide another way to engage students in meaningful activities. In these activities, the scenarios or case studies are more often used within an integrated curriculum (or within a learning community) and the problem may be very technical in nature but requires the student to use skills in mathematics, science, and English. Problems of this kind are often vaguely defined, and often with several acceptable solutions. This kind of learning appeared to make students more responsible and more involved in discussions. The problems introduced may be very technical in nature but require the student to use skills in mathematics, science, and English. In the beginning, I planned to assess students via problem-based learning, but because of the time factor, my plan changed to the grading of solved problems from exercise worksheets.

The post-test was given to the students at the second last lesson without prior announcement. The post classroom environment and attitude survey were distributed during the last lesson. During this time I took the opportunity to thank the students for their cooperation and chose three students from each class for a one-on-one interview to be conducted the following week. The six students chosen represented capable, fair and weak students. The outcomes of these interviews are presented in Chapter 7.
6.4 Narrative (A snapshot of one of the Lessons)

The narrative has become a way of providing educators and researchers with special access to understanding the learning and teaching process (Casey, 1995). The following narrative describes what I consider to be a typical class. It gives a clearer picture and insight of what happened during the implementation of the package.

It was Tuesday the 15th of January, 2002. The class for RTE group that day was scheduled for 2.00 pm – 3.00 pm, after lunch, and in hot, humid weather and with a full stomach, students would certainly be inclined to doze off. I entered the class determined to make the day’s lesson worthwhile.

“Assalamualaikum, Miss” greeted most of the students. “Waalaikum Mussalam”, I greeted them back. After some chatter about what they had for lunch, I added, “Today, we are going to look at the application problems of radian measure. We would also see how Erathosthenes used it to find the radius of the earth”.

Before asking them to group together, I asked them to listen to me so that I could show two examples on applications of radian measure – namely the earth’s radius problem and the area of a segment (refer Appendix 5C3, p. 318). Some of the students were quite attentive while I could see one or two at the back of the class trying their best to keep their eyes open.

“It’s amazing that someone would have thought about it and solve the radius of the earth more than 2000 years ago”, quipped a girl. I volunteered; “Well, among all of us, there would always be someone who thinks. That makes it very important that all of us started thinking about the phenomena around us and find answers to them. Do you know that according to research, a person normally use only about 10% of his/her brain capacity?”.

There were more discussions on how we could replicate the experiment and establish the earth’s radius that we now know. I then asked them to group themselves into their usual arrangement and started distributing the worksheet
on “Investigative type of problem” (refer Appendix 5C3, p 319 - 320). There were four questions on the worksheet and, since there were four students in each group, I asked each student to choose the problem that they liked and to regroup themselves into those that had the same problem to solve. This was like having each group send a representative to discuss a particular problem given, and each of them was supposed to return to their original group to explain their solution to their fellow group members (the jigsaw).

There was considerable discussion taking place as I moved around from group to group, helping them if my assistance was needed. The two sleepy students were wide-awake now. With five minutes remaining in the session the students were still deeply engrossed in discussions with their original group members. I had to stop them to distribute more problems, which they took away as homework.

“I like this activity, Miss”, said a student. “We should have more activities of this kind. It saves us a lot of time and it’s fun”, he added. I was fully satisfied with that comment and went out of the class smiling.

6.4.1 Interpretive Commentary

Students liked the change from the ordinary, routine lessons that they were having everyday and the traditional classes that were routine and boring. I assumed that was the reason why the ‘Innovation’ scale scored the lowest in the classroom environment scale of the pre-survey. I attempted to provide variety for my students and this I believe resulted in a statistically significant increase in the ‘Innovation’ scale in the survey of the learning environment conducted after the package implementation. Teachers should try their best to make lessons meaningful especially when the classes are not conducted at an appropriate time; students were sleepy after a heavy lunch of rice as a main course, and in a hot, humid weather that is typical of Brunei. One of the ways of making lessons at this time meaningful has been shown here.
6.5 Summary

I consider the implementation phase of this research to have been successful despite the few minor challenges that I experienced (refer Chapter 8, Section 8.6.4). The outcomes answered the first secondary research question for this phase:

What were the students' and teachers' reactions to the package?

With regard to students' and teachers' reactions, they were mostly favourable. The teachers that I spoke to said that they would also like to write a similar package when the opportunity arises (refer Appendix 7A, Teacher 2). The students enjoyed many of the classes but were not satisfied when they could not dwell on some topics long enough (refer Appendix 7B, Student 4). The second secondary research question was:

What are the problems faced by students and teachers during implementation?

A number of students needed to become used to the student-centred way of learning. I had anticipated sufficient time to implement the package, a better physical condition of classrooms and better facilities in terms of the availability of graphing calculators and internet accessed computers. More details of the problems that the students and I faced are presented in Chapter 8, Section 8.6.4. Despite the shortcomings in this regard, I was able to adjust accordingly. I was satisfied with the cooperation provided by the principal, teachers and students that had made the implementation of this research easy.

The third secondary research question was:

Were the standard and quality criteria of the research ensured?

I was able to ensure the standard and quality criteria of the research during the implementation period by adhering to the quality criteria listed by Guba and Lincoln (1985) described in Chapter 3, Section 3.8. I was able to apply triangulation due to the different kinds of data and the circumstances under which the data were collected (refer Chapter 3, Section 3.3.1); I was also able to satisfy the prolonged engagement criterion because the duration of the study was adequate; the member checking and peer debriefing criteria was enforced because I continuously discussed students' reaction to the package and their work, with the two class teachers as well
as having a senior teacher to observe my teaching and providing me with constructive criticisms about the whole project. The criterion of persistent observation was also satisfied because I was in the classroom with the students at all times, acting as their mathematics teacher during the implementation period. As for the criterion of negative case analysis, I was able to refine certain perceptions and abandon faulty judgements as the implementation moved along.

The next chapter will present the summative evaluation of the entire research study where the results of the surveys and interviews conducted after the implementation of the package are presented in detail.
Chapter 7

Phase 4: Package Evaluation

There is a great danger in the present day lest science-teaching should degenerate into the accumulation of disconnected facts and unexplained formulae, which burden the memory without cultivating the understanding.

J. D. Everett [In the preface to his 1873 English translation of Elementary Treatise on Natural Philosophy.]

7.1 Overview of the Chapter

This chapter focuses on the evaluation of the study. It includes a discussion of both the quantitative and the qualitative data gathered and provides detailed statistical analyses and comparisons of the results. Section 7.2 discusses the evaluation processes that were carried out in this study, while Section 7.3 discusses the data analysis and briefly highlights the properties of the sample and the methods used to analyse the data. Both the cognitive and the affective results are discussed in section 7.4, and section 7.5 describes the association found between the cognitive and the affective outcomes. Section 7.6 presents the interview data collected after the package implementation, and section 7.7 evaluates the cooperative learning strategy employed in the package. Research questions are answered in Section 7.8 and a summary in Section 7.9 concludes the chapter.

7.2 Introduction

Evaluation is the process of determining the significance or the worth of something, usually by careful appraisal and study (LinguaLinks, 1999). It is the analysis and comparison of actual progress versus prior plans, oriented towards improving plans for future implementation. In the case of this study, evaluation was carried out to determine whether the intervention of the package was successful. Comparisons of data before and after the implementation of the package were made
on students' cognitive and affective achievements to investigate whether any improvement was due to the intervention.

Evaluation also involves assigning values to the object or person being evaluated, and these values were measured and analysed to determine the effectiveness and the efficiency of the package after it was implemented over a period of eight weeks. A more appropriate term used here would be "summative evaluation", where the overall effectiveness of the package was assessed. Summative evaluation is a method of judging the worth of a program at the conclusion of that program, where the focus is on the outcomes.

7.3 Methods of Evaluation

The aims of this phase of the study were to evaluate the package in order to establish its effectiveness in enhancing technical students' understanding of mathematics, and its effectiveness in enhancing their attitude and motivation. Research questions incorporating specific objectives to evaluate separate elements of these aims guided the data collection and the analysis. The focus of the evaluation was to take into account the issues involved in students' attaining the following abilities:

1. Cognitive ability (mathematical understanding) – the cognitive achievement was measured via tests prior to and after the implementation of the package (pre- and post-test). There were also other assessments to measure students' understanding of each sub-topic as described in Chapter 6. The results of students' phase tests were included in order to make informal comparisons between the treatment and non-treatment group.

In terms of mathematical understanding, I divided students' proficiency in mathematics according to;

a. procedural skills,
b. conceptual understanding,
c. problem solving ability.

Questions in the pre and post-test were categorised into the three groups above, and each category was analysed in an appropriate manner.
2. Affective ability – affective abilities were measured through two instruments: One on students’ perception of the learning environment, and the other on their attitude towards mathematics.

Table 7.1 summarises the evaluation measures that had been conducted. It includes the various types of evaluation used together with the characteristics, goals and a summary of the outcomes of each evaluation.

7.4 Results

The brief statements made under the types of achievements (cognitive and affective) in Table 7.1 will be further explained, according to their categories, namely the procedural skills, conceptual understanding and problem solving abilities as was defined earlier.

7.4.1 The Cognitive Results

The percentage scores of the students’ performance in their pre and post-tests are shown in Figure 7.1.

![Graph showing pre and post-test results for ELE, RTE classes.](image)

*Figure 7.1:* Pre and post-test results for overall as well as for ELE, RTE classes.

The graph in Figure 7.1 clearly shows that there was a noticeable difference between the pre- and post-test result for ELE, but only a small difference for the RTE class.
<table>
<thead>
<tr>
<th>Type of achievements</th>
<th>Evaluation Measures</th>
<th>Characteristics</th>
<th>Evaluation Goals</th>
<th>Outcomes Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive</td>
<td>Pre-Test Content Questions</td>
<td>Questions based on learning objectives from the &quot;guide book&quot;. Self-devised and checked by the teaching staff. Ten objective type questions in Section A and nine subjective type questions in Section B</td>
<td>To determine the pre-knowledge of students in subject area and also to identify areas of difficulty and misconceptions</td>
<td>Students' performance is mediocre. An average score for students combined from both classes was only 27%</td>
</tr>
<tr>
<td></td>
<td>Post Test Content Questions</td>
<td>Set of comparable questions to pre-test, again linked to learning objective. Self-devised and checked by teaching staff. Administered after the implementation of package. Ten objective type questions in Section A and ten subjective type questions in Section B</td>
<td>To determine the learning gains made in subject area after using the package</td>
<td>Significant increase in mean performance in overall result. Significant increase in conceptual, procedural problem solving categories.</td>
</tr>
<tr>
<td></td>
<td>Phase Test</td>
<td>Two-hour test set by the Math Dept. as part of student assessment common for every student learning same syllabus.</td>
<td>To compare students' understanding between non treatment and treatment groups</td>
<td>7% increase in the mean score for treatment group</td>
</tr>
<tr>
<td>Type of achievements</td>
<td>Evaluation Measures</td>
<td>Characteristics</td>
<td>Evaluation Goals</td>
<td>Outcomes Summary</td>
</tr>
<tr>
<td>----------------------</td>
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</tr>
<tr>
<td>Affective</td>
<td>Pre Actual LE</td>
<td>Seven items each on the following scales: Teacher Support, Innovation, Task Orientation, Cooperation and Relevance</td>
<td>To determine students’ perception of their “actual” and “preferred” LE</td>
<td>All difference between preferred and actual changes are relevant</td>
</tr>
<tr>
<td></td>
<td>Questionnaire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Actual LE</td>
<td>Seven items each on the following scales: Teacher Support, Innovation, Task Orientation, Cooperation and Relevance</td>
<td>To determine students’ perception of their “actual” LE after intervention study</td>
<td>Increases in almost all scales of LE, significant in innovation only</td>
</tr>
<tr>
<td></td>
<td>Questionnaire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre Attitude</td>
<td>Seventeen items altogether. Nine items on enjoyment/Interest, four on relevance and four on importance</td>
<td>To study students’ attitude towards mathematics (whole population)</td>
<td>Very high scores in almost all attitude scales.</td>
</tr>
<tr>
<td></td>
<td>Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Attitude</td>
<td>Seventeen items altogether. Nine items on enjoyment/Interest, four on relevance and four on importance</td>
<td>To study any change in attitude after intervention study (treatment group only)</td>
<td>The increase/decreases in all categories not significant</td>
</tr>
<tr>
<td></td>
<td>Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Classroom Observation (pre/post)</td>
<td>Analysis of actions and interactions of students in the classroom setting before and after implementation. Unusual or unexpected outcome documented</td>
<td>To observe context in which learning took place and document significant change, issues/problems in program.</td>
<td>T/L traditional (pre). Students need time to adjust to reform, but successful overall (post)</td>
</tr>
<tr>
<td>Type of achievements</td>
<td>Evaluation Measures</td>
<td>Characteristics</td>
<td>Evaluation Goals</td>
<td>Evaluation Summary</td>
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<td>----------------------</td>
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<td>----------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Students’ interview (prior)</td>
<td>Eighteen students were interviewed from various classes. The interview was conducted in groups of three. Each group was from a different class.</td>
<td>To investigate students’ feelings and to determine what can be done to improve mathematics T/L</td>
<td>Quite satisfied with current TL style but prefer an improvement</td>
<td></td>
</tr>
<tr>
<td>Teachers’ interview (prior)</td>
<td>Six teachers were interviewed individually over a period of six days</td>
<td>To investigate what teachers think of the students and what to do to improve mathematics T/L</td>
<td>Teachers admit that there is a need for change in teaching approaches and LE</td>
<td></td>
</tr>
<tr>
<td>Students’ interview (after)</td>
<td>Six students were interviewed, three from each of the treatment class. The students were interviewed one at a time</td>
<td>To determine students’ feeling about mathematics after the package implementation</td>
<td>Students say that reform had been effective and successful</td>
<td></td>
</tr>
<tr>
<td>Teachers interview (after)</td>
<td>Two teachers were interviewed. Both were class teachers of the treatment groups</td>
<td>To determine what teachers think of the package</td>
<td>Very positive about the package &amp; overall reform</td>
<td></td>
</tr>
<tr>
<td>Students’ opinion sheet</td>
<td>Opinion sheet attached to activity to ask students’ opinion on cooperative learning.</td>
<td>To seek opinion about cooperative learning</td>
<td>Group management needed improvement</td>
<td></td>
</tr>
</tbody>
</table>
Table 7.2 confirms what is exhibited in the graph from an examination of the values of the paired sample t-test. The result shows that there was a significant improvement for students in ELE (p < 0.001), but improvement for the RTE students was not significant. The result also showed significant improvement (p < 0.01) in the overall scores (from students in the ELE and RTE classes combined) between the pre and post-test.

On of the reason for the relatively large difference in achievement between the two classes is, most likely because, although both classes were told that the result of this test would not count towards their college grade, it was noticeable (through observation) from the way they did the test that the RTE students were not as serious as the ELE students were in their attempts at the test.

Table 7.2: Correlations, means, standard deviations and the paired t-test values. The numbers in the bracket are the degrees of freedom.

<table>
<thead>
<tr>
<th>Class</th>
<th>Correlation</th>
<th>Mean Pre</th>
<th>Mean Post</th>
<th>Mean Diff(df)</th>
<th>SD Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELE</td>
<td>0.68*</td>
<td>26.33</td>
<td>40.95</td>
<td>14.61(11)</td>
<td>9.05</td>
<td>5.59**</td>
</tr>
<tr>
<td>RTE</td>
<td>0.88**</td>
<td>31.80</td>
<td>34.66</td>
<td>2.86(9)</td>
<td>12.29</td>
<td>0.76</td>
</tr>
<tr>
<td>Overall</td>
<td>0.74**</td>
<td>28.71</td>
<td>39.26</td>
<td>9.27(21)</td>
<td>11.98</td>
<td>3.96*</td>
</tr>
</tbody>
</table>

** p < 0.001, * p < 0.01

I also analysed the tests according to the categories of mathematical proficiency mentioned earlier (Chapter 3, Section 3.6) – procedural skills, conceptual understanding and problem-solving ability. In both tests, I classified the questions according to the categories mentioned. The classifications with their corresponding questions are shown in the Table 7.3:

Table 7.3: Test categories according to the question numbers.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Question Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
</tr>
<tr>
<td></td>
<td>Section A</td>
</tr>
<tr>
<td>Procedural</td>
<td>2, 3, 4, 5, 6,7</td>
</tr>
<tr>
<td>Conceptual</td>
<td>1, 8, 9</td>
</tr>
<tr>
<td>P-Solving</td>
<td>10</td>
</tr>
</tbody>
</table>
The tests were graded according to the marking scheme (Appendix 3E) and according to the criteria mentioned in Appendix 3G. The scores were then averaged according to the different categories before being analysed. The figures shown in Table 7.4 represent the students’ percentage scores in each category for both the pre-test and the post-test. Paired t-tests were also conducted to find out whether the changes in the results were significant. The t-tests values exhibited encouraging results for the ELE class and thus influenced the percentage of the results when the two classes were combined. The results for the RTE class were not as encouraging.

Table 7.4: Pre and post percentage scores and their paired t-test values in the three categories for the ELE, RTE class and overall

<table>
<thead>
<tr>
<th>Categories</th>
<th>Result (mean percentage)</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ELE</td>
<td>RTE</td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Procedural</td>
<td>23.07</td>
<td>42.09</td>
</tr>
<tr>
<td>Conceptual</td>
<td>26.27</td>
<td>40.76</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>19.38</td>
<td>33.18</td>
</tr>
</tbody>
</table>

** p < 0.001, * p < 0.05

The graph in Figure 7.2, based on the details from Table 7.4 give an alternative picture of the information. In Figure 7.2, which shows the graph for the result of RTE and ELE combined (overall) an increase in each category mentioned can be observed, with the largest increase being in procedural skills, followed by problem solving and last, conceptual understanding. From Table 7.4, after applying the t-tests, I found that the improvement in the procedural category and problem-solving were significant (p < 0.001 and p < 0.05 respectively) and that the whereas the improvement for the conceptual understanding was not significant. Overall, students demonstrated improved procedural skills and problem-solving capabilities.
Figure 7.2: Comparison of the overall pre and post percentage scores in three categories.

However, since the increase in the conceptual understanding appeared quite substantial, I performed a one-sample t-test (refer Table 7.5) and the result proved to be significant ($t = 2.108$ was significant at 0.05 significance level). It can therefore be concluded that overall, students improved significantly in all categories.

Table 7.5: One-sample t-test for procedural understanding

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>S.D</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>24</td>
<td>32.52</td>
<td>16.81</td>
<td>2.108**</td>
</tr>
<tr>
<td>Post-test</td>
<td>24</td>
<td>40.37</td>
<td>18.25</td>
<td></td>
</tr>
</tbody>
</table>

** P < 0.05

In examining the results according to the two different classes, it was obvious that the increase was mainly due to the improved results of students in the ELE class.

There were increases in all categories for the ELE class and these increases were all significant at (refer Table 7.4). A significance level of 0.001 was used for the category of procedural skills, whereas 0.05 level was used for both categories of problem-solving and conceptual understanding. The reason for the significant outcome may have been due to improved student understanding of the topic after the package implementation. Another factor may have been because ELE students had lower scores than the RTE students in the pre-test.
Figure 7.3: Comparison of ELE pre and post percentage scores in the three categories.

In the RTE class, increases in all categories were not significant. The conceptual category had the lowest increase when compared to the other two categories. With a one-sample t-test, the results (not shown) were again not significant in all categories. I believe that results for RTE were not significant due to:

- Students failing to respond to the post-test seriously because they knew that this test wouldn’t count in their overall grade.
- One or two uninterested students who from my observation, although not disruptive in behaviour, managed to distract the other students.
- The unsuitable time the test was administered to the students. It was administered from 2.00 pm to 3.00 pm in the afternoon and, as was cited in the narrative in Chapter 6 (Section 6.4), this was a time when students had difficulty remaining alert.
- The package might not meet the need of the RTE students as well as it did those of ELE students.
Figure 7.4: Comparisons of RTE pre- and post percentage scores in the three categories

I also had access to the results of the students' phase test that was conducted by the Mathematics Department on the 2\textsuperscript{nd} of February 2002. Four classes took the same test, all of which were studying the same syllabus and thus were given a common phase-test. Two of these classes were involved in the implementation of the package and I had labelled them as the treatment classes, while the other two classes that were not involved were labelled as non-treatment classes. As was mentioned in Chapter 3, Section 3.3.2 and 3.9, the accessibility of every students' results worked to my advantage as I could use them to informally compare the students' ability from both the treatment and non-treatment groups.

Table 7.6: Comparison of phase test results of treatment and non-treatment groups using independent sample t-test.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Non-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELE</td>
<td>RTE</td>
</tr>
<tr>
<td>Mean marks(%)</td>
<td>84.6</td>
</tr>
<tr>
<td>S. Deviation</td>
<td>15.68</td>
</tr>
</tbody>
</table>

The result shows a 6.98\% difference between the treatment group and the non-treatment group. However, the $t$-value is not significant at 0.1 level (the significance level of $t = 1.60$ is 0.117).
7.4.2 The Affective Results

The learning environment survey and the attitude towards mathematics survey were used in this study to measure students' affective change. These two instruments were also used in the identification phase to determine students' perception of their classroom environment and their attitude towards mathematics. The reliability and validity of the two instruments had been determined earlier (refer Chapter 4, Section 4.4.1). The result for the post-implementation phase that was analysed was contrasted with the results from the pre-implementation phase to determine any level of enhancement that existed on the means of the various scales. I commence the report with an analysis of the learning environment survey, and follow it with the analysis of the attitude survey.

7.4.2.1 The Learning Environment

![Graph showing learning environment survey results comparing the actual, preferred and post-actual survey for both classes.]

*Figure 7.5: Learning environment survey results comparing the actual, preferred and post-actual survey for both classes.*

Analysis of the "actual" and "preferred" learning environments has been presented in Chapter 4, Section 4.4.1. The results of the "actual" (results obtained before package implementation) and "post-actual" (results obtained after package implementation) survey of the learning environment will now be analysed and contrasted. From Figure 7.5, it can be seen that there is a noticeable increase in both the 'Teacher Support' and the "Innovation" scale whereas the other scales failed to...
exhibit any noticeable differences. Closer scrutiny of Table 7.7 shows that there is a slight drop in the values for Cooperation, and a slight increase in both Task Orientation and Relevance. Comparing this to the graph obtained earlier for the whole population (refer Chapter 4, Figure 4.1), there is also an improvement in many of the scales (especially Innovation) for the perceived classroom environment.

Paired t-tests were performed to determine whether the changes in the means of the scales were significant. The results in Table 7.7 show that the significant difference only exists in the “Innovation” scale (p < 0.05). However, since the difference in “Teacher Support” appear to be relatively substantial and also because I was interested in examining what happened to the whole class mean after the package implementation, I conducted a one-sample t-test (using the mean from the pre result for comparison value) for this scale.

Table 7.7: Means, standard deviations and paired t-test values comparing pre and post LE survey overall

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/ Support</td>
<td>Actual</td>
<td>3.8968</td>
<td>.6681</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>4.0286</td>
<td>.5361</td>
<td>0.132</td>
</tr>
<tr>
<td>Innovation</td>
<td>Actual</td>
<td>2.7029</td>
<td>.4155</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.0400</td>
<td>.2458</td>
<td>0.3371</td>
</tr>
<tr>
<td>Cooperation</td>
<td>Actual</td>
<td>3.9210</td>
<td>.7448</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.8286</td>
<td>.4246</td>
<td>-0.092</td>
</tr>
<tr>
<td>Task Orient</td>
<td>Actual</td>
<td>3.4971</td>
<td>.4740</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.5714</td>
<td>.3956</td>
<td>0.074</td>
</tr>
<tr>
<td>Relevance</td>
<td>Actual</td>
<td>3.6941</td>
<td>.5292</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.7600</td>
<td>.4378</td>
<td>0.066</td>
</tr>
</tbody>
</table>

*p < 0.05

From Table 7.8 it can be seen that the change in “Teacher Support” is still not significant. A one-sample t-test can be used in this situation because the data is from a single sample of subjects. The mean of the population from the post sample is the same as the pre mean (hypothesized mean) and was used as the test value.
Table 7.8: Means, standard deviations and one-sample t-test for comparing pre and post LE survey overall

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/ Support</td>
<td>Actual</td>
<td>3.8968</td>
<td>.6681</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>4.0286</td>
<td>.5361</td>
<td>0.132</td>
</tr>
</tbody>
</table>

After breaking down the figures into different classes, the graphs in Figures 7.6 and 7.7 together with tables in Table 7.9, and 7.10 were obtained. The graph for the RTE class shows some increase in both the “Teacher support” and “Innovation” scales. In fact, the post-actual value for the “Teacher Support” nearly matches the preferred figure. The other scales do not exhibit noticeable changes.

![Graph](image)

*Figure 7.6: Learning environment survey results for RTE class*

A paired t-test was performed for all scales and the results are shown in Table 7.8. The “Teacher Support” and the “Innovation” scales were both found to be significant (at the 0.05 significance level).
Table 7.9: Means, standard deviations and paired t-test values for comparing pre and post LE survey of RTE class

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/ Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3.7527</td>
<td>0.782</td>
<td>0.416</td>
<td>2.455*</td>
</tr>
<tr>
<td>P/actual</td>
<td>4.1688</td>
<td>0.597</td>
<td>0.350</td>
<td>2.270*</td>
</tr>
<tr>
<td>Innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>2.7019</td>
<td>0.597</td>
<td>0.350</td>
<td>2.270*</td>
</tr>
<tr>
<td>P/actual</td>
<td>3.0519</td>
<td>0.597</td>
<td>0.350</td>
<td>2.270*</td>
</tr>
<tr>
<td>Cooperation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3.974</td>
<td>0.682</td>
<td>-0.078</td>
<td>-0.428</td>
</tr>
<tr>
<td>P/actual</td>
<td>3.8961</td>
<td>0.682</td>
<td>-0.078</td>
<td>-0.428</td>
</tr>
<tr>
<td>Task Orient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3.5714</td>
<td>0.616</td>
<td>0.078</td>
<td>0.469</td>
</tr>
<tr>
<td>P/actual</td>
<td>3.6494</td>
<td>0.616</td>
<td>0.078</td>
<td>0.469</td>
</tr>
<tr>
<td>Relevance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3.6618</td>
<td>0.714</td>
<td>0.053</td>
<td>0.284</td>
</tr>
<tr>
<td>P/actual</td>
<td>3.7143</td>
<td>0.714</td>
<td>0.053</td>
<td>0.284</td>
</tr>
</tbody>
</table>

*p < 0.05

There were also slight increases in the Task Orientation and Relevance mean scores, and a slight decrease in the Cooperation mean score. The changes in these scales were not significant.

* Figure 7.7: Learning environment survey results for ELE class
As for the ELE class, the graph in Figure 7.7 shows slight changes in all scales except in the "Innovation" scale. Further tests were carried out to determine whether these changes were significant.

The paired t-test values (refer Table 7.10) do not exhibit any significant change, but the one-sample t-test (refer Table 7.11) yielded a significant result for the "Innovation" scale (p < 0.01).

Table 7.10: Means, standard deviations and paired t-test values for comparing pre and post LE survey of ELE class

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/ Support</td>
<td>Actual</td>
<td>4.010</td>
<td>0.824</td>
<td>-0.092</td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.918</td>
<td>0.824</td>
<td>-0.092</td>
</tr>
<tr>
<td>Innovation</td>
<td>Actual</td>
<td>2.718</td>
<td>0.749</td>
<td>0.313</td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.031</td>
<td>0.749</td>
<td>0.313</td>
</tr>
<tr>
<td>Cooperation</td>
<td>Actual</td>
<td>3.879</td>
<td>0.718</td>
<td>-0.108</td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.776</td>
<td>0.718</td>
<td>-0.108</td>
</tr>
<tr>
<td>Task Orient</td>
<td>Actual</td>
<td>3.439</td>
<td>0.629</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.510</td>
<td>0.629</td>
<td>0.071</td>
</tr>
<tr>
<td>Relevance</td>
<td>Actual</td>
<td>3.719</td>
<td>0.797</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td>P/actual</td>
<td>3.796</td>
<td>0.797</td>
<td>0.077</td>
</tr>
</tbody>
</table>

The mathematics teacher of the ELE class was very popular and this may have contributed to the slight decrease in ‘Teacher Support’ as seen in the table above (this was the teacher who received positive comments in the interview (refer Appendix 4C and 7B). Also, the students may have needed more time to accept me in the same measure as their teacher. As for a slight decrease in the ‘Cooperation’ score, the reason may have been because students were not well-organized enough in distributing tasks among themselves because they were not used to group work. This is also true for the RTE class. There was a very slight increase in the ‘Task Orientation’ and in the ‘Relevance’, both representing insignificant changes.
Table 7.11: Means, standard deviations and one-sample t-test value for comparing pre and post LE survey of ELE class

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation Actual</td>
<td>2.718</td>
<td>0.749</td>
<td>0.313</td>
<td>3.015*</td>
</tr>
<tr>
<td>P/actual</td>
<td>3.031</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.01

7.4.2.2 The Attitude Survey

An attitude survey was administered at the same time as the classroom survey. Results were compared in order to examine students’ attitude towards mathematics before and after the implementation of the package, and to examine any improvements that existed. The overall graph from the survey is shown in Figure 7.8 following:

![Image](image)

*Figure 7.8: Pre and post attitude towards mathematics survey results of overall students

The graph shows a minimal decrease in Enjoyment & Interest, no change in Relevance and a minimal increase in Importance. The increase and decreases were found to be ‘not significant’ when paired t-test was performed and also when a one-sample t-test was performed (refer Table 7.12).
Table 7.12: *Means, standard deviations and one-sample t-test values comparing pre and post attitude results overall.*

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>Pre</td>
<td>3.813</td>
<td>0.519</td>
<td>-0.129</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.684</td>
<td>0.409</td>
<td></td>
</tr>
<tr>
<td>Relevance</td>
<td>Pre</td>
<td>4.120</td>
<td>0.511</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.120</td>
<td>0.495</td>
<td></td>
</tr>
<tr>
<td>Importance</td>
<td>Pre</td>
<td>3.990</td>
<td>0.424</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.050</td>
<td>0.462</td>
<td></td>
</tr>
</tbody>
</table>

The percentage of students responding ‘agree’ and ‘strongly agree’, as well as ‘disagree’ and ‘strongly disagree’ were calculated as described in Chapter 4 (Table 4.6). The results were compared with the pre-survey (refer Table 4.6) and are shown in Table 7.13.

Table 7.13: *Percentages of students responding to ‘strongly disagree’ and ‘disagree’ (1&2) and also ‘agree’ and ‘strongly agree’ (4&5)*

<table>
<thead>
<tr>
<th>Scale</th>
<th>Pre/Post</th>
<th>1&amp;2(%)</th>
<th>4&amp;5(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>Pre</td>
<td>4.00</td>
<td>65.11</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>2.24</td>
<td>55.86</td>
</tr>
<tr>
<td>Relevance</td>
<td>Pre</td>
<td>2.00</td>
<td>86.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.00</td>
<td>86.00</td>
</tr>
<tr>
<td>Importance</td>
<td>Pre</td>
<td>0</td>
<td>77.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0</td>
<td>79.00</td>
</tr>
</tbody>
</table>

For the ‘Enjoyment & Interest’ category, I concluded that although there was a decrease in the percentage of students responding to ‘agree’ and strongly agree’, there was also a decrease in the percentage of students’ responses to ‘disagree’ and ‘strongly disagree’ (refer Table 7.13). This implies that fewer students considered Enjoyment/Interest negatively from pre to post-survey. Upon further examination of the survey transcripts, I found that the percentage decrease occurred in items 13 (I am enthusiastic about learning in mathematics class) and 15 (I am willing to spend
my free time studying mathematics) of the survey. Students complained about the rushed lessons and about too much work, which may have contributed to this result. As for the ‘Relevance’ category, although the percentage of students that agreed and strongly agreed remained the same, the percentage that disagreed and strongly disagreed decreased. In the ‘Importance’ category, the percentage of students who disagreed remained the same, but the percentage that of students agreeing increased. This suggested that although there were no significant changes in the attitude survey results on the whole, the percentage of students possessing a more negative attitude decreased because less number of students seemed to “disagree”.

The overall data was again divided into the two classes that it represented, and it was found that the decrease was due to the ELE class and not due to the RTE class at all as shown in Figures 7.9 and 7.10. This was due probably to the project work titled ‘Trigonometric Waveform Around Us’ given to the ELE students (see Chapter 6, Section 6.3.3.1) which they did not enjoy initially (refer Chapter 6, Section 6.3.3.2), and because the attitude survey was administered when they still hadn’t completed their project.

![Graph showing the pre and post attitude of ELE students](image)

**Figure 7.9:** Graph showing the pre and post attitude of ELE students

For the ELE class, there was a slight decrease in ‘Enjoyment & Interest’ while there was no change in ‘Relevance’, and the increase in ‘Importance’ was slight. Both the increase and decrease were not significant as can be seen in Table 7.14 when the paired t-test was performed.
Table 7.14: Means, standard deviations and paired t-test values comparing pre and post attitude result ELE.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>Pre</td>
<td>3.881</td>
<td>0.439</td>
<td>-0.2143</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.667</td>
<td>0.493</td>
<td></td>
</tr>
<tr>
<td>Relevance</td>
<td>Pre</td>
<td>4.161</td>
<td>0.496</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.161</td>
<td>0.434</td>
<td></td>
</tr>
<tr>
<td>Importance</td>
<td>Pre</td>
<td>4.071</td>
<td>0.409</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.107</td>
<td>0.478</td>
<td></td>
</tr>
</tbody>
</table>

The RTE class did not register any changes in the ‘Enjoyment & Interest’ as well as the ‘Relevance’ categories, whereas there was a slight increase in the ‘Importance’ category but the increase was not significant as can be seen from the t-test in Table 7.15.

![Graph showing the pre and post attitude of RTE students](image)

*Figure 7.10: Graph showing the pre and post attitude of RTE students*
Table 7.15: Means, standard deviations and paired t-test values comparing pre and post attitude result RTE.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D</th>
<th>Mean Diff</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>3.727</td>
<td>0.269</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Pre</td>
<td>3.727</td>
<td>0.617</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>4.068</td>
<td>0.5819</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Relevance</td>
<td>4.068</td>
<td>0.5488</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>3.886</td>
<td>0.454</td>
<td>0.091</td>
<td>0.425</td>
</tr>
<tr>
<td>Post</td>
<td>3.977</td>
<td>0.438</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.5 Association between Cognitive and Affective Achievements

From the results above, it appeared that the package yielded mixed results. Although it was able to significantly increase the students’ cognitive achievements in ELE class, the students seemed to perceive their classroom environment less favourably in the “Cooperation” and “Teacher Support” scales, and although they seemed to believe that mathematics was more important, their “Enjoyment & Interest” in mathematics appeared to decrease. The significant increase in the “Innovation” scale score suggests that the variety of instructional modes adopted (trying new ideas, innovative and unusual activities) was successful. Since “Innovation” scale had produced the lowest mean score, I had tried my best to make teaching more innovative. The slight increase in the “Relevance” scale suggests that although more relevant, real-life concrete examples and problems were emphasised, they may not have been effective enough to relate to significant change. ‘Relevance’ was one of the criteria that were emphasized during teaching (in both LE and Attitude survey as well as the ARCS model used).

As for the students in the RTE class, although their improvement in the cognitive achievement was not significant, they only perceived their classroom environment less favourably in the Cooperation scale, while the other scales registered an increase (although two of the increases are slight). The same thing can be said about their attitude results. There were no changes in the ‘Enjoyment & Interest’ and ‘Relevance’ categories but there was a notable increase in ‘Importance’. 
From interviews that were conducted with them they seemed to be quite positive about the changes brought by the package in terms of its approaches (Appendix 6B and 7B). Students’ realize the importance of mathematics but were not motivated enough to cause changes in other categories and to work harder in the post-test.

A standard correlation (the one-tailed simple Pearson correlation coefficient \( r \)) was performed to determine if any bivariate associations existed between the learning environment scales and the post-test results, and also between the attitude towards mathematics and the post-test results. Associations were also sought between the difference of the post-test and pre-test scores (test diff) in the post-attitude and LE scales. A linear regression analyses was then conducted to examine the association between the post-test and also the test diff scores with each particular environment scale when all other CCEI scales were controlled. This association is represented by the regression coefficient \( \beta \). The results are as shown in Tables 7.16 and 7.17 and described below.

There was a significant positive association between the ‘Teacher Support’ scales and the post-test result, and also a significant positive association between ‘Relevance’ and the achievement change (test diff). This suggests that students’ performance in the post-test may have improved because of teacher support, and also their achievement may have improved because of the relevance aspect shown in teaching. In the standardised regression coefficient (\( \beta \)) columns, none of the values shown were significant. This implies that none of the scales were independent predictors of the post-test and test difference.

**Table 7.16: Correlation between learning environment scales and pre and post-tests in terms of simple correlation \( r \) and standardised regression coefficient \( \beta \)**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Test Diff</th>
<th></th>
<th>Post-test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( r )</td>
<td>( \beta )</td>
<td>( r )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>Teacher Support</td>
<td>-0.026</td>
<td>-0.042</td>
<td>0.395*</td>
<td>0.514</td>
</tr>
<tr>
<td>Innovation</td>
<td>-0.337</td>
<td>-0.198</td>
<td>-0.071</td>
<td>0.088</td>
</tr>
<tr>
<td>Cooperation</td>
<td>-0.109</td>
<td>-0.134</td>
<td>0.097</td>
<td>-0.087</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>0.048</td>
<td>0.092</td>
<td>0.077</td>
<td>0.069</td>
</tr>
<tr>
<td>Relevance</td>
<td>0.410*</td>
<td>0.430</td>
<td>0.284</td>
<td>0.274</td>
</tr>
<tr>
<td>Multiple R Correlation</td>
<td>0.511</td>
<td></td>
<td>0.469</td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.261</td>
<td></td>
<td>0.220</td>
<td></td>
</tr>
</tbody>
</table>

\* \( p < 0.05 \)
No significant association exists between the attitude scales and the post-test results, as well as between the attitude scales and the difference in test scores for both the standard correlation $r$ and regression coefficient $\beta$ (refer Table 7.17).

Table 7.17: Correlation between attitude scales and pre and post-tests in terms of simple correlation ($r$) and standardised regression coefficient ($\beta$)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Test Diff</th>
<th></th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r$</td>
<td>$\beta$</td>
<td>$r$</td>
</tr>
<tr>
<td>Enjoyment &amp; Interest</td>
<td>-0.071</td>
<td>-0.191</td>
<td>0.128</td>
</tr>
<tr>
<td>Relevance</td>
<td>-0.011</td>
<td>-0.024</td>
<td>0.088</td>
</tr>
<tr>
<td>Importance</td>
<td>0.024</td>
<td>0.033</td>
<td>-0.250</td>
</tr>
<tr>
<td>Multiple R Correlation</td>
<td>0.189</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
<td>0.036</td>
<td></td>
</tr>
</tbody>
</table>

I also performed correlation analyses between the test diff scores (The difference between the pre- and post- cognitive scores) and the difference between the pre and post results in all the learning environment scales (TS diff, IN diff, CO diff, TS diff and REL diff), as well as the attitude scales (Enjoyment/Interest diff, Relevance diff and Importance diff). The standardised regression was also performed and the results are displayed in Tables 7.18 and 7.19.

Table 7.18 shows that there was a negative association between the test diff and Teacher Support diff, but there was positive association between the test diff and the Relevance diff. It suggests that the improvement between the tests is more positive when students perceived more relevance in the classroom. It is difficult to explain the fact that the test difference is improved when students perceived less teacher support, which is what the negative value signifies. This may have been due to the ELE students who mostly demonstrated a significant increase in test difference scores but perceived teacher support less favourably in the post-survey (because they had a very popular teacher before I took over). The only significant $\beta$ value observed from the table above is between the Relevance diff and test diff, which suggests that increased Relevance perceived by students can be an independent predictor for a better improvement in results. All five independent variables explain 44.5% of the variance in the test result difference (significance level 0.055), showing the result to be not significant.
Table 7.18: Correlation between the difference in pre and post learning environment scales scores and the test difference scores in terms of simple correlation ($r$) and standardised regression coefficient ($\beta$)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Test Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r$</td>
</tr>
<tr>
<td>Teacher Support diff</td>
<td>-0.405*</td>
</tr>
<tr>
<td>Innovation diff</td>
<td>0.301</td>
</tr>
<tr>
<td>Cooperation diff</td>
<td>0.081</td>
</tr>
<tr>
<td>Task Orientation diff</td>
<td>0.037</td>
</tr>
<tr>
<td>Relevance diff</td>
<td>0.453*</td>
</tr>
<tr>
<td>Multiple R Correlation</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
</tr>
</tbody>
</table>

* $p < 0.05$

Table 7.19 shows that there was no significant association at all (both $r$ and $\beta$ values) between the test result difference and the attitude towards mathematics scales. The reason for negative association with Enjoyment/Interest was because of the decrease in the scores in that category, whereas in most cases the test difference increased.

Table 7.19: Correlation between the difference in pre and post attitude scales and the test difference in terms of simple correlation ($r$) and standardised regression coefficient ($\beta$)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Test Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r$</td>
</tr>
<tr>
<td>Enjoyment/Interest diff</td>
<td>-0.209</td>
</tr>
<tr>
<td>Relevance diff</td>
<td>0.039</td>
</tr>
<tr>
<td>Importance diff</td>
<td>0.097</td>
</tr>
<tr>
<td>Multiple R Correlation</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
</tr>
</tbody>
</table>

I also observed significant associations between all three attitude-scales (refer Table 7.20). The ($r$) values indicate that the associations were significantly positive between the scale of 'Enjoyment & Interest' and the scale of "Relevance" and "Importance". In summary, "Enjoyment & Interest" was higher when students perceived the subject as relevant and important. The $\beta$ weights revealed that
"Relevance" and "Importance" were positively associated with student "Enjoyment & Interest". The R² value suggests that both "Relevance" and "Importance" explain 36.9% of the variance in students' enjoyment and interest. An examination of the t-value indicates that both variables contribute to the prediction of "Enjoyment & Interest".

Table 7.20: Correlation between attitude scales in terms of simple correlation (r) and standardised regression coefficient (β)

<table>
<thead>
<tr>
<th>Scale</th>
<th>r</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance</td>
<td>0.437*</td>
<td>0.413*</td>
</tr>
<tr>
<td>Importance</td>
<td>0.445*</td>
<td>0.421*</td>
</tr>
<tr>
<td>Multiple R Correlation</td>
<td>0.607**</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.369**</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05, ** p < 0.01

After closer examination of the classroom environment and the attitude survey results, I found that irregularities such as higher test scores but lower Enjoyment/Interest and Cooperation, and negative associations in some categories with the outcomes could be explained to a reasonable degree (refer Chapter 8, Sections 8.3.4 and 8.3.5). Consequently, implementation of the package indicated some favourable results and there were some increases both in affective and cognitive outcomes, although the increases were not as desired.

### 7.6 Interview Data

Teachers' and students' comments support the success and effectiveness of the package in terms of its emphasis on certain aspects of the classroom environment and instructional approach. The comments also support the success of the package in engaging students in real life examples and problems.

#### 7.6.1 Teacher Interviews

Two teachers (the mathematics teachers whose classes I took over) were interviewed (refer Appendix 7A) after the implementation of the package. They were asked what they thought of the package, how they would rate it (on the scale of 1 to
10) and if they noticed any difference in the students' understanding and behaviour after the package was implemented.

The first teacher (refer Appendix 7A) considered that the package was impressive and he had rated it to be of more than seven. He liked the materials and said that he himself would not have the time to search for such materials to produce a similar package for teaching. At the time of interview, he still could not say whether the students' attitude and mathematical understanding had changed for the better because his class had just been returned to him. However, there was a positive comment from a student saying that she enjoyed the interesting problems from the work-sheets that I distributed. Having the same opinion on this, he thought that the activities were interesting, the problems were varied and that I had done well to include real-life problems. He regarded some of them as quite hard to solve.

He said that if the package could be implemented as planned, the result should turn out to be quite impressive. He agreed that there should be improvements in teachers' instructional approaches and in the learning environment to increase students' motivation. According to him, the investigation sheet named 'Roof' was interesting. "It will be suitable for my construction students", he said.

The second teacher also gave encouraging comments, awarding the package a rating of eight. He considered the package as useful and mentioned that the package could be further improved as its implementation progressed. Complimenting me for my efforts, he thought that considerable research and reading had been carried out to obtain the materials for the package and if properly implemented, it could improve students' understanding and attitude. He said that he was also thinking of developing similar material for teaching and asked me where he might obtain them. As for students' attitude, he mentioned that he had not had the opportunity to test the students, but changes would surface sooner or later. According to him, his students had been a joy to teach and had always been supportive of him (the popular teacher identified before). He questioned whether there would be enough time to conduct activities and projects that were part of the package since the fastest mode of delivery was, in his opinion, still through lectures.

I did not take all the comments from both teachers at face value because I suspected that now and then they only conveyed the positive comments and preferred to be silent about the negative ones. Therefore, I did not really take the comments seriously.
7.6.2 Student Interviews

Six students were interviewed (refer Appendix 7B). They were chosen to represent an “above average”, an “average” and a “weak” student from each class to see if there were any differences in opinion based on the questions below.

1. Do you like mathematics? Why?
2. Do you think mathematics is important? Why?
3. What do you think of the classroom environment for mathematics lessons now? Do you think the current mathematics classroom is conducive to learning? How do you feel about the class so far?
4. Do you like the way mathematics is taught now?
5. Can you see the relevance to your chosen profession?
6. Has there been any improvement in the way mathematics is taught and in the environment?
7. Has the attempted improvement been successful?
8. What else can be done to improve mathematics?

The first question was asked so that I could contrast the opinion of students about mathematics before and after package implementation. I was hoping to examine differences in the general impression of students regarding mathematics. Their responses were as follows:

Student 1: I have always liked maths. I have liked it since I was small. In fact everybody except one in my family like maths (refer Appendix 7B, p. 418).

Student 2: I haven’t liked maths since primary. I think it involves a lot of memorisation. I now understand that mathematics doesn’t necessarily mean memorisation (refer Appendix 7B, p. 418).

Student 3: I haven’t really minded maths since primary school. Now that I have left studying for quite a while (being an in-service student), I really have to work hard to catch up and improve. But I am beginning to feel at ease with it (refer Appendix 7B, p. 419).

Student 4: I didn’t like maths in school. After leaving school (now 31 yrs old, in-service student) and studying at this college, I am
beginning to like it but I still have to work hard (refer Appendix 7B, p. 419).

*Student 5:* I like maths and now I like it better because it is a challenge for me (refer Appendix 7B, p. 420).

*Student 6:* I’ve always liked maths because I like to solve problems (refer Appendix 7B, p. 420).

Two of the students had always liked mathematics. Student 2 still seemed to dislike mathematics although he had began to realise that mathematics didn’t mean memorisation. Three students indicated an increase in their liking of mathematics. When contrasted with students’ initial interviews before the implementation, the proportion of students who liked mathematics still remained the same (i.e. one third). Although none of the students interviewed during the first phase said they didn’t like mathematics, I would expect from their responses that, given a different approach, they would learn to like it and that I was able to trace the gradual interest in the responses from students 2, 3, 4 and 5.

The second question was asked also to contrast the students’ opinion on whether they thought mathematics was important. As in the interview before the implementation of the package, every student agreed that mathematics is important. These students’ viewpoints are supported more clearly with the increase in the attitude survey score in the category of ‘Importance’. Below are their comments:

*Student 1:* I think maths is important because it is related to everyday life (refer Appendix 7B, p. 418).

*Student 2:* I am very certain that it is very important because we need maths to pursue almost every course (refer Appendix 7B, p. 418).

*Student 3:* Yes, maths is important and we need to do well especially to go for further studies (refer Appendix 7B, p. 419).

*Student 4:* Yes maths is important because it is used in everyday life (refer Appendix 7B, p. 419).

*Student 5:* Yes because maths is used in almost everything (refer Appendix 7B, p. 420).

*Student 6:* Yes, because even to go shopping and calculate the discount, we need to use maths (refer Appendix 7B, p. 420).
Question 3 was asked also with the purpose of contrasting what students thought of their classroom environment before and after the intervention. Many students that were interviewed indicated that they liked the environment and liked the emphasis on group learning. One student liked the informal nature of the class and another liked the idea of being able to communicate directly with fellow students and teachers. Only one student indicated that he was happy doing work individually. Overall, students liked group learning, however the 'Cooperation' scale decreased over the survey. I believe, this was mainly due to a few students who didn't like working together because they did not always work at, nor discuss, on-task matters (refer Appendix 8A). Below are their comments on this question:

**Student 1:** I think the environment now is conducive for studying. I like the group work and I think that it is important because we can discuss among friends (refer Appendix 7B, p. 418).

**Student 2:** I think the physical environment is not very comfortable. I think group work and discussion helps a lot and I like the way that students are able to communicate now (refer Appendix 7B, p. 418).

**Student 3:** I think the way maths is learnt is different now compared to before. I like the peer learning (cooperative learning) that was emphasised and thinks that the classroom is conducive for learning (refer Appendix 7B, p. 419).

**Student 4:** The environment is good. Friends' and teachers' help make it easier to go through hard problems. I like the group work (refer Appendix 7B, p. 419).

**Student 5:** The environment is okay. At least classes are not so formal and we can talk among us (refer Appendix 7B, p. 420).

**Student 6:** Yes. I am quite happy doing things alone but if I am stuck I'll refer to the better students and teachers (refer Appendix 7B, p. 420).

On the question whether they liked the way mathematics was taught then, each student said they liked it, especially when mathematics was connected to everyday life. But this fact doesn't seem to coincide with the 'Enjoyment & Interest' category in the attitude survey. The way mathematics was taught didn't seem to
motivate their interest although they appeared to appreciate it. One particular student indicated that their class teacher also instilled their interest in mathematics.

*Student 1:* I like the way mathematics is taught now. I can see the links to relate it to everyday life (refer Appendix 7B, p. 418).

*Student 2:* I like the way maths is taught now (refer Appendix 7B, p. 419).

*Student 3:* I like the way maths is taught now. More practical applications can be seen. At first I thought that the way was a bit strange and unfamiliar but I learned to like it (refer Appendix 7B, p. 419).

*Student 4:* I really like the way mathematics is taught now and also before this. Our teacher before has also done a lot in making us interested in mathematics. He tries very hard to make things clear for us (refer Appendix 7B, p. 420).

*Student 5:* Yes because the problems and examples were real and you could imagine the problems as you do them. That made the problems easier for me (refer Appendix 7B, p. 420).

*Student 6:* Yes, I remember that my F5 teacher also tried activities with us. They were interesting (refer Appendix 7B, p. 421).

Question 5 asked the students whether they could see the relevance of mathematics to their chosen career. This question is similar to the one asked during the interview before the implementation. In that interview, many students gave examples of what could be relevant to their course, but in this interview, only student 2 mentioned the kind of applications directly relevant to his course. One student mentioned the relevance of the project, which meant that he could see the relevance of trigonometric graphs to his course. Below are their comments:

*Student 1:* I can see a lot of use in my chosen profession like the project that we did (refer Appendix 7B, p. 418).

*Student 2:* I can see the relevance to my course. Some of them like the wiring problem, the trigonometric graphs and the use of law of sine and cosine to solve triangles (refer Appendix 7B, p. 419).

*Student 3:* I can see the relevance. I know that maths is important in engineering (refer Appendix 7B, p. 419).
Student 4: Before this we learnt how to do a problem and remember the formula. But it's hard to remember when you don't know which formula to use. Now the approach is more suitable to our course (refer Appendix 7B, p. 420).

Student 5: The problems and examples were real and you could imagine the problems as I did them. That made the problems easier for me (refer Appendix 7B, p. 420).

Student 6: Yes, you have included many examples that are relevant (refer Appendix 7B, p. 421).

Question 6 asked if the students thought that there were improvements in the way mathematics was taught and also in the environment. All of the students said that there were improvements, however students 5 and 6 seemed unsure about admitting if there were improvements. Here are their comments:

Student 1: There have been many improvements since then (refer Appendix 7B, p. 418).

Student 2: Yes, a lot (refer Appendix 7B, p. 419).

Student 3: Yes, but still trying to accommodate myself to the new style (refer Appendix 7B, p. 419).

Student 4: This class is also hard work, but you learn a lot as you're working so there is an improvement in the way math is taught and also in the environment (refer Appendix 7B, p. 420).

Student 5: There were a lot of changes in the way maths was taught. I think it is for our own good (refer Appendix 7B, p. 420).

Student 6: Yes, I guess (refer Appendix 7B, p. 421).

On the question whether the improvements had been successful, there were positive comments from students 1, 4 and 5 while the others gave vague answers. They used words like "I think so" and "not sure". Only students 4 and 5 seemed sure of what kind of improvements they had been through. Below are their comments:

Student 1: Some success (refer Appendix 7B, p. 418).

Student 2: Thinks so (refer Appendix 7B, p. 419).

Student 3: Not sure (refer Appendix 7B, p. 419).
Student 4: This class is fun, exciting, creative and makes people use their mind and common sense to solve problems that you might face in real life situations. So, I think the improvement has been successful (refer Appendix 7B, p. 420).

Student 5: I like being able to work together to figure things out. At least that is successful (refer Appendix 7B, p. 420).

Student 6: I am not so sure. But since I have always liked maths, more improvements to the way it is taught would be better (refer Appendix 7B, p. 421).

The last question asked whether anything else could be done to improve mathematics. This question was similar to the last question asked before the implementation of the package. I asked this question to see if students could suggest fresh ideas after going through some changes themselves. There was nothing new in their suggestions except from student 6 where she mentioned that more projects should be given. Below are their comments:

Student 1: Make mathematics more fun. More field work and activities (refer Appendix 7B, p. 418).

Student 2: More applications should be emphasised (refer Appendix 7B, p. 419).

Student 3: More field work (refer Appendix 7B, p. 419).

Student 4: Friendly teachers who take an interest in whether we understand or not (refer Appendix 7B, p. 420).

Student 5: Don’t give too much homework (laughs) (refer Appendix 7B, p. 420).

Student 6: More projects, as I think I learn a lot when doing projects (refer Appendix 7B, p. 421).

Student 1 and 4 were above average, 2 and 5 were average while 3 and 6 were weak students. From the interview data gathered, the more able students always had positive responses, and the weaker ones were non-committal or had little to say. Therefore, I conclude that the better students in the class had a more positive outlook and perception towards mathematics.
7.7 Cooperative Learning Evaluation

Felder and Brent (1994) believe that students working cooperatively tend to exhibit higher academic achievement, greater persistence through graduation, better high-level reasoning and critical thinking skills, deeper understanding of learned material, more on-task and less disruptive behaviour in class. These students also experience lower levels of anxiety and stress, greater intrinsic motivation to learn and achieve, greater ability to view situations from others’ perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem compared to students taught traditionally - i.e., with instructor-centered lectures, individual assignments, and competitive grading.

Cooperation was the theme of the teaching and learning advocated in the package. From previous surveys, I found that Bruneian students scored highly on student cohesiveness and cooperation (Khine & Fisher, 2001; Riah, 1998), hence I decided to use this favourable disposition to the advantage of the students in this study. In a recent project on improving technical students’ attitude towards mathematics through cooperative learning, improvements were noted in the anxiety, confidence and enjoyment dimensions of attitude (Silva Das & Alias, 2004). However, these gains were not statistically significant when t-tests were performed. From observation and experience of teaching for eight years in Bruneian high schools and at college level, I agree with the findings mentioned above. From my own survey, although I did not include the result of Student Cohesiveness in the report of the survey outcomes (as was explained in Chapter 4, Section 4.4.1.1), the mean for Student Cohesiveness was 4.026 and 3.85 for Cooperation (refer Chapter 4, Table 4.5), which were considerably high mean scores when compared to the highest possible score of 5. I decided to probe students’ opinion on cooperative learning by asking them to complete the “Cooperative Learning Activity Report” (refer Appendix 7C) that was given out when they were completing the graphing activity cooperatively. This data helped me in explaining why the mean of the “Cooperation” scale decreases. I applied the effective strategies for cooperative learning advocated by Felder and Brent (2001) and divided the students into four groups in each class. All four groups in each class answered, “yes” to the following questions:

1) Did each member of the group contribute to the discussion?
2) Did each member of the group participate in the activities?
3) Did each member fulfil his/her responsibility?

4) Did your group complete all assigned activities?

Students were also asked other questions including: what mathematical concept was addressed by the activity; the strengths and weaknesses of the activity, and what could be done to make the group interaction more effective. The reason for this was to make sure they knew what they were doing and were on-task the next time they were involved with cooperative learning.

The following paragraphs summarises students’ responses starting with the ELE class, followed by the RTE class (refer Appendix 7C for sample responses).

In the ELE class, only one group could explain clearly the mathematical concept that this activity tried to address. Other groups simply stated the obvious title of the activity, while another group did not have a clear idea of the activity because their response was “different frequency and amplitude can cause different wave and height” – which doesn’t make sense and implies that nobody discussed or explain to each other (or ask the instructor) what concept was being addressed although I had clearly explained the aims. As to the strength of this activity, all four groups mentioned how it made them understand more about amplitudes and frequencies in trigonometric graphs, and one group mentioned the advantage of allowing students to interact with each other in enhancing team work. As for the disadvantages, students were critical about too little work done because of the time they wasted before actually starting work on the activity; the activity took too much time, and the graphs were too complicated to draw.

With regard to the last question, two groups stated the obvious reasons of teamwork, mutual understanding and hard work. One group mentioned expecting more exposure to real-life and about interactive work (on the computer or graphic calculator), and another group suggested dividing the work for each student and having each of them explain their part to each other (similar to jigsaw). I think the group wanted the teacher to divide the work for them and didn’t realise that, as mature students, they were expected to divide the work themselves.

From the RTE class, two groups explained that they were trying to understand the behaviour of the graph when the amplitude, frequency and phase change were varied. Not one of the groups could state precisely what the weaknesses of the activity were. They only stated the strengths, and all groups had similar
answers – such as helping them to understand further about graph behaviour. To the final question on what could be done to make group interaction more effective, one group mentioned about seating arrangement (facing each other) when in fact they were free to move around, while another stated ‘working together all the time’ and another stated about more discussion before drawing the graphs.

From the above data, I concluded that generally students had not adapted well to group work. They seemed to know the benefit of group work, but had problems implementing it. After going through the real process, they came to realise certain aspects in cooperative learning that they might not have realised before, and I attributed this reason for the slight decrease in ‘Cooperation’ in the post classroom environment survey depicted in Figure 7.5. I believe, cooperative learning can be a success because dividing work among themselves, having friends to discuss their work with later, and time management should come automatically once students were used to it. According to Schoenfeld (1992), students who have not had collaborative experiences will most likely find it difficult to coordinate their efforts, while those who have often worked collaboratively will readily fall into certain kinds of cooperative behaviours. Felder and Brent (1996) have said that cooperative learning tends to be the hardest student-centred method to sell initially. This survey was given halfway through the implementation of the package and I found that group work had improved by the end of the study. Students’ reaction to ‘jigsaw’ and to the project (later) showed that students realized certain benefits of cooperative learning (refer Appendix 7B, p. 418 and Appendix 6E). Woods (1994) observed that students adapting from traditional to non-traditional classes can experience a number of different conditions associated with trauma and grief (shock, denial, strong emotion, resistance and withdrawal, surrender and acceptance, struggle and exploration, return of confidence, and integration and success). I classified my students as falling under his “surrender and acceptance” category.

7.8 Answering the Research Questions of Phase 4

The effectiveness of the package was evaluated first through detecting changes of performance on the initial diagnostic test as compared to the post-test and also changes in students’ perception of their classroom environment and their attitude. Other areas that were examined with improvements noted were the reduction in basic errors in weekly assignments, and the improved interest and
involvement, as could be seen during implementation and as was described in Chapter 6. Both of these sources combined with interviews, observations and the cooperative learning survey influenced my conclusions in answering the research questions.

The main issue that this phase of study attempted to determine was whether the reform and changes incorporated in the package were successful in increasing students’ mathematical understanding and improving their attitudes. It can be summed up in one single question of “How effective was the package?”. The associated secondary research-questions were listed in Chapter 1, Section 1.6.4 and below.

*Did the treatment group develop a better understanding of mathematics after the implementation of the package?*

Overall, the treatment group did develop a better understanding of mathematics and the improved understanding was especially evident in all the three areas of procedural skills, conceptual understanding and problem-solving ability following use of the package. This outcome was evident from the pre- and post-test results as reported in Section 7.4.1. From observations, interviews and assessments during the implementation as reported in Chapter 6, I can state that the treatment group did develop at least a better understanding of mathematics than they had before the implementation.

*Did the perception of the classroom environment and the attitude towards mathematics of the treatment group improve after the study?*

There was a significant improvement in one of the scales of the classroom environment – the ‘Innovation’ scale – whereas the changes in other areas, although not significant, indicated noticeable increases. The ‘Cooperation’ scale exhibited a decrease in mean. On the whole, I can conclude that students’ perception of their learning environment improved only in certain scales of the learning environment after the package implementation. As for the attitude towards mathematics survey, the changes exhibited were not significant although there was an increase in ‘importance’, no change in ‘relevance’ and decrease in ‘Enjoyment & Interest’. As can be seen from the explanation (refer Section 7.4.2, The attitude survey), although the results were not conclusive, only a slight improvement in students’ attitude was
observed. Overall, the students displayed a mixed perception of the LE and attitude after the implementation of the package and after the outcomes from both qualitative and quantitative data were subsequently analysed.

*Is there a positive correlation between cognitive achievement of the treatment group and particular aspects of the classroom environment as well as attitude?*

From the quantitative data results, I can conclude that there was a degree of association between the cognitive and two of the affective achievement of students (as explained in Section 7.5). There were significant positive associations between the learning environment scales of 'Relevance' and 'Teacher Support' with the test improvements and post-test results respectively but not in other scales. There were also significant positive association and significant negative association between the difference in test scores and the difference in learning environment means of 'Relevance' and 'Teacher Support' respectively. No statistically significant association was registered between the cognitive outcomes and attitude survey. From the qualitative data, I can also conclude that the better students were more positive in attitude compared to weaker students, therefore there were correlations between the cognitive and affective achievement but only with certain categories.

*What was the overall achievement compared to other groups that were not administered the package?*

When the result of the phase test with treatment and non-treatment groups was compared, it was found that there was a slight increase in achievement for the treatment group (p < 0.117) which is not significant. Compared to the non-treatment group, the treatment group only performed by about 7% better.

### 7.9 Summary

Both the qualitative and the quantitative data and analysis had been used to explain the results for this study. Therefore when making conclusion, both of these results hold equal importance. I was satisfied with the outcomes however more refinement could be made for an even more successful implementation of the package. Constraints and limitations to this study and suggestions on how to make the study more successful will be discussed in Chapter 8.
Chapter 8

Discussion and Conclusion

The principal goal of education is to create men who are capable of doing new things, not simply of repeating what other generations have done.

– Jean Piaget (1896-1980) Swiss cognitive psychologist

8.1 Overview of the Chapter

In this chapter the results of the study and its main findings are reviewed and discussed. Section 8.2 revisits the events that initiated this study and summarises the procedures adopted. Section 8.3 encompasses the discussion on methods and outcomes; Section 8.3.1 discusses the appropriateness of the research strategy and methods, while Section 8.3.2 discusses the teaching and learning package’s design and content. Students’ learning outcomes in terms of cognitive and affective achievements are discussed in Sections 8.3.3 and 8.3.4, while Section 8.3.5 discusses the associations found in this study between cognitive and affective findings and explains some contradictions between the results revealed within this study and others mentioned in the literature review. A summary of the main findings and their implication for classroom practice are highlighted in Sections 8.5 and 8.6, while Sections 8.7 and 8.8 include the discussion of the scope and limitations of the study and provide suggestions for future research. A conclusion in Section 8.8 completes the thesis.

8.2 Introduction

This study was undertaken because I have always believed that most students can succeed in mathematics if teachers implement the effective approaches and teaching strategies, and if students themselves are motivated and practice effective learning strategies. I began to realise that a need for reform (both from teachers’ and students’ perspectives) is necessary when confronted with students pursuing
technical studies in Brunei. Being academically weak, these students come to the
college carrying with them the negative perceptions of mathematics learning that
they had absorbed in the Brunei secondary schools where instruction has always
been teacher-centred and traditional in nature, and in an environment where they had
failed. I then started to search for what I believe to be favourable and effective
teaching and learning strategies.

I was convinced that something positive could be done at the college level
when a few students commented to me that they were doing quite well in
mathematics after a while at the college, whereas they had never passed the subject
before. I then put my efforts into analysing the factors that contributed to this
situation. I believe that mathematics becomes more meaningful to students when
they can see the relevance of the subject to their life and to their course of study, and
that this can become one of the main sources of motivation for students. With this in
mind, I set out to identify other factors that could improve motivation to learn
mathematics, and I set out to incorporate these facts into a teaching and learning
package that emphasised those contributing factors. These factors became the
foundation of the learning environment and instructional approach that I developed
for the study. The development was done in order to make learning more meaningful
for the students and to prepare them with the skills needed not only to cope in the
working world, but also for ongoing and lifelong self-education purposes.

The study was centred around a teaching and learning package that was
developed over four phases (refer Chapter 1, Section 1.5) – the identification phase,
the design and development phase, the implementation phase and the evaluation
phase. During the identification phase, students and teachers were surveyed and
interviewed and classes were observed to identify existing teaching and learning
approaches; the problems that teachers and students faced in teaching and learning
respectively; students’ current and preferred classroom environment, and also
students’ attitudes to mathematics. The findings obtained in the first phase coupled
with information from the literature review were used to design a teaching and
learning package during phase two of the study. In phase three, the package was
implemented and it was finally evaluated in phase four.

The package was designed around the topic of trigonometry, intended for
Bruneian technical students’ use, but it could have been designed for any topic that
suited students studying mathematics. It was implemented over an eight-week
intervention period in order to test its effectiveness with two classes of students. One of the main aims of the study was to enhance students' mathematical understanding by developing and focussing on their conceptual understanding. Historically, vocational mathematics has provided only a narrow range of skills limited to middle school topics and is devoid of conceptual understanding (National Center for Education Statistics [NCES], 1996). After undergoing the implementation of the package, I believe that the students had experienced mathematics that was enriched beyond the usual lecture and practice sessions. This was due to lessons being made more contextual than the students normally experienced. From my own experience of teaching technical students, I observed that they expressed anxiety and showed a lack of motivation when the teaching and learning context was not clear to them. Lessons stating the learning objectives at the very beginning (as was the norm of every lesson in the package) enhance orientation and provide students with better and proper guidance. This approach also allows the possibility for students to make connections between other topics of their courses and with information that they already possess. Such a strategy guided them on how to approach a classroom session in order to become more confident and satisfied with each learning episode.

8.3 Discussion of Methods and Outcomes

In the following section I discuss the results and draw a number of conclusions from the study, with the discussion laid out according to the sub-sections that cover the study's methodology; package design and content; cognitive and affective learning outcomes, and the associations between the two.

8.3.1 Methodology

Both qualitative and quantitative data were collected and analysed in order to provide the study with greater credibility. Both types of data complemented each other and in some cases helped to clarify and explain certain results. The study employed a 'pre-experimental design' method where a group was observed and surveyed; an intervention study was implemented (using the study package to the groups mentioned), and observations and survey were again applied to measure the resulting changes. Post-tests and pre-tests were employed to measure any gains in both cognitive and affective abilities in the following ways:
- The pre-test provided a baseline measure of the students' situations; a treatment was introduced, then the post-test measurement was taken
- The post-test measurement was compared to pre-test measurement
- If the treatment did have an influence, then post-test and pre-test measures should be significantly different statistically.

In general, the evaluation instruments utilised appear to have served their purposes. In particular, asking students to indicate their perception of the learning environment and also their attitude to mathematics before and after the package implementation was very useful in assessing learning effectiveness from a student's viewpoint. This has also acted as a satisfactory counterbalance to the pre and post-test quantitative cognitive measures. Interviews with students and teachers, observation of students in classroom setting, and comments made during discussions among themselves have all proved invaluable in building up a picture of how students have approached the learning tasks. They also revealed where the strengths and weaknesses of the packages and teaching methods lie.

8.3.2 Package Design and Content

When designing and developing the package, the five aspects of the learning environment were emphasized and incorporated into the four components of the ARCS motivational strategies in each lesson (refer Chapter 5, Section 5.3). Teaching/learning strategies (including content) that captured attention, highlighted relevance, as well as provided confidence and satisfaction have all formed part of the approaches introduced to enhance students’ motivation and understanding. The use of technology and the physical classroom environment were also stressed. Worksheets, activities and projects were designed to improve the effectiveness of the reception of knowledge, and assessments were varied and made more authentic for the purpose of motivating the students in their quest for further knowledge.

The instructional approach was constructivist in nature and this was complemented by traditional methods such as drills and practice through homework. Applying Jonassen’s (1991, 1994), Wilson and Cole’s (1991), Ernest’s (1995) and Honebein’s (1996) recommendations listed in Chapter 2, (Section 2.4) to the design of the lessons had resulted in mixed responses from the students. While most of the recommendations were applicable and appropriate to the Bruneian technical students
culture, a few (for example: Jonassen’s – Instructional goals and objectives to be negotiated and not imposed; Wilson and Cole’s – provide for student control; Honebein’s – Encourage ownership and voice in the learning process) were not. Generally, Asian students and Bruneian students in particular are not used to being treated as equal partners in a teaching/learning process. Negotiating instructional goals is foreign to these students and is not their priority as they are happy enough to be directed and instructed by teachers.

Students seemed to enjoy the lessons although they needed to familiarise themselves to the new approach and they took some time to become used to the idea of a different environment. The observations of the students were carried out more as a whole class rather than concentrated on individual students, therefore the results of individual understanding were not assessed in great depth. Overall impressions suggest that the students could adapt themselves to the reform methods introduced: In fact, the vast majority of the remarks made during discussions and on questionnaires confirmed the earlier evaluation findings, and show that the design and style of the package was well received by students.

Chapters 6 and 7 include many quotations and instances (from observation and interviews) that demonstrate the generally favourable acceptance of the package by the students and teachers in the study. Most of the students clearly recognised the benefit of the package. The findings show that the package design was well received although further improvements and modifications could be made – for instance the allocation of time and material content as well as having appropriate activities for different groups and different lessons.

Although strategies for improving student study methods need not rest with the instructor alone, the design of the package clearly helped the students to be more structured and methodical with their study methods, and to be more directed to learn about learning. This is evident from the graded exercises and project that the students submitted. Searching for materials on the internet during project work, having to explore and provide appropriate formulae, and solving problems have all contributed to this outcome.

Since the package began with a pre-test, instructors were able to use it as a diagnostic tool to find out the areas that needed to be concentrated on, and to detect any misconceptions that the students possessed. Instructors could then design a
strategy to address this problem and readjust the package to suit the need of each student.

8.3.3 Learning Outcomes – Cognitive

Cognitive learning outcomes were assessed using several measures – pre and post-test content questions, concept mapping, project work, graded exercises and homework, including students’ views and responses to several questions in discussion groups. In most cases the enhanced level of students’ confidence, the pre and post test scores and the students’ responses all indicated the same positive trends. A significant improvement in learning had been recorded, as was evident from the students’ test scores. Their verbal responses too indicated that generally students felt that they had benefited from the teaching episodes.

Examining the mathematics proficiency results according to the categories mentioned in Chapter 2 (Section 2.4.3), it can be said that, overall, students’ proficiency in all three areas of conceptual understanding, procedural fluency and problem-solving capabilities had definitely improved. From their research, Rittle-Johnson and Stiegler (1998) found that conceptual understanding and procedural skills are highly correlated. The package in this study emphasized conceptual understanding and the results implies that the package was successful in enhancing students’ conceptual understanding, and that this had led to an increase in procedural fluency – as suggested by Brown, Seidelmann and Zimmerman (2002) (refer Chapter 2, Section 2.4.3). Grouws and Cebulla (2000a) have stated that students who develop conceptual understanding early, perform best on procedural skills later, while those with sound conceptual understanding are able to develop procedures and skills they were not taught. On the other hand, students without conceptual understanding could acquire procedural knowledge when the skill is taught, but with low levels of conceptual understanding they need to practice more to acquire and consolidate those skills. Grouws and Cebulla also mentioned that according to one study, students were able to understand concepts without prior or concurrent skill development, and there was also evidence that students can learn new skills and concepts while working out solutions to problems. Therefore, research suggests that it is not necessary for teachers to focus first on skill development and then move on to problem solving (Grouws & Cebulla, 2000b). Both can be conducted simultaneously.
In this study, given the improvement in both areas of procedural skills and conceptual understanding, it was not surprising that the problem-solving abilities also improved because when the students improved their understanding of the concepts and procedural fluency, their problem-solving abilities were enhanced. Although I was satisfied with the significant increase in the problem-solving ability category, I believe that the students would perform much better if teachers had more time to devote to problem-solving sessions, and if students were taught problem solving approaches as developed by Mason et al. (1982), Polya (1957) and Schoenfeld (1983).

The results and findings in this study agreed with those of Briar (2001), as quoted in Schoenfeld’s (2002) paper. In that particular study, increases were observed in all three categories of mathematics ability after students went through a reform curricula. In the same paper by Schoenfeld (2002), he stated that there was no difference in performance for the basic skills between students who learnt from traditional or reform curricula, but students studying reform curricula outperformed the students studying traditional curricula on conceptual and problem solving by a wide margin. The largest increase in marks was observed in the skills category; second largest in the conceptual category, and the least in problem solving. In the case of the present study, the largest increase was in procedural skills, followed by problem-solving ability and finally, conceptual understanding.

Although most of the improvements came from the ELE class, the RTE class also did reasonably well. The small improvement in test scores exhibited by the RTE class was most likely due to the fact that the students’ results were compared to a higher score than the ELE class because the RTE class performed better in the pre-test (refer Table 7.2). Other reasons that might contribute to this result were stated in Chapter 7 (after Figure 7.4). A further reason might have been due to one or two students who simply read the test paper, attempted a few questions then ignored the rest. Because of the small numbers (10) attempting the test in this class, any extreme results would affect the average.

Comments from the students established that they were non-critical of the package. They accepted it and dealt with it, on some days with more passion and energy, and on other days less enthusiastically. Students expressed anxiety only when the amount of work to be done was substantial and because of the limited time that was allowed for the package implementation. This became a major source of
irritation for students. They were also originally critical of the amount of work that they had to do for the project, but in the end were pleased with their results.

Formative evaluation, conducted during the implementation of the package, was established to assess the effectiveness of the materials from an early stage. This had helped in the reorganization of the materials by determining the appropriateness of the material for the students, adjusting the time spent on each activity and lesson, and in determining the students’ mathematical understanding. There was a significant increase in understanding in the topic of radian measure, trigonometric graphs and trigonometric ratios because students had more time to indulge in the activities provided and were not pressured to complete the syllabus as they had been in the cosine rule and area measurement topics.

Applying the model of Chapter 2 (Section 2.4.1) had provided a positive result in terms of mathematical understanding for students and this can be clearly seen from the significant improvements described in Chapter 7 (Section 7.4.1).

8.3.4 Learning Outcomes – Affective

8.3.4.1 Students’ Perception of LE

The “What Is Happening In This Class” (WIHIC) had been conducted and validated in many studies in Brunei. The learning environment questionnaire that I used had some items selected from the WIHIC, some from the “College and University Classroom Environment Inventory” (CUCEI) and some other items that were self-created. Since Khine, Larwood and Fisher (2000) suggested that language difficulty should be overcome when using learning environment tools, I reworded some of the statements taken from those two questionnaires. However, I believe that the language should be simplified further for use in the Bruneian context. I was unable to provide a larger sample as was mentioned in Chapter 2, (Section 2.3.4) because the entire population of students taking National Diploma Year 1 was quite small. The total of 239 covered the entire population of students enrolled in the first year Diploma in Brunei.

Khine (2001) also suggested that, due to cultural reasons, students might not respond openly or genuinely to the questionnaires. I do not agree with that statement. In my opinion, students were quite open and genuine when responding to the questionnaire (from the not very positive post-survey results), but might not have
been as open during interviews. Not wanting to appear rude or to offend me, they were reluctant to discuss openly or make negative comments about any of their teachers or any situation in which they were involved. They appeared quite genuine in responding to questionnaires, but not being exposed to reform methods, or genuinely believing in the system and that a teacher knows best, they were more inclined to register high scores to many of the statements in the questionnaire.

The results in Chapter 7 (Section 7.4.2) showed that there were improvements in each of the learning environment scales except in “Cooperation”, with the improvement being statistically significant only in the “Innovation” scale. I will now comment on each of the LE scale to provide a clearer picture of the situation.

**Teacher Support:** Overall, the mean score on this scale increased by 0.1318. It was not statistically significant but the increase can be considered close to being significant (refer figures in Table 7.6), mainly due to the responses from the RTE class. The increase from RTE was strongly significant, whereas there was a slight decrease in the ELE class. I have explained the reason for the slight decrease (refer Chapter 7, Section 7.4.2.1, after Table 7.9). This suggests that the teacher plays a significant role in educating students and in determining their attitude and achievements.

**Innovation:** As mentioned earlier, this scale’s mean score increased by 0.3371 and was statistically significant when a paired t-test was performed. This was expected since this scale scored the lowest during the pre-survey. Due to this reason I attempted to introduce a variety of innovative activities and assessment techniques in my classroom teaching. Activities like the “jigsaw” were new to the students and even the seating arrangement did not conform to convention and students noticed these differences.

**Cooperation:** This scale’s mean score decreased by 0.0924. Although it was a very slight decrease, both groups exhibited the phenomenon. I attribute this decrease to the students not being familiar with the concept of division of labour during group work, although they believed that they were a very close-knitted group (refer Chapter 7, Section 7.7). I conclude that teamwork needs to be initiated and nurtured.

**Task Orientation:** The increase in this scale’s mean score was 0.0743, which was very slight. In order to improve the mean of this scale, tasks could be orientated more to the students’ liking. Upon further examination of students’ responses to the
questionnaire, the small increase appears to have been due to the one or two students who did not think some of the tasks were necessary or interesting.

Relevance: This scale's mean score increased by 0.0765. I had anticipated a significant increase in this score because I had spent a considerable amount of time looking for materials that were real-world, everyday, authentic problems that made students think that what they learn in mathematics was relevant, and so increase their motivation. In the interviews, many students agreed that the materials they used in class were relevant to their field of study. Given more time, more relevant materials could be taught and the result would, hopefully, be much better.

8.3.4.2 Students’ Attitude

There were only slight differences in the students’ attitude when the pre and the post survey results were compared. I believe that more time was needed to develop and change students’ attitude as the length of time available was probably insufficient to change and develop positive attitude among the students. All categories tested for the students’ attitude were not statistically significant.

Enjoyment/Interest: This scale’s mean score showed a decrease of 0.1289, which was not statistically significant. The ELE class contributed to the decrease since there was no change for the RTE class responses. The main reason for this was explained in Chapter 7 (after Table 7.11). The ELE class did not enjoy some of the activities (as evidenced by the comment of one student regarding measuring the circle using a string in (Chapter 6, Section 6.3.2.2). Then there was the initial feeling about the project (refer Chapter 6, Section 6.3.3.2) that was only given to the ELE class. As was stated by Armstrong (1985), students’ attitude would improve in an environment where intellectual demand and problem difficulty is lower. Since the package was quite demanding and required greater commitment from the students, the enjoyment/interest category decreased. Enjoying a lesson and enjoying tasks appear to be two different things. Students might enjoy the lessons that they attended (enjoying their teachers and friends) but did not enjoy the difficult tasks they had to perform.

Constructivist approaches to teaching and learning had been used and designed to have a positive influence on students’ perceptions of their classroom-learning environment. This study has shown however that the students did not enjoy these approaches as much as I had anticipated. It was perhaps due to their Asian
culture (Fung, 2002) and the attitude that teachers are all knowing and students should derive knowledge directly from them, hence the reluctance to accept exploratory work. This finding is consistent with those of Green (1994) and Bridson (2002) in their studies conducted in Australia.

Relevance: The relevance category mean-score value remained the same. This result agrees with the findings by Armstrong (1985), Fennema and Sherman (1987) and Hyda (1996), where they suggested that curriculum and instructional variables made little or no difference to attitude. However, in the results shown in Chapter 7 (Table 7.17), relevance and importance were found to be associated with enjoyment and interest in this study, which means that students enjoyed and were more interested in the subject when they could see the relevance and importance of what they were learning.

Importance: My attempts in trying to use examples and problems to show the importance of mathematics appeared to be successful. Although the scale increase was minimal and insignificant, students' comments verify that they became more convinced that mathematics is important in life after seeing the examples and problems and experiencing the package. Following Aiken's (1971) suggestion to differentiate between enjoyment and usefulness appeared to lead to the contradictory results. Although students knew that mathematics was important, and although they were more convinced of the importance after the package implementation, they still exhibited less enjoyment — for the reasons described earlier (the section on Enjoyment/Interest).

8.3.5 Associations between Cognitive and Affective Outcomes

The link between students' perception of their learning environment and attitude, along with their corresponding test scores, can be examined to expose positive and negative associations between these outcomes.

In Chapter 4 (Section 4.5.1), I presented the results and analysis of a pre-survey that showed that there were significant positive associations between almost all of the classroom environment scales (Teacher Support, Innovation, Cooperation, Task Orientation and Relevance) and the attitude scales (Enjoyment/Interest, Relevance and Importance), which agrees with the findings of Cooper (1988), and Valas and Slovik (1993). This outcome also agrees with the results of Khine's (2001)
study, which demonstrated that students’ attitude, and thus motivation, is greatly influenced by the learning environment.

As was shown in Chapter 7 (Section 7.5) significant associations were observed between the post-test results and teacher support, as well as between relevance and the difference between the pre- and post-test results. The result also exhibited a negative association between students’ outcomes and “teachers’ support” (refer reasons in Chapter 7, after Table 7.15), which contradicts the findings of Reed (1968) and Moore (1993) (refer Chapter 2, Section 2.3.5, last paragraph). A significant positive association was also exhibited between “Relevance” and students’ post-test outcome, which implies that teaching students with materials that are authentic, and with meaningful real-life problems that point out practical application of concepts and the use of concrete everyday examples leads to improved student outcomes. A similar result has been shown in studies in Brunei (Riah, 1998) where there were strong associations between the learning environment and the student outcomes.

This study was unable to demonstrate any statistical association between attitude and students’ outcomes, as was confirmed in studies by Gadalla (1999) as well as Lokan and Greenwood (2000). Students’ comments were generally favourable, but the mean scores were reduced rather than increased in some of the survey components carried out after the teaching episodes. Since it takes a considerable amount of time to develop positive attitudes among students – probably longer than eight weeks of involvement with the package – this should not discourage other researchers or teachers from implementing outcomes suggested by the findings of this research.

An examination of the effects of a low or high pre-score was undertaken and could be developed further and again linked to specific parts of the package. Further analysis could also be carried out to quantify specific problem areas cited, along with the extent of students' understanding of the context from the responses to the question: "What did you expect to learn from each mathematics class?"

8.4 **Summary of Main Findings**

On the whole, students’ mathematical understanding appeared to be enhanced with the introduction of the package but their attitude was unchanged. Although students’ perception of the learning environment exhibited an improvement that is
not significant, I believe that these changes may have led to some degree of enhanced student motivation (however minimal) as was proposed in the model of Figure 1.1 advocated by the package. From the results in chapters 4, 6 and 7, I summarise the main findings as follows:

1. Students’ mathematics proficiency in all three areas of procedural skills, conceptual understanding and problem solving abilities improved as the result of the implementation of the package.

2. Students’ perception of the learning environment improved in all areas except that of “cooperation” as a result of the implementation of the package. However, the improvement was only significant in “innovation”.

3. Although students’ attitude towards mathematics exhibited no significant change, from analysis of each item of the attitude survey, it was found that more students believe that mathematics is important in everyday life; that mathematics is not just about memorising formula; that mathematics is not just important to mathematicians, and that they were now more relaxed in mathematics classes. From interviews and observations data, students appeared more positive than before the implementation.

4. Students who had experienced the package implementation performed by 7% better in an examination that tested their mathematical understanding than students who did not. However, the improvement was not statistically significant and this comparison is informal.

5. Constructivist approaches to teaching did not necessarily lead to a more enjoyable mathematics experience. This appeared to lead to a decrease in scores in the attitude survey results for the Interest/Enjoyment category.

6. Students need to be guided to succeed in cooperative learning. They also need time to adjust to this kind of learning, to be aware of the importance of teamwork and the value of cooperation cooperation. They need to be nurtured to become familiar with cooperative or collaborative work (refer Section 7.7).

7. There exist associations between learning outcomes and the learning environment in certain scales such as “Relevance” and “Teacher Support”. Relevance plays a significant role in the enhancement of students’ outcomes whereas “Teacher Support” seemed to play the opposite role.
8.5 Implication for Classroom Practice

Since the introduction of the package did produce a number of positive cognitive outcomes, I recommend that the following features that appeared to work well in the study and even those that fail to work but are considered important, be extended to classroom practice. The features listed would correspond well with the educational objectives that include the enhancement of mathematical skills in the implementation of relevant, responsive and flexible technical education programmes (refer Chapter 1, Section 1.3.3):

1. Group work or cooperative learning should be encouraged. This is not just to achieve improved cognitive understanding, but also to develop students as future workers. The workplace has now become more collaborative in nature and an effective team player is needed in that kind of environment. However, for cooperative learning to succeed, students’ need time and guidance to familiarise themselves with.

2. Integration with other subjects should also be encouraged so that mathematics is viewed as relevant and important as can be seen in the case of the project. Students need to see the context in which mathematics is used, and integrating it with other courses is one of the best ways to do this. Integration has been proven to be successful in school programs (refer Chapter 2, Table 2, for example ‘Curriculum Integration’ and ‘Career Academics’). An integrated curriculum is in line with the provision of Brunei’s education policy (refer Chapter 1, Section 1.3.2).

3. Teaching should be made more contextualised and relevant (meaningful) to the students in order to motivate them to learn mathematics. This has been proven to be successful in programs such as Tech Prep and Curriculum Integration (refer Chapter 2, Section 2.4.2).

4. Teachers should be encouraged to use real world, authentic and relevant materials in teaching. Real data should be used to familiarise students with what really happens in the day-to-day world. This is related to point 3 above.

5. Use of technology, especially graphic calculators should be encouraged for teaching and learning purposes (because of the obvious difficulty that resulted from not using them in this study). Graphics calculator and computers would assist students in learning, as was seen in the instances of
graphing and interactive learning. Using calculators would save a considerable amount of time and energy, as was described in Chapter 6 (Sections 6.3.3.1 and 6.3.3.2). Furthermore, this would also expose the students to the real world, since technology is used in all kinds of work situations today.

6. Soft skills (refer definition in Chapter 2, Section 2.3) are very important in the world of work (refer Chapter 2, Section 2.3). Soft skills such as analytical thinking, problem-solving, communicating effectively, flexibility, diplomacy and creativity can be developed by devolving responsibilities to students, and can be measured by assessing their attitude towards project and team work. In fact this approach has been recognised by the Department of Technical Education in Brunei with their emphasis on common skills – an area that has become important and has attracted a compulsory assessment strategy as from the year 2001.

7. Projects should be a regular feature of teaching and learning because students learn more and develop better study skills and team-work while carrying out such activities. A good project should cover all aspects of points 1 – 6 mentioned above.

8. Critical thinking skills and learning to learn should be developed. Since these two characteristics are important in today’s world, teachers and curriculum developers have the responsibility to encourage them. The inclusion of more authentic problem-solving in the curriculum as well as making learning more meaningful and interesting would positively develop the students’ skills and the desire to learn respectively. Helping students to identify their learning styles would also help them in learning to learn.

9. The views of teachers and learners regarding their beliefs and perceptions in teaching and learning need to be sought. Teachers should use surveys regularly and this feedback should be used to evaluate the course and prepare work that will suit students.

10. Since many students go for further studies after they complete, and the content and style of teaching that they experienced is different from that at the university (refer Chapter 1, Section 1.4, page 14), mathematics courses taught at the college should articulate with university courses so that students can transfer smoothly when they commence their university study. This
would provide students with opportunities for higher education as was stated in Brunei’s education policy (refer Chapter 1, Section 1.3.2) and reduces students’ transition problems when they pursue further studies (Section 1.4, p. 14).

11. The suggestion in point 10 above implies that curriculum developers and professional bodies should provide resources and professional development courses for teachers to guide and assist them in instructional methods and new reform methods for teaching and learning.

12. Teachers should be encouraged to be flexible and innovative in their teaching. Professional development programmes could be designed to achieve this goal.

The Department of Technical Education in Brunei is charged with responsibilities such as evaluating and maintaining standards of VTE and training programmes, promoting greater access to learning and career opportunities by bridging the gap between academic and VTE (refer Chapter 1, Section 1.3.6). It has the authority to ensure that the items listed above are practiced. In doing so, the DTE would be responding to the rapid changes occurring in workforce training; enhancing VTE; and enhancing students’ achievement in mathematics for technical programmes (refer Chapter 1, Section 1.3.6, Future Challenges Facing the Department).

8.6 Scope and Limitations of the Study

In this section I questioned myself whether there could have been better ways for implementing the study; what could have been done differently, and what might have produced better results? Were the methods employed in the study appropriate? Was the design and content of the package appropriate? Was the learning outcome as expected? Were instruments used to measure the students’ attitudes and perceptions appropriate and suitable? What are the possible reasons for any contradictory findings? Were the quality criteria by Guba & Lincoln (1989) addressed?

8.6.1 Strategy and Methods

In the strategy and methods chapter (Chapter 3), I explained in detail the design that was applied (the pre-experimental design) to the study. Using this kind of design, Campbell and Stanley (1963) stated that history (events that occur between
the first and second measurements that are unrelated to the experiment that could affect result) and participants maturing (changes in participants that occur as time passed and not specific to the experiment) could have skewed the results (refer Chapter 3, Section 3.2). As was mentioned in that section, I believe that the period of eight weeks implementation time is not long enough to become concerned about history and the possibility of participants maturing, but rather that it is long enough to satisfy the two quality criteria of prolonged engagement and persistent observation mentioned by Guba and Lincoln. However, the eight weeks period is perhaps not long enough to expect changes in students’ attitude.

I was interested to know how the students who were treated with the package would fare as compared with the rest of the students. I was able to informally compare the performance between the treatment and non-treatment groups because of the availability of the students’ phase test results as mentioned before. The treatment group exhibited a better score than the non-treatment group. This result further provided validity to the results obtained previously that the students who experience the package had better mathematical understanding. However, although both groups of students were admitted with the same minimal requirements, I had no confirmed knowledge of whether these groups were equivalent.

The approach to this study was broad rather than deep, and whilst this has enabled me to evaluate the package and approach using different techniques (both qualitative and quantitative), the results represent a set of indicators rather than a comprehensive and exhaustive study. Nevertheless the approach has been able to maximise the time and resources available.

8.6.2 Instruments Used

Chapter 4 discussed the results of the identification phase (phase 1). There, it was noted that although the survey questionnaires for both the learning environment and the attitude towards mathematics survey had been piloted, the number of students involved with the pilot study (n = 24) was not large enough to detect internal consistencies and factorial validity when factor analysis was performed (overlap between and within scales existed). Although the statistical test (the validation of CCEI and Attitude towards Mathematics Survey) indicate that this did not affect the overall analysis of the result and hence the use of the instrument was
valid, it would have been preferable if the rewording of items had been carried out earlier.

The package in this study was only introduced to two classes of students so as to avoid disturbing the college’s programme too much. A much larger sample might have produced a more significant outcome in the quantitative analysis of surveys. The small sample may also have influenced the results because even one or two very low scores and extreme responses to the questionnaire would affect and skew the quantitative outcomes in both the cognitive and affective areas.

8.6.3 Content and Package Design

The design of the pre and post-test content questions could be further improved for easier analysis by ensuring that there were equal numbers of questions for the different categories assessed. Although it is difficult to avoid overlap between the problem-solving category with the other two categories, the questions could be devised to indicate precisely which particular category was being tested. Whilst the length of each test appears to have been appropriate, the content questions should in future be more finely created to encourage students to attempt them. This leads to the conclusion that considerable skill is required in setting such tests.

As this study was limited to only a few topics in the area of trigonometry, some of the conclusions arrived at (in chapter 6 especially) cannot be generalised to include other content areas.

8.6.4 Package Implementation

I consider myself fortunate to have been able to implement the package myself because I knew first hand what was to be done and the reasons behind the choice of activities included in the package. The disadvantage in this situation was that I could not observe the students as closely as I would have preferred on some occasions because I was busy conducting the class. I would have been able to observe the students by documenting each of their expressions and body language, which would have revealed more information by being a full-time observer. Students would also be more open to an observer, and as an observer I would be neutral if there happened to be any disagreements between the students and a teacher. A cooperative colleague that I identified in Chapter 3, Section 3.6.7 observed my
teaching on several occasions, but it would have been more satisfying and desirable if it had been done for all classes.

Detailed observations of two or three students from each class in the form of a case study would provide a good basis for evaluating students' acceptance of the package and their understanding of mathematics, thus ensuring that all components of the package were useful and appropriate. This would also make it possible to detect any changes in students’ attitude, from the beginning to the end of the study.

The main hindrance encountered during the implementation of the study was the limited time available. There were so many strategies to use and so much content to teach and yet I was restricted because of the time available for the intervention programme. The package was delivered expeditiously because the students were scheduled to sit for an exam on the topic within two months of commencing the package. Apart from the vast content to be covered, the students would have appreciated more time to become used to a new teacher and to a new approach to learning.

Although the Technical Department, the college principal and the mathematics department granted permissions to conduct research, I still had to abide and conform to the college's calendar where activities and functions were already set. Sometimes classes had to be cancelled for these reasons and my planned routine was upset. I also had to be careful that I did not appear to be "bossy" and intimidating because although the teachers were supportive and cooperative, the classes were only "lent" to me.

As for the choice of class, I was thankful that the two teachers willingly allowed me to use their classes for research purposes. Class availability really depended on teachers’ good nature and willingness to participate. A larger group (more classes) with all teachers participating in the implementation of the package would have been more desirable.

Students’ involved in this study needed time to familiarise themselves with “cooperative learning”. Although they appeared cooperative, they were not used to cooperative learning because the “division of work” and “urgency in completing tasks” did not come to them automatically. Used to being ‘spoon-fed’, they had to be told and instructed on what to do and to be guided all the way through in most of the lessons. Activities designed for discovery or inquiry approach took longer time to be completed because students were not used to the approach and, as one student said:
"it is a waste of time". Students also lacked seriousness in attempting the tests given (especially the post-test to RTE class) because they knew that their overall results at the college would not be affected. They gave up when they could not proceed with a problem.

Package implementation might have been improved if resources such as internet-connected computers and graphing calculators were available. There was a computer lab that had to be booked in advance to use at the college, but it was constantly in use and it was not easy to obtain. Graphics calculators were not used (in fact had never been used) and to ask the students to buy a set for the package implementation was out of the question.

The negative case analysis (Guba & Lincoln, 1989) was not fully applied because I did not really work on a full set of written assumptions. However, I was able to refine certain perceptions and views when contrary findings emerged (for instance, thinking that students would not like to present solution to the class (refer chapter 6, Section 6.3.2.2)). I could also abandon other judgements when there was no supporting evidence (for instance, that there existed significant associations between improved enjoyment/interest and improved cognitive outcomes.)

8.7 Suggestions for Future Research

In the interest of technical students' mathematics understanding and attitude enhancement, teachers or researchers could conduct further research to confirm the findings in this study. A replication of this study with some changes to the design and method to confirm the credibility and sustainability of the results would be useful.

1. A longitudinal study would be appropriate to confirm the results. In the case of my study, because of the constraints, the strategy and methods that was adopted was in my view the best alternative that I could adopt.

2. A larger sample for the quantitative component of the study would have been desirable. In many other classroom environment studies, the sample consisted of several thousands students (Aldridge et al., 1999; Majeed et al., 2001; Poh, 1996; Riah, 1998).
3. Case studies should also be part of the longitudinal study mentioned in point 1 above, because more information and better insight might be derived by carrying out case studies on weak, average and above average students.

4. Test instruments used in this study could be examined, revised and refined to suit different groups of students. Surveys conducted in studies of this kind provides important feedback, therefore the importance of trustworthy instruments cannot be ignored.

5. Further research should be encouraged to investigate students' and teachers' beliefs regarding teaching and learning in Brunei. This will surely help future Bruneian researchers to design suitable methods and strategies to obtain optimum input and results from their investigations.

6. Because of cultural reasons, students were not willing to criticise their teachers and the system therefore, interviews could be improved to provide more information related to this issue. Students who were reluctant to criticise could be encouraged to do so, and probing techniques should be employed by the researchers in order to encourage students to voice their opinions and complaints.

8.8 Final Remarks

For some time, I have been trying to convey to my students that mathematics is not just about computation; it is not simply a tool: It is more than just the skills to be applied to science or to mundane tasks such as balancing a cheque-book. Mathematics is an art in which clever insights lead to beautiful results, a way of thinking and a kind of logic. It is a way of telling a story. The mathematical story is not just one of numbers, but of problems and of knowing how to interpret, approach, solve, and understand them. It is also a story of mathematicians, questions, methods, contemplation and beauty. Designing and developing a package in this study was my way of hopefully making students aware of the above and to appreciate mathematics in the way that other mathematics lovers perceive the subject.

In the package, mathematics became an important tool for solving many problems in real life situations and other disciplines. The role of mathematics in solving a variety of problems has made it closer to students' lives so that many students, mathematics is more interesting and challenging. For too long I "taught" concepts by "telling" students what they should know. I could see the lack of
understanding in so many of their eyes, but I had no better way of helping them to learn. Now, students can perhaps make sense of the concepts themselves, and perhaps many more of them are experiencing a true, deep understanding. Smart students must learn to "think & explain." All students can think and some students just need confidence to express themselves.

I know that there is still a considerable amount of work to be done to make students realize this dream, but this study is my starting point. After this, I would not hesitate to conduct further research and apply the results in classrooms for a new batch of students who would hopefully, appreciate mathematics and be motivated to learn the subject. This is important in keeping with the changing trends in the world-of-work and as part of the challenges of the DTE (refer Section 1.3.6).

Continuous professional support is necessary in making this a reality and therefore I hope that I would continually receive encouragements and support from various bodies connected to education – in this case, the Mathematics Department of the Technical Colleges, the Ministry of Education and the Department of Technical Education because this kind of research is important in developing well-educated workers and citizens and in helping the DTE to develop “appropriate curricula and delivery system to maximise access to education and training” (refer Chapter 1, Section 1.3.6). Teachers should be encouraged to take part in studies of this kind at the same time, so that results can be contrasted and specific views could be elicited among them. Since my last visit to the Mathematics Department of MTSSR, teachers have been encouraged to conduct research to improve classroom teaching and learning. The change in teachers’ attitude about research was noticeable. Conducting research and providing manpower training issues is now one of the responsibilities of the DTE (refer Chapter 1, Section 1.3.6). This is definitely a promising initiative for Bruneian education.
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Appendix IA: Structure of the School system in Brunei. Source: Brunei Darussalam Ministry of Education
http://www.moe.gov.bn/system%20structure.htm
Appendices

VTE Preparation Levels in Brunei Darussalam

**Key:**
- VTE programmes at VTE institutions
- VTE programmes at secondary institutions
  - as technical stream
  - as components of core general curriculum

'N Level' refers to the scheme where students cover approximately 70-80% 'O' Level content in three years before taking the Brunei Cambridge General Certificate of Education Examination (BCGCE Examination)

Appendix 1B: VTE preparation levels in Brunei. Source: Brunei Darussalam Ministry of Education, [http://www.moe.gov.bn/departments/dteweb/Figure2.htm](http://www.moe.gov.bn/departments/dteweb/Figure2.htm).
Appendices

Appendix 2: Reform programmes in USA with their essential features, process findings and outcome findings. Source: (Castellano, Stringfield & Stone, 2001).

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<thead>
<tr>
<th>Essential Features</th>
<th>Process Findings</th>
<th>Outcome Findings</th>
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<tr>
<td><strong>Tech Prep</strong></td>
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<tr>
<td>* An articulation agreement—a formal arrangement aligning curricula among Tech Prep consortium members, such as school districts and community colleges</td>
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<tr>
<td>* Two years of secondary and two years of postsecondary education for apprenticeship leading to a degree or certificate</td>
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<tr>
<td>* A strong case of required proficiency in math, science, and communication</td>
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<tr>
<td>* Technical preparation in specified occupational fields</td>
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<tr>
<td>* Placement in employment (Bussel and McFarland 1994)</td>
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<td>* Parents and students often balk at strictly defined sequences of courses explicitly preparing students for a postsecondary education at a local community college. (Hershey et al. 1990)</td>
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<tr>
<td>* Lack of confidence in the community college level that high school courses are equivalent to postsecondary courses. (Urquiza et al. 1997)</td>
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<tr>
<td>* In comparison to graduates of the same high school who did not participate, graduates of &quot;model&quot; Tech Prep programs are more likely to—</td>
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<tr>
<td>* enter two-year postsecondary education, to a greater degree</td>
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<tr>
<td>* be employed and earning higher wages</td>
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<td></td>
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<tr>
<td>* receive larger wage increases</td>
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| **Curriculum Integration** |                  |                  |
| * Teaching communication skills, mathematics, and science to the context of occupations that students are studying in order to increase their relevance and utility |
| * Teachers typically do not have enough time to work on curriculum integration. (Bussel and McFarland 1994) |
| * Both academic and vocational teachers are resistant to the idea. |
| * High school graduation and college admission requirements often do not recognize or grant credit for integrated courses. (Parry et al. 1995) |
| * It is difficult to "scale up" from demonstration to full school adoption. (Levacus et al. 2003) |
| * There have been few studies that assess the effectiveness of integration. (Stear et al. 1998) |
| * Anecdotal evidence suggests increased student engagement and achievement. (Lynn and Wills 1994) |

| **Work-Related Experience** |                  |                  |
| * Participation in workplace learning opportunities that are coordinated and sequenced with learning at school, e.g., youth apprenticeships, cooperative education |
| * Firms with limited contact with schools often have negative attitudes toward youth. (Zausky 1994) |
| * Programs that began before grade 10 were more likely to succeed in keeping young people engaged in high school. (Purdy et al. 1999) |
| * Firms that provide structured work-based learning opportunities are pleased with the quality of the work done by young people. (Steinberg 1998) |

<p>| <strong>School-to-Work (STW)</strong> |                  |                  |
| * Use of school-based learning, work-based learning, and connecting activities to achieve systemic change that provides students with the knowledge and skills needed for success following high school in postsecondary education and employment. |
| * Limited number of workplaces willing and able to work with schools to provide sites for students |
| * Limited application or exploration of school-based knowledge such as reading, writing, or mathematics on the job |
| * Student experiences at their work sites rarely used as the basis for structured academic activities or assignments at school (Hughes et al. 1999) |
| * Some evaluations found slight negative outcomes (decline in grades and attendance) for STW students versus a comparable control group; others found slightly positive effects including lower school absences rates, higher college attendance rates, and lower and higher-paying employment. (Urquiza et al. 1997) |
| * Students felt that involvement in STW activities helped them clarify career goals and broaden options. (Hershoy et al. 1998) |</p>
<table>
<thead>
<tr>
<th>Essential Features</th>
<th>Process Findings</th>
<th>Outcome Findings</th>
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<tr>
<td><strong>High Schools That Work</strong></td>
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<tr>
<td><em>Rigorous vocational courses along with more required academic coursework</em></td>
<td>About half of vocational teachers report they need professional development in integrating academic and occupational content. (Bottoms and Pearson 2000)</td>
<td><em>Schools that implement the model faithfully usually see improved student achievement, and higher rates of attendance, graduation, retention, and postsecondary enrollment (NWREL 1999).</em></td>
</tr>
<tr>
<td><em>Common planning times for teachers to collaborate on curriculum integration</em></td>
<td></td>
<td><em>Improvement on HSTW assessment, based on the National Assessment of Educational Progress (NAEP) tests occurs. (Kemple et al. 2000)</em></td>
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<tr>
<td><em>Higher standards and expectations for all students</em></td>
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<td><em>Extra help for students</em></td>
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<td><em>Individualized advising system</em></td>
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<tr>
<td><em>Use of assessment information to improve student learning</em></td>
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<tr>
<td>(Bottoms and Pearson 2000)</td>
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<td><strong>Career Academies</strong></td>
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<td><em>School within a school, where students stay with a group of teachers over 3 or 4 years</em></td>
<td><em>Teachers and administrators at both secondary and postsecondary levels often question the rigor of an integrated curriculum.</em></td>
<td><em>Among students at risk of dropping out, career academies significantly reduced dropout rates and increased attendance and credits earned.</em></td>
</tr>
<tr>
<td><em>Both academic and vocational curriculum, usually integrated around a career theme</em></td>
<td><em>Many teachers need training and practices to develop such curricula.</em></td>
<td><em>Among students at low risk of dropping out, career academies increased their likelihood of graduating on schedule and increased their vocational course taking without reducing academic core curricular.</em></td>
</tr>
<tr>
<td><em>Established partnerships with businesses to order to build connections between school and work</em></td>
<td><em>Teachers need to spend time in workplaces to understand how their subjects are used, which requires administrative support for release time and common planning periods.</em></td>
<td><em>Academies that provided strong mentorship support to students in the early years of high school appeared to be most successful in achieving positive outcomes. (Kemple and Snipes 2000)</em></td>
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<tr>
<td>(Kemple and Snipes 2000)</td>
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<tr>
<td><strong>Career Magnets</strong></td>
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<tr>
<td><em>Career magnet schools include college preparation and are designed to attract students from across a district because of their career focus.</em></td>
<td>Career magnet schools in one city studied were required to serve certain percentages of minority students without additional resources, and some schools felt that this diverted resources from the career focus. (Cain et al. 1999)</td>
<td><em>Students of average reading ability who attended freestanding magnets earned more course credits and increased their reading skills.</em></td>
</tr>
<tr>
<td><em>Some magnets are schools within schools whereas others are freestanding.</em></td>
<td></td>
<td><em>Low-scoring readers at freestanding career magnets were twice as likely to attend high school and three times as likely to pass the state Regents math test.</em></td>
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<tr>
<td>(Cain et al. 1999)</td>
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<tr>
<td><strong>Career Pathways</strong></td>
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</tr>
<tr>
<td><em>A means of reorganising the high school, career pathways replace the traditional college preparatory, vocational, and general tracks.</em></td>
<td>No process studies to date</td>
<td><em>No large-scale, random assignment outcome studies to date.</em></td>
</tr>
<tr>
<td><em>Students are organized along chains of occupations with similar interests and strengths, such as allied health. Specific jobs have varying training and education requirements.</em></td>
<td></td>
<td><em>At one high school with a large limited English speaking population, the rate of public college attendance in the second and third years of implementation increased by 39%.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>At the same high school, enrollment in advanced placement courses increased. In the case of AP Calculus, enrollment increased 87% (Robinson 1999)</em></td>
</tr>
</tbody>
</table>

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Appendices

Appendix 3A: CCEI Questionnaire

College Classroom Environment Inventory (CCEI)

Directions

This questionnaire contains statements about practices which could take place in this class. For each item, you will be asked how often each practice actually takes place and how often you would prefer each practice to take place.

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

Think about how well each statement describes what this class is actually like for you.

Draw a circle around

1. if the practice actually takes place
2. if the practice actually takes place
3. if the practice actually takes place
4. if the practice actually takes place
5. if the practice actually takes place

Almost Never
Seldom
Sometimes
Often
Almost Always

Then, think about what you would prefer the class to be like.

Draw a circle around

1. if you would prefer the practice to take place
2. if you would prefer the practice to take place
3. if you would prefer the practice to take place
4. if you would prefer the practice to take place
5. if you would prefer the practice to take place

Almost Never
Seldom
Sometimes
Often
Almost Always

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Example

Suppose that you were given the statement: “Students are given responsibility”. You first need to decide whether you actually believe that students are given responsibility ‘Almost Never’, ‘Seldom’, ‘Sometimes’, ‘Often’ or ‘Almost Always’. If you choose ‘Often’, then circle 4.

Then you need to decide whether you would prefer that students be given responsibility ‘Almost Never’, ‘Seldom’, ‘Sometimes’, ‘Often’ or ‘Almost Always’. If you choose ‘Almost Always’, then circle 5.

Please fill in the information below:

College: 1. SULTAN SAIFUL RIJAL TECHNICAL COLLEGE
         2. JEFRI BOLKIAH ENGINEERING COLLEGE
Course Code: ........................................... Male/Female: ............

- 257 -
### SC (Student Cohesion)

<table>
<thead>
<tr>
<th></th>
<th>ACTUAL</th>
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<tbody>
<tr>
<td></td>
<td>Almost Never</td>
<td>Seldom</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>1. Students in this class like each other.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>2. Members of this class work well with each other.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>3. Friendships are common among students in this class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>4. Students have the chance to get to know each other in this class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>5. Students in this class help others who have difficulty with their work.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
<td></td>
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<tr>
<td>6. Members of the class socialize outside the classroom.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>7. Students in this class help each other.</td>
<td>1 2 3 4 5</td>
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<td>1 2 3 4 5</td>
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### TS (Teacher Support)

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<tr>
<td></td>
<td>Almost Never</td>
<td>Seldom</td>
<td>Sometimes</td>
<td>Often</td>
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<tr>
<td>8. The instructor goes out of his/her way to help the students.</td>
<td>1 2 3 4 5</td>
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<td>1 2 3 4 5</td>
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<tr>
<td>9. The instructor considers the students’ feelings.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>10. The instructor helps the students when they have trouble with the work.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>11. The instructor talks to the students.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>12. The instructor is interested in students’ problems.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>13. The instructor moves about the class to help each student.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>14. The instructor’s questions help students to understand.</td>
<td>1 2 3 4 5</td>
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<td>1 2 3 4 5</td>
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</table>

### IV (Involvement)

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<tr>
<td></td>
<td>Almost Never</td>
<td>Seldom</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>15. Students discuss ideas in class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>16. Students put effort into what they do in the class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>17. There are opportunities for students to express opinions in the class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>18. Students present their work to the class.</td>
<td>1 2 3 4 5</td>
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<td>1 2 3 4 5</td>
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<tr>
<td>19. Students in the class pay attention to what others are saying.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>20. Students discuss with each other how to solve problems.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>21. Students are asked to explain how they solve problems to the class.</td>
<td>1 2 3 4 5</td>
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</table>

### IN (Innovation)

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<tr>
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<tbody>
<tr>
<td></td>
<td>Almost Never</td>
<td>Seldom</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>22. New ideas are tried out in this class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>23. New and different ways of teaching are used in this class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>24. The instructor thinks up innovative activities for students to do.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>25. Teaching approaches are characterised by innovation and variety.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>26. The seating arrangement in the class is the same each week.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>27. The instructor thinks of unusual activities.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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<tr>
<td>28. Students seem to do the same type of activities every class.</td>
<td>1 2 3 4 5</td>
<td></td>
<td>1 2 3 4 5</td>
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</table>
Appendices

<table>
<thead>
<tr>
<th>CO (Cooperation)</th>
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<tbody>
<tr>
<td>29. Students cooperate with each other when doing assignment work.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
<td>1</td>
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<tr>
<td>30. Students share books and resources when doing assignments.</td>
<td>1</td>
<td>2</td>
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<td>1</td>
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<tr>
<td>31. There is teamwork when students work in groups.</td>
<td>1</td>
<td>2</td>
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<td>1</td>
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<tr>
<td>32. Students work with each other to achieve class goals.</td>
<td>1</td>
<td>2</td>
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<td>1</td>
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<tr>
<td>33. Students learn from each other in the class.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>34. Students cooperate with each other on class activities.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<tr>
<td>35. Students work with each other on other projects in the class.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
<td>1</td>
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<tr>
<th>TO (Task Orientation)</th>
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<tbody>
<tr>
<td>36. Students know exactly what has to be done in the class.</td>
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<td>2</td>
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<td>5</td>
<td>1</td>
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<tr>
<td>37. Getting a certain amount of work done is important in the class.</td>
<td>1</td>
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<tr>
<td>38. The group sticks to the point and is not sidetracked.</td>
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<tr>
<td>39. The class is well organised.</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>40. Class assignments are clear so everyone knows what to do.</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>41. The class usually starts on time.</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>42. Activities in this class are clearly and carefully planned.</td>
<td>1</td>
<td>2</td>
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<tr>
<th>IND (Individualisation)</th>
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<tbody>
<tr>
<td>43. Teaching approaches allow students to proceed at their own pace.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
<td>1</td>
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<tr>
<td>44. It is the instructor who decides what is to be done in the class.</td>
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<td>5</td>
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<tr>
<td>45. There are opportunities for a student to pursue his/her particular interest in this class.</td>
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<tr>
<td>46. Students are allowed to choose activities and how they work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<tr>
<td>47. Students have a say in how class time is spent.</td>
<td>1</td>
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<td>5</td>
<td>1</td>
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<tr>
<td>48. Students are generally allowed to work at their own pace.</td>
<td>1</td>
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<td>5</td>
<td>1</td>
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</tr>
<tr>
<td>49. All students in the class are expected to do the same work, in the same way in the same time.</td>
<td>1</td>
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<td>4</td>
<td>5</td>
<td>1</td>
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<tr>
<th>REL (Relevance)</th>
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<tbody>
<tr>
<td>50. The instructor uses concrete everyday examples to explain concepts and principles.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>5</td>
<td>1</td>
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<tr>
<td>51. The instructor points out practical applications of the concept.</td>
<td>1</td>
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<td>5</td>
<td>1</td>
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<tr>
<td>52. The assignments given are integrated with other subjects.</td>
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<td>5</td>
<td>1</td>
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<td>5</td>
<td></td>
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</tr>
<tr>
<td>53. What we learn is related to our course of study.</td>
<td>1</td>
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<td>5</td>
<td>1</td>
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<td>5</td>
<td></td>
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<tr>
<td>54. We are given real life problems that are meaningful.</td>
<td>1</td>
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<td>4</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55. What I learn in this class gives me a better understanding of the world outside.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
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<td>4</td>
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</tr>
<tr>
<td>56. We work with 'authentic' (real) problems in class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
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</tbody>
</table>

Thank you for your assistance in completing this questionnaire
Appendices

Appendix 3B: Mathematics Attitude Survey

We are also interested in your ideas about mathematics in this class. Your answers to the following questions will help us to understand what you think mathematics as all about.

Draw a circle around

1. if you STRONGLY DISAGREE with the statement
2. if you DISAGREE with the statement
3. if you are NEUTRAL/UNSURE with the statement
4. if you AGREE with the statement
5. if you STRONGLY AGREE with the statement

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral/Unsure</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics is enjoyable and stimulating to me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. I have never liked mathematics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I plan to take as much mathematics as I can for my education.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Mathematics is important for my chosen profession.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. I enjoy mathematics lessons more than other lessons.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. My former mathematics teacher made lessons boring.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. I am interested and willing to acquire further knowledge in mathematics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. The skills I learn in this class will help me in other classes related to my chosen profession.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. I look forward to mathematics classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. My past experiences make me fear mathematics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11. I now see the benefits of learning mathematics, which I didn’t see before.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12. Mathematics is not important in everyday life.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13. I am enthusiastic about learning in mathematics class</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14. There is nothing creative about mathematics; it is just memorising formula and things.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15. I am willing to spend my free time studying mathematics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16. Mathematics is only important to mathematicians.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17. I work persistently in mathematics regardless of how I do in tests.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18. I am usually tensed up in mathematics classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19. I want to develop more mathematical skills</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20. I can see applications of mathematics in my chosen course of study.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

*Thank you, you have completed all of the questions. Please check that you have an answer for each of them.*
Appendices

Appendix 3C: Lesson Checklist

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
  ☐ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☐ Teacher showing solution on board if necessary

☐ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☐ Interactive discussion
  ☐ Example worked on board with the whole class
  ☐ Immediate revision of forgotten/misunderstood topics
  ☐ Relevant/real life examples and problems given to students

☐ Individual work (exercise/activities)
  ☐ Teacher continually taking note of what everyone is doing
  ☐ Class kept together working through exercises
  ☐ Solutions reviewed with whole class
  ☐ Mistakes immediately pointed out to the whole class
  ☐ Pupils offer their solutions to class for discussion

☐ Whole class on task throughout lesson

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☐ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learn in lesson
  ☐ link with next lesson

☐ Summary of main points at end of lesson

Comments
Appendices

Appendix 3D1: Diagnostic Test on Trigonometry

Pre test (Diagnostic Test on Trigonometry)

This paper is made up of two parts.
Section A – 10 objective type questions and
Section B – 9 subjective type questions where working and explanation should be given.

Instructions:

a) Answer as many questions as you can.
b) Show working to all of the questions in Section B.
c) You may use calculators or any other tools to help you.
d) You have 1 hour to complete this test.
e) This test is just to find out your background knowledge in Trigonometry.
   Scores from here will not contribute to your final assessment total.

Section A
Circle the right answer

1. What is the value of θ if \( \cos \theta = 0.5 \), and \( \theta \) is an acute angle?
   A. 60°     B. 1.046 rad     C. neither 60° nor 1.046 rad
   D. both 60° and 1.046 rad   E. none of the above.

2. In a circle whose radius is 10 cm, a central angle \( \theta \) intercepts an arc of 8 cm. What is the radian measure of that angle?

   \[ \theta \]
   \[ \frac{8}{10} \]
   A. 80  
   B. 0.8  
   C. 1.6  
   D. 8  
   E. none of the above

3. Given that \( s = r \theta \) and \( A = \frac{1}{2} r^2 \theta \) and \( s \) is the length of arc, \( r \) the radius, \( \theta \) the angle that subtends the arc, \( A \) the area of the shaded sector, find the area of the shaded sector if \( s = 20 \text{ cm} \) and \( r = 10 \text{ cm} \).
   A. 200 cm\(^2\)  B. 100 cm\(^2\)  C. 50 cm\(^2\)  D. 120 cm\(^2\)  E. none of the above

4. \( \cos^2 x = \)
   A. \( 1 - \sin^2 x \)  B. \( (1 - \cos 2x)/2 \)
   C. \( (1 + \cos 2x)/2 \)  D. A and B  E. A and C
5. Which of the following is identical to \((\csc^2 x)(\sec^2 x)\)?
   A. \((\tan^2 x)(\csc^2 x)^2\)  
   B. \(1/(\sin^2 x) + 1/(\cos^2 x)\)  
   C. \((\sin x)(\tan x)\)  
   D. A & B  
   E. B & C

6. In the diagram, \(\cot \theta = \text{opp/adj}\)

7. In the diagram, \(\tan \theta = -y/x\)

8. \(\sin 73^\circ = \)  
   A. \(\cos 73^\circ\)  
   B. \(\cos 17^\circ\)  
   C. \(\sin 107^\circ\)  
   D. A and C  
   E. B and C

9. Which of the following statements are true regarding equations for curve \(a\) and \(b\)?
   A. \(a\) is \(y = 0.5 \sin x\)  
   B. \(b\) is \(y = \sin 2x\)  
   C. \(b\) is \(y = \sin 0.5x\)  
   D. A & B  
   E. none of the above

10. Find the angle \(B\) in the triangle \(ABC\) given below:
    A. \(85^\circ\)  
    B. \(58^\circ\)  
    C. \(45^\circ\)  
    D. \(38^\circ\)  
    E. none of the above
Appendices

Section B
Write your working and answer in the space provided

1. Do you know of any other angle measurement besides in degrees? If so, list them.

2. Convert:
   
   a) 236° 25' 35" to radian.
   b) 1.345 rad to degree, minute and seconds.

   a)  
   b) 

3. A railroad track is to be laid out in the shape of a circle in which the radius is 100 yards. A train travel along the track, making a central angle of 83°. Find the distance that the train travelled.
4. A cross section of a pipe is filled with water as shown in the diagram below. The diameter of the pipe is 3 cm and the height of water that fills the pipe is 0.7 cm. Find:
   a) The wetted perimeter of the pipe.
   c) The area of the cross section of water shown.

5. Solve for $\theta$, if $0^\circ \leq \theta \leq 360^\circ$.
   a) $\sin \theta = 0.76$
   b) $\cos \theta = -0.86$
   c) $\tan \theta = 1.5$
6. On the same axis provided below, draw the graph of \( y = \cos x \) and \( y = 1.5 \cos 2x \) for \( 0^\circ \leq x \leq 360^\circ \)

![Graph of trigonometric functions](image)

7. If \( \sin x = k \), then find in terms of \( k \):
   a) \( \cos x \)
   b) \( \tan x \)

8. The local farm has allowed a tourist operator to erect a fairground attraction called “The Big Swing” in a field by the main road. This consists of an arm, 6 metres long, which swings back and forth with a basket at one end. The height of the basket above ground is given by the formula:
   \[ h = 6(1 - \cos \theta) \]
   where \( \theta \) is the angle the arm makes with the vertical.

   If the basket is 5m above ground when it reaches the highest point of a swing:

   (a) find the size of the angle \( \theta \);

![Diagram of the swing](image)
Appendices

(b) find how far the basket will travel on its next swing. You may assume that it rises to the same height again.

9. Two ships A and B both left O at the same time. Ship A is cruising slowly at 8 km/h and ship B is cruising slowly at 6 km/h. Find the distance $d$ between them in terms of $t$ hours.
Appendices

Appendix 3D2: Diagnostic Test on Trigonometry

Post Test on Trigonometry

This paper is made up of two parts.

Section A – 10 objective type questions and
Section B – 10 subjective type questions where working and explanation should be given.

Instructions:

f) Answer as many questions as you can.
g) Show working to all of the questions in Section B.
h) You may use calculators or any other tools to help you.
i) You have 1 hour to complete this test.
j) This test is just to find out your background knowledge in Trigonometry. Scores from here will not contribute to your final assessment total.

Section A
Circle the right answer

1. What is the value of \( \theta \) if \( \sin \theta = 0.5 \), and \( \theta \) is an acute angle?
   A. 30\(^\circ\)              B. 0.5236 rad  C. neither 30\(^\circ\) nor 0.5236 rad
   D. both 30\(^\circ\) and 0.5236 rad  E. none of the above.

2. How many radians does the hour hand on a circular clock sweeps through in a 24-hour period?
   
   \[ F. \quad \frac{4\pi}{2}\]
   \[ G. \quad \frac{5\pi}{2}\]
   \[ H. \quad 6\pi\]
   \[ I. \quad 48\pi\]
   \[ J. \quad \text{none of the above}\]

3. Given that \( s = r \theta \) and \( A = \frac{1}{2} r^2 \theta \) and \( s \) is the length of arc, \( r \) the radius, \( \theta \) the angle that subtends the arc, \( A \) the area of the shaded sector, find the length of the arc shown if \( A = 200 \text{ cm}^2 \) and \( r = 10 \text{ cm} \).
   A. 80 cm              B. 60 cm              C. 40 cm              D. 20 cm
   E. none of the above

4. A graph \( y = 3 \cos 2x \) has
   A. an amplitude of 3          B. a period of \( \pi \)          C. a period of \( 4\pi \)
   D. A and B                   E. A and C
5. \( y = \sin^2 x + \cos^2 x \). Which of the following functions are equivalent to \( y \) for all values of \( x \) such that \( 0 < x < \frac{1}{2}\pi \)?

- A. \((\tan x)(\sin x)\)
- B. \((\sec x)(\cos x)\)
- C. \((\tan x)/(\cos x)\)
- D. A & B
- E. B & C

6. In the diagram, sec \( \theta = \)

[Diagram with hyp, opp, adj, and \( \theta \) labeled]

- F. adj/opp
- G. hyp/adj
- H. opp/adj
- I. adj/hyp
- J. opp/hyp

7. In the diagram, \( \cot \theta = \)

[Diagram with point \((-x,y)\) and angle \( \theta \)]

- F. \(-x\)
- G. \(-x/y\)
- H. \(1/y\)
- I. \(y\)
- J. \(-y/x\)

8. \( \cos 26^\circ = \)

- A. \(\sin 64^\circ\)
- B. \(\sin 26^\circ\)
- C. \(\cos 334^\circ\)
- D. A and C
- E. B and C

9. The instantaneous values, \(i_1\) and \(i_2\) of two alternating currents are represented by the two sides of a triangle as shown. The third side is the resultant current \(i_r\). Calculate \(i_r\).

- A. 12.97
- B. 27.91
- C. 29.17
- D. 21.79
- E. none of the above.

[Diagram with vectors labeled: \(i_1=10\), \(i_2=15\), angle 60°, \(i_r\)]

10. From the diagram above, find the angle \( \phi \)

- A. 39°56′
- B. 36°36′
- C. 33°56′
- D. 39°36′
- E. none of the above
Section B
Write your working and answer in the space provided

1. In which quadrant of the circle does 2.35 radians fall? Explain

2. Convert:
   
   d) $198^\circ 33' 40''$ to radian.
   
   e) 2.123 rad to degree, minute and seconds.

3. The rotation of the smaller gear (radius 5 in) forces the larger gear (radius 8 in) to rotate. If the smaller gear rotates through $50^\circ$, through how many degrees does the larger gear rotate?
Appendices

4. A cross section of a pipe is filled with water as shown in the diagram below. The diameter of the pipe is 5 cm and the height of water that fills the pipe is 4 cm. Find:
   a) The wetted perimeter of the pipe.
   f) The area of the cross section of water shown.

5. Solve for $\theta$, if $0^\circ \leq \theta \leq 360^\circ$.
   d) $\tan \theta = 1.25$
   e) $\sec \theta = -2.4$
   f) $\sin \theta = 0.8$
Appendices

6. If \( \cos a = b \), then find in terms of \( b \):
   a) \( \sin a \)
   b) \( \sin^2(90^\circ - a) + \sin^2 a \).

7. On the same axis provided below, draw the graph of \( y = \cos x \) and \( y = 0.5 \sin 2x \) for \( 0^\circ \leq x \leq 360^\circ \).

8. A child is swinging on a garden swing with supporting rope lengths of 3.5 m. When the swing angle (with respect to the vertical) is \( 30^\circ \), how high is the child from the ground if her lowest position from the ground is 0.5 m?
9. Jamil is a pilot and travels 200 km from point A to point B. He travels 120 km from point B to point C. How many km does he travel calculated as a straight-line distance from point A to point C (to the nearest km)?

10. A large flagpole has two support wires which were pegged to the ground 3.2 m apart. If the shorter wire is 6.8 m long, find the length of the other wire, and the distance up the flagpole from the ground to where the wires meet.
Appendices

Appendix 3E1: Pre-test marking Scheme

Marking scheme

PRE TEST

Section A

<table>
<thead>
<tr>
<th>Q No</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ans</td>
<td>D</td>
<td>B</td>
<td>B</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>E</td>
<td>E</td>
<td>D</td>
<td>B</td>
</tr>
</tbody>
</table>

Section B

1. radian, gradian etc. (1 point for each answer)

2. a) $236^\circ 25' 35'' = 236.4264$ 
   
   \[ 236.4264 \times \frac{\pi}{180} = 4.126 \]  
   
   (1)

   b) \[ 1.345 \times \frac{180}{\pi} = 77.06^\circ = 77^\circ 3' 46'' \]  
   
   (2)

3. \[ s = \theta r = 83 \times \frac{\pi}{180} \times 100 = 144.86 \text{ yards} \]  
   
   (2)

4.

\[ \begin{array}{c}
1.5 \\
\downarrow \\
1.5 - 0.7 = 0.8 \\
\end{array} \]

\[ \cos \theta = \frac{0.8}{1.5} \Rightarrow \theta = 1.00826 \Rightarrow 2\theta = 2.01652 \]  
   
   (2)

a) wetted perimeter = \[ \theta r = 2.01652 \times 1.5 = 3.025 \]  
   
   (2)

b) area of cross section = area (segment – triangle)

\[ \frac{1}{2} \times r \times r \times \theta - \frac{1}{2} \times r \times r \times \sin \theta \]

\[ \frac{1}{2} \times 1.5 \times 1.5 \times (3.025 - \sin 3.025) \]

\[ \frac{1}{2} \times (1.5)^2 \times 2.90845 = 3.272 \text{ cm}^2 \]  
   
   (3)

(total mark for Q4 is 8)

5. a) \[ \theta = 49.5^\circ \text{ or } 180^\circ - 49.5^\circ = 130.5^\circ \]  
   
   (2)

c) \[ \theta = 149.32^\circ \text{ or } 360^\circ - (180^\circ - 149.32^\circ) = 210.68^\circ \]  
   
   (2)

d) \[ \theta = 56.31^\circ \text{ or } 180^\circ + 56.31^\circ = 236.31^\circ \]  
   
   (2)

6. (2 marks for each curve)
Appendices

7.

\[\cos x = \frac{1}{\sqrt{1-k^2}} \quad (1)\]
\[\tan x = \frac{k}{\sqrt{1-k^2}} \quad (1)\]

8. a) \[5 = 6(1 - \cos \theta) \Rightarrow \cos \theta = \frac{1}{6} \Rightarrow \theta = 80.41^\circ \text{ or } 1.4033 \text{ radian} \quad (3)\]

b) from A to B the basket will travel in an arc form

Therefore, arc AB = 2 x 1.4033 x 6 = 16.84 m \quad (3)

(Total for Q8 is 6)

9. The speed between them would be

\[AB = \sqrt{(8t)^2 + (6t)^2 - 2(8t)(6t)\cos60^\circ} = 7.21t \text{ km/h} \quad (4)\]

(Total for Q9 is 4)

Full Mark = 50
Appendix 3E2: Post-test marking Scheme

Marking scheme

POST TEST

Section A

<table>
<thead>
<tr>
<th>Q No</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ans</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td>B</td>
<td>B</td>
<td>E</td>
<td>D</td>
<td>D</td>
<td>B</td>
</tr>
</tbody>
</table>

1 point for each correct answer

Section B

1. Quadrant II because…. (1 point for each answer)

2. a) \(198^\circ 33' 40'' = 198.5611\) \((1)\)
   \(198.5611 \times \frac{\pi}{180} = 3.4655\) \((1)\)

   b) \(2.123 \times \frac{180}{\pi} = 121.64^\circ = 121^\circ 38' 20''\) \((2)\)

3. \(s = \theta\)
   \(50^\circ \times \frac{\pi}{180} \times 5 = \theta \times 8\) \((1)\)
   \(\theta = 4.3633/8 = 0.5454\) radian = \(31.25^\circ\) \((1)\)

4. 
   (1 for diagram)

   \[
   \begin{align*}
   \cos \theta &= 1.5/2.5 \quad \Rightarrow \quad \theta = 0.927295 \quad \Rightarrow \quad 2\theta = 1.85459 \quad (2)
   
   \text{e) wetted perimeter} &= (2\pi - 1.85459)\tau = 4.42859 \times 2.5 = 11.07\text{ cm} \quad (2)
   
   \text{f) area of cross section} &= \text{area (segment + triangle)}
   
   &= \frac{1}{2} \cdot r \cdot \tau \cdot \theta + \frac{1}{2} \cdot r \cdot \tau \cdot \sin \theta
   
   &= \frac{1}{2} \cdot 2.5 \cdot 2.5 \cdot (4.42859 + \sin 1.85459)
   
   &= \frac{1}{2} \cdot (2.5)^2 \cdot 5.3886 = 16.84\text{ cm}^2 \quad (3)
   
   \text{(total for Q4 is 8)}
   
5. a) \(\theta = 51.34^\circ\) or \(180^\circ + 51.34^\circ = 231.34^\circ\) \((2)\)
   
   g) \(\theta = 114.62^\circ\) or \(360^\circ - (180^\circ - 114.62^\circ) = 245.36\) \((2)\)
   
   h) \(\theta = 53.13^\circ\) or \(180^\circ - 53.13^\circ = 126.87^\circ\) \((2)\)

6. 

\[
\begin{align*}
\sin a &= \sqrt{1 - b^2} \quad (1)
\sin^2(90 - a) + \sin^2 a =
\cos^2 a + \sin^2 a = 1 \quad (2)
\end{align*}
\]

(Total marks for Q6 is 4)
Appendices

7. (2 marks for each curve)

8. 

\[ \cos 30 = y/3.5 \quad \Rightarrow \quad y = 3.5 \cos 30 = 3.03 \quad (2) \]

\[ X = 3.5 - y = 3.5 - 3.03 = 0.47 \quad (2) \]

The child is 0.5+0.47 = 0.97m above the ground. (1)

(total marks for Q8 is 6)

9. The angle in between is 180 – 60 + 30 = 150 \quad (1)

The distance between them would be

\[ AC = \sqrt{(200)^2 + (120)^2 - 2(200)(120)\cos 150^\circ} = 309.8 \text{ km/h} \quad (3) \]

10. Using sine rule,

\[ \frac{\sin 15}{3.2} = \frac{\sin ACD}{6.8} \quad (1) \]

\[ ACD = \sin^{-1}(6.8*(\sin 15/3.2)) = 33.37^\circ \quad (1) \]

so \[ ADC = 180 - (15 + 33.37) = 131.63^\circ \quad (1) \]

\[ \frac{y}{\sin 131.63} = \frac{3.2}{\sin 15} \quad \Rightarrow \quad y = 9.24 \quad (2) \]

So, \[ ADB = 180 - 131.63 = 48.37^\circ \quad (1) \]

Now, \[ \sin 48.37^\circ = x/6.8 \]

So, \[ x = 6.8 \times \sin 48.37^\circ = 5.08 \quad (2) \]

(Total mark for Q10 is 8)

Full Mark = 58
Appendices

Appendix 3F: Permission to conduct research

23rd April, 2001

Directo
Department of Technical Education,
Ministry of Education,
Brunei Darussalam.

From,
Madihah Khalid,
Science and Mathematics Education Centre,
Curtin University of Technology,
GPO Box U1987 Perth,
Western Australia, 6845.

Dear Sir,

Re: Permission to conduct research

Until end of January this year, I had the pleasure of working as a Senior Technical Instructor at Maktab Teknik Sultan Saiful Rijal, teaching Mathematics to the National Diploma and Pre-National Diploma students. Right now, I am pursuing a PhD degree in Mathematics Education at the Science and Mathematics Centre, Curtin University of Technology, Western Australia.

I am doing a research on:
"The Development, Implementation and Evaluation of a Teaching and Learning Package for Enhancing Mathematical Achievement in the BDTVEC National Diploma Year 1."

Below is a paragraph of the abstract that I hope will give a clear picture of what I will be doing.

"This research is an attempt to improve the mathematical skills of technical students in Brunei by developing a teaching and learning package that can be used by mathematics instructors and students alike. The package will focus on enhancing mathematical achievement will then be implemented and evaluated to determine its effectiveness and power to improve students' cognitive mathematical abilities. The package will shift the teaching and learning of mathematics from instruction that fosters the procedure of practice and memorisation toward instruction that emphasises mathematical inquiry and conceptual understanding. It will also use integrated and cooperative learning techniques to link both the mathematics understanding of materials and their composition, to the application of materials in the world of work. Three major aspects of teaching and learning that will be taken into consideration are the environmental aspects, the authenticity aspects and the instructional aspects. Other aspects would include students' attitudes and students' misconceptions. The factors mentioned would be identified through surveys, diagnostic tests and interviews. The use of technology to pursue mathematical investigations and as learning aids will also be explored, as the influence of technology is very great in our lives today.
Appendices

Technical students and instructors in Brunei will be the target group of this study. They will include students taking first year mathematics, and instructors teaching the subject, together with some instructors in charge of the curriculum. Frameworks for analysis of classroom activities will be based on the constructivist approach. Qualitative and quantitative analysis will be used in this study and case studies will also be included.

I would like to ask for permission from you sir, to conduct research according to the following schedule:

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Target Group</th>
<th>Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Survey (via questionnaires) on the aspects of teaching and learning which influences mathematical achievement</td>
<td>National Diploma Year 1 students from MTSSR and MKJB</td>
<td>Sometime in July or September, 2001</td>
<td>1 week</td>
</tr>
<tr>
<td>2. The implementation of the teaching and learning package</td>
<td>One or two classes of National Diploma Year 1 students</td>
<td>January to March 2002</td>
<td>About 9 weeks</td>
</tr>
</tbody>
</table>

The package will be developed for the algebra class, which according to the schedule already prepared by the curriculum development committee is supposed to be taught at that time. This will ensure that the students and teachers will experience minimal interruption.

The full thesis proposal is attached. In addition, I have provided a letter of support from my thesis supervisor, Professor John Malone. I hope this letter explains my purpose and I look forward to a favourable reply. Thank you.

Yours Sincerely,

(Madiah Khalid)

cc: 1). Principal,
     Maktab Teknik Sultan Saiful Rijal
     Negara Brunei Darussalam

       2). Principal,
          Maktab Kejuruteraan Jefri Bolkiah,
          Negara Brunei Darussalam.
23 April 2001

The Director
Department of Technical Education
Ministry of Education
Brunei Darussalam.

Dear Sir,

I am writing to you in my capacity as the supervisor of the research project proposed by Madihah Khalid as part of her studies for the Doctor of Philosophy (PhD) program conducted at this University.

Her study is entitled:

The development, implementation and evaluation of a teaching and learning package for enhancing mathematical achievement in the BDTVEC National Diploma Year 1.

I believe that her study has the potential to provide a wealth of information for improving the efforts of mathematics students studying in the technical education system in Brunei. Madihah has carefully planned her research methodology, has developed a fitting strategy to implement her study, has proposed effective methods to collect data and analyse it, and has formulated appropriate techniques to evaluate the outcomes of her work.

I have every confidence that Madihah will produce a first class thesis, and accordingly request your support in facilitating the planning and implementation stages of her study. The study’s outcomes will, I am sure, further the educational mission of the Technical Education Department while at the same time augment the mathematical achievement of the Department’s mathematics students.

Thank you for considering this request and in anticipation of your positive response.

Sincerely,

John A. Malone
Professor of Mathematics Education.
Appendices

Mr Madijah Khalid,
Science and Mathematics Education Centre,
Curtin University of Technology,
P.O. Box U1987 Perth,
Western Australia 6845.

Dear Madam,

I refer to your letter dated 23rd April 2001. It is gratifying to note that you are now pursuing a higher study focusing on the teaching and learning of mathematics.

You are welcome to conduct research utilising National Diploma Year 1 students at Maktab Teknik Sultan Saiful Raja and Maktab Kejuruteraan Jefri Bolkiah as target groups. In order to secure administrative arrangements you are advised to communicate directly with the respective principals.

I wish you success in your research.

Yours sincerely,

{ Dato Paduka Haji Mustafa Abu Bakar }
Director of Technical Education.

cc: Principal MTSSR
    Principal MKJB
Appendices

Appendix 3G: Guide for determining students’ proficiency in the categories of conceptual understanding, procedural skills and problem solving ability

MATHEMATICS PROFICIENCY GUIDE

CONCEPTUAL UNDERSTANDING: Proficiency Guide

Conceptual understanding includes the ability to interpret the problem and select appropriate information to apply a strategy for solution. Evidence of this understanding is demonstrated through ability to make connections between the problem situation, relevant information, appropriate mathematical concepts and logical/reasonable responses. Students exhibit:

COMPLETE CONCEPTUAL UNDERSTANDING, if they are able to:
- Use all relevant information to solve the problem
- Answer question/problem in a consistent manner.
- Translate the problem into appropriate mathematical concepts.

PARTIAL CONCEPT UNDERSTANDING, if they are able to:
- Extract the "essence" of the mathematics in the problem, but is unable to use this information to solve the problem.
- Only partially able to make connections between/among the concepts.
- Partly relate solutions to the question (not fully).
- Understand one portion of the task, but not the complete task.

LACK OF CONCEPTUAL UNDERSTANDING, if they would:
- Offer solution that is inconsistent or unrelated to the question.
- Translate the problem into inappropriate mathematical concepts.
- Use incorrect procedures without understanding the concepts related to the task.

PROCEDURAL SKILLS: Proficiency Guide

Procedural skills deal with the student's ability to demonstrate appropriate use of procedures. Evidence includes the verifying and justifying of a procedure using concrete models, or the modifying of procedures to deal with factors inherent in the problem. Students exhibit:

COMPLETE PROCEDURAL SKILLS, if they:
- Use principles efficiently while justifying the solution.
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- Use appropriate mathematical terms and strategies.
- Solve and verifies the problem.
- Use mathematical principles and language precisely.

**PARTIAL PROCEDURAL SKILLS, if they:**
- Are not precise in using mathematical terms, principles, or procedures.
- Are unable to carry out a procedure completely.
- Use incorrect process to verify the solution.

**LACKS PROCEDURAL SKILLS, if they:**
- Use unsuitable methods or simple manipulation of data in his/her attempted solution.
- Fail to eliminate unsuitable methods or solutions.
- Misuse principles or translates the problem into inappropriate procedures.
- Fail to verify the solution.

---

**PROBLEM-SOLVING ABILITY: Proficiency Guide**

Problem-solving ability requires the use of many skills, often in certain combinations, before the problem is solved. Students demonstrate problem-solving abilities with clearly focused, good reasoning that lead to a successful resolution of a problem. Students exhibit evidence of:

**THOROUGH / INSIGHTFUL PROBLEM-SOLVING ABILITIES, if they:**
- Use skills and strategies that show some evidence of insightful thinking to explore the problem.
- Show work that is clear and focused.
- Use skills/strategies that are appropriate to the problem.
- Give possible extensions or generalizations to the solution or the problem.

**PARTIAL PROBLEM-SOLVING ABILITIES, if they:**
- Use skills and strategies have some focus but clarity is limited.
- Apply strategies, which are only partially useful.
- Apply strategies, which are not fully executed.
- Start the problem appropriately, but changes to an incorrect focus.
- Recognize the pattern or relationship, but expands it incorrectly.
LIMITED PROBLEM-SOLVING ABILITIES, if they:

- Use skills and strategies that lack a central focus and the details are sketchy or not present.
- Do not record the procedures (i.e. only the solution is present).
- Use strategies that are random.
- Do not fully explore the problem looking for concepts, patterns or relationships.
- Fail to see alternative solutions that the problem requires.
Appendices

Appendix 4A: Interview Questions

INTERVIEW QUESTIONS:

(1st stage) (Before implementation of package)

For students
1. Do you like mathematics? Why?
2. Do you think mathematics is important? Why?
3. What do you think of the classroom environment for mathematics lessons now? What do you think is the best and the most conducive mathematics classroom?
4. Do you like the way mathematics is taught now?
5. Can you see relevance of the subject to your chosen profession?
6. Do you have any suggestions to improve mathematics teaching/learning in class?

For Teachers
1. What do you think are the areas that need to be addressed and improved in teaching/learning mathematics for the student.
2. Do you agree that improvement is needed in the area of learning environment, instructional approach especially in exploring real-life problems? How can we improve them?

(2nd stage) (During and after implementation of package)

For students
1. Do you like mathematics? Why?
2. Do you think mathematics is important? Why?
3. What do you think of the classroom environment for mathematics lessons now? Do you think is the current mathematics classroom is conducive to learning? How do you feel about the class so far?
4. Do you like the way mathematics is taught now?
5. Can you see the relevance to your chosen profession?
6. Has there been any improvement in the way mathematics is taught and in the environment?
7. Has the attempted improvement been successful?
8. What else can be done to improve mathematics?

For Teachers
1. What do you think of the package?
2. Do you notice any difference in student attitude and achievement after using the package?
3. How would you rate the package?
Appendices

Appendix 4B: Pre-Implementation Teacher Interview

Teacher 1:

Generally, the students’ level of understanding is below average because those who came in mostly have C6, D7 or D8 in N-level and “N” level maths which isn’t as elaborate a syllabus as compared to O-level.

Provide students a classroom environment as preferred by them. Make an effort to find out what kind of environment the students want and try to teach accordingly. This will definitely see an improvement in students’ motivation and interest in learning maths.

Move away from traditional form of teaching, which is teacher centred. Provide more investigative type of activities, which will improve the students understanding of maths. Rote learning is something that should be shelved.

The main focus of math curriculum at MTSSR is application of maths concept to work related problems. This will definitely help students see how the math theorem/concept/skills that they learn can be applied or related to work. By doing this their interest and understanding of maths will definitely improve.

Teacher 2:

Students are too dependent on teachers. They don’t have time to look for references because of tight, packed classes, and limited sources available. New books are seldom obtainable. Entry qualification should be increased so that we have better students.

Teachers should prepare suitable lesson notes, give personal attention to students to motivate them, let students see their flow of progress, ask them to prepare a folder to record their own progress, individualisation (understanding between teacher and students and allow students to set their own time schedule), let students discuss among themselves and try to relate as much as possible to their course.

Teacher 3:

Students are weak in basic starting from arithmetic, their knowledge is disconnected, there is no continuity in the syllabus, no attempt to connect
Appendices

things together, no reasoning and understanding, just memorising – rote learning.

Teachers should show passion while talking mathematics to create interest for math in them. Through history, this interest can be instilled. Emphasise should be on how to think.

Real authentic problem should be encouraged.... Apply to economics, personal problems etc....

Teacher 4:

Generally weak when they came. But they improve as they progress because classes are smaller. They are doing better now. Depending on attitude although they can succeed. They are not hopeless because they are still can do the procedural skill

Move away from traditional approach. More investigative kind of problem we teachers provide the background and students find out how to solve. More discussion, collaborative and peer learning.

I don’t know where we can find those kinds of problems. Students should understand mathematics first before they solve real life problem. There is no short cut otherwise students will lose interest e.g. solving simultaneous equations. Trig graph can be fully applied to electrical & electronic engineering. But not all the time we can show the relevance of mathematics to them. Some topics that might not be relevant now still need to be taught for higher further studies.

Teacher 5:

Students are weak. They don’t usually understand

More exercise. Have more application problems. Have to change rote learning. We have to move to real life problem but the problem is no resources for this kind of problems. MIP problems are made to create interest to students. Maths quiz. Crossword puzzle.

Relevance goes according to department.

Teacher 6:

From the diagnostic test that I conducted, five out of ten students are very weak. Students learn math just to pass exam. After going for holidays and come back next year, they cannot remember any more. Mathematics is linked (hierarchical). They should remember what they have learnt. Then
there's the language problem too. From one problem that I gave, they
don't consider the word less as discount. Maybe the problems started
from kindergarten. Then there's the big gap between PND and ND1
syllabi. PND syllabus is too simple

Classroom environment very important Unfortunately, time is not enough.
Should have math lab where we can have charts, project etc. More
student centred approach. Instructors should learn teaching skills. Ask
the industry, what kind of mathematics is needed. Try to upgrade teaching
skill by research by themselves

Unfortunately, this is not happening. Can also use newspaper for
teaching. Concept of approximation & estimation is a very important
topic. Teaching tables in primary school is not important. Authentic
problems should be introduced from small. Authentic problem is even
more crucial for technical studies.
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Appendix 4C: Pre-implementation Student Interview
Student Interviews 18/9/2001 – 21/9/2001
Student 1:

Q1. I quite like mathematics because you don’t have to write a lot of
things. What we learn is about the same. It has a lot of application and
the answer is exact, specific.
Q2. Yes, very important. We use mathematics everywhere.
Q3. Now the lesson is teacher centred which I don’t mind.
Q4. Okay. But investigation and group work would make us understand
better.
Q5. Depreciation, accounting.
Q6. Concentrate on simple mathematics applicable to everyday life.

Student 2:

Q1. I just accept it. Not a matter of liking it. I don’t dislike it. Because it is
connected to everyday life e.g shopping, going to Limbang (currency
exchange).
Q2. Of course, we use math everyday. Even to count the days,
measurement. But math is not a major part or influence in my life.
Q3. The teacher is very helpful to me. We can discuss maybe because I
am a mature student. The class is usually noisy. Outside interference (the
student was referring to the noise outside the class)
Q4. Okay. Teacher will explain if we don’t understand. But I like it that
way. The teacher centred way. Teacher should relate school work and
working life. But this is not the case at all. So, I expect more relevant
problems. Some things that we learn in class is not useful, but I don’t
mind learning it just for general knowledge.
Q5. Yes. In evaluation. Calculate the life span of building. Calculate cost
and value
Q6. More exercise related to work. Tangent, cosine, I don’t see the
relevance at all. If the lesson is mixed with some business dealings, it will
be much better. Experience is important to make someone see the
usefulness of math. I don’t see that kind of application with science.
Market forces, current and future values are all important to be taught.

Student 3:

Q1. Yes, it stimulate our mind.
Appendices

Q2. Yes. In everyday life.
Q3. It can be improved. The physical environment is okay. And I like it that we could discuss with friends.
Q4. It can be improved. But slow changes, please. Not too abrupt. I don’t like it when teachers give different formula to solve the same problem. Make it uniform with other classes. Students should be serious in math classes. Don’t make noise. Teachers, please don’t scold the students if they make mistakes.
Q5. In drawing. Yes. But we are using a different formula in math and construction class.
Q6. Don’t know.

Student 4:
Q1. Yes. But there are a lot of formulae to remember. The way problems are worded in math is hard to understand. I hate word problem.
Q2. Yes. We use math everyday and every where.
Q3. Can be improved. Teachers should bring models, colourful pictures, and more exercise from easy to difficult. Staggered. Not straight away to the difficult questions. There should be more mathematics activities that stimulate thinking. More examples and exercise so that it is easier to recall in examinations.
Q4. Okay. But can still improve.
Q5. I can see it in structural mechanics.
Q6. Teacher should give more examples. So that we can do the problems after that during exercise.

Student 5:
Q1. Yes, I love it. Makes I mind active. Even when it is difficult, we can solve it via teamwork.
Q2. Yes. There is application everywhere. Especially in engineering.
Q3. It can be improved.
Q4. Okay. But some instructors are boring. They should elaborate more when explaining and they should bring in models. I don’t mind copying notes from blackboard. It makes me think and not fall asleep.
Q5. Yes. A lot.
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Q6. Show more application. Although we were given formulae, I don’t know how to use it. During lessons, we should group ourselves, discuss among ourselves, then the teacher can ask questions.

Student 6:

Q1. It is interesting, playing with numbers. Use a lot of thinking too.
Q2. Yes. Everything. Trading etc. Everybody knows that.
Q3. More detail explanation from teacher. Class must be fun. I like the way teacher X teach. He taught in detail the history) and full he makes us laugh.
Q4. No comment
Q5. In metallurgy
Q6. Students should show working in front of the class. Teacher correct any mistakes that students makes.

Student 7:

Q1. Sometimes. I don’t like it when it is hard. If the teacher makes it interesting, then I like it.
Q2. Yes. Very important. Buying, if we don’t know math, people can cheat us.
Q3. Teacher don’t just sit. He must attract our attention. Task orientation must be clear. There should be a balance. Teacher can teach and we should also find out.
Q4. Give us challenging questions.
Q5. Teamwork is better than working individually. If a teacher knows that the student is not good, approach him/her.

Student 8:

Q2. Yes. In or outside school. Especially to apply for jobs. They would want your math.
Q3. Okay but sometimes too noisy. We support each other and our teacher is very good.
Q4. Our math class now is better than last year. It depends on the teacher.
Q5. Yes, math is relevant. Angle calculation.
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Q6. Teacher should be more involved with the students. Not just explain things on the board.
   Student 9:

Q1. Sometimes. Depend on the topic. I don’t like algebra. What we are learning now is okay.
Q3. Our teacher now is okay. It’s easy to communicate with teachers and students in this class. Avoid too much noise.
Q4. A teacher cannot be boring. They need to be more friendly.
Q5. We were taught application in class.
Q6. No comment
   Student 10:

Q1. Yes, I like it since primary. My sister instil that in me.
Q2. Yes. It is important to do everything. Even to come here to take this course, they ask for mathematics.
Q3. Can be improved. More cooperation and discussion in class. To understand. Now, we don’t do that.
Q4. No comment
Q5. Models
Q6. A balance of everything. Group work, individual and teacher explanation.
   Student 11:

Q1. I like math when the question is easy and I don’t like it when it is hard.
Q2. Yes, of course. Mathematics is used anywhere
Q3. Okay. I don’t know what to comment
Q4. No comment
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Appendix 4D: Sample Field Notes of Pre-implementation Classroom Observation

Classroom Observation (Field notes)

Classroom 1

Date: 2/10/2001

No of student: 6

Classroom setting:  
*Dimension:* 2 x 3.5 m  
*Furniture arrangement:* Not very neat. Haphazard.

Whiteboard.

*Wall:* Wooden. No mathematics chart

*Teacher Access:* The classroom is small but because there were only 6 students, teacher could access each student easily.

*Lighting:* Bright. Good lighting. Sunlight comes in. Well ventilated

Teaching/Learning:

*Teacher:* Came in. Greetings. Very friendly with students. Did not revise. No whiteboard teaching (no preliminary activities). Just handed out worksheet of problems. Goes from one student to another while students attempted the problems. Tried hard to ensure students attempted the problems. Voice is clear and students seemed to adore him (confirmed from interviews).

*Students:* All males. Politely acknowledged my presence. One was my former student from Berakas Secondary school. Seemed familiar with the instructional way. Discussed quietly among themselves and also with the teacher. Relaxed mood and seemed not in a hurry to finished the problems. Good relationship with each other.

General Comments: I would say that this is a happy classroom. Students were happy to do what the teacher asked. Friendly banter between students and teacher is common. A lot of noise (banging) outside but despite this, does not seemed to bother students. Very normal, traditional class. Text-book problems given.
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Classroom Observation (Field notes)

Classroom 2  Date: 2/10/2001 (PM)

No of student: 10

Classroom setting:  Dimension: 3 X 4 m  

Wall: Brick. No mathematics chart

Teacher Access: Easy access

Lighting: Okay. Well ventilated. Row of windows on one side.

Teaching/Learning:

Teacher: Came in. Greeted students with “Assalamualaikum”. Asked students to take out worksheet. Sits on his desk doing his own work. Did not go around checking students work at all. Only get up once or twice when students called for help.


General Comments: Gloomy feeling. Students were bored. Teacher doesn’t really care. No preliminary activities. Not much interaction between teacher and students. No formal beginning and end.
Classroom Observation (Field notes)

Classroom 1  
Date: 4/10/2001

No of student: 14

Classroom setting:  
Dimension: 3 x 3 m  
Furniture arrangement: 6 straight, heavy tables with 2 or 3 students at one table. Whiteboard. Small teachers desk in front. Not suitable for discussion

Wall: Wooden. No mathematics chart. 3 charts associated with engineering.

Teacher Access: Not very easy to go from one student to another because of the nature of the furniture.

Lighting: Bright rooms. Well ventilated.

Teaching/Learning:


Students: 3 females and 11 males. All the females sit at one table. Looked happy. Laughed at teacher’s joke. Took notes. Seems to like the teacher very much. Close knitted among them. Did problems chatting away. Attentive to teacher.

General Comments: Bright atmosphere. Teacher asked questions but did not really expect answers. Students also asked questions. No preliminary start like revision of previous lesson. Examples given were relevant. Not very traditional compared to other classes.
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Appendix 5A: Information for students (Before Implementation Started)

Course Title: Trigonometry  \hspace{1cm} \textbf{Length of course:} 34 hours

\textbf{Required:} Calculator
- Ring binders with a set of index dividers
- One or two formatted IBM 3.5" disks.
- For some classes, compass and protractor.

\textbf{Objectives:}

1) To make student understand the concepts in trigonometry and being able to apply and connect it to the real life.
2) To make student enjoy and appreciate trigonometry through student-centred activities and investigations.
3) To provide a student-centred learning environment that is non-threatening in which student can think creatively.
4) To improve mathematics communication skills, both written and oral.
5) To make student able to work individually as well as in a team and accept personal responsibility
6) To enhance mathematical achievements of students.

\textbf{Course strategy:}

1) Students would be divided into cooperative groups of three to four members (it has been found this is the optimal number, no member would be left out and no member becoming dominant). Each group work at their own table working through activities and worksheets.
2) Teacher discusses and interacts with groups and also individuals.
3) Each group member is expected to be active in discussion.
4) Each sub topic would be approached through
   a) Launch: Lessons begin with a full-class discussion of a problem situation and of related questions to think about. This discussion sets the context for the student work to follow and helps to generate student interest; it also provides an opportunity for the teacher to assess student knowledge and to clarify directions for the group activities.
   b) Explore: Classroom activity then shifts to investigating focused problems and questions related to the launching situation by gathering data, looking for patterns, constructing models and meanings, and making and verifying conjectures. As students collaborate in small groups, the teacher circulates from group to group providing guidance and support, clarifying or asking questions, giving hints, providing encouragement, and drawing group members into the discussion to help groups work more cooperatively. The unit materials and related questions posed by students drive the learning. Teacher is facilitator.
   c) Checkpoint: A full-class discussion of concepts and methods developed by different small groups then provides an opportunity to share progress and thinking. This discussion leads to a class summary of important ideas or to further exploration of a topic if competing perspectives remain. Varying approaches and differing conclusions that can be justified should be encouraged.
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d) Apply: students were given application problems related to lesson objectives to complete cooperatively in groups. The teacher circulates in the room assessing levels of student understanding.

e) Practice/Homework: To make sure that students have enough practice, more application problems were given as homework so that they can complete it either on their own or with their friends.

5) Any misconceptions would be diagnosed and addressed in the class immediately.

Syllabus:

Below is the summarized syllabus in this course:

a) Radian Measure: Angles can be measured in both degree and radian. You will learn how to convert degree to radian and vice-versa. You will also be finding the length of arc, area of sectors and area of segments.

b) Trigonometric ratio: You will calculate the trigonometric ratios (including the reciprocal) of angles between 0° and 360°. You will plot the graphs and identify the periodic properties of the curves.

c) Trigonometric identities: You will look at proves of the basic trigonometric identity, look at sine rule including $D = \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$ and cosine rule.

d) Area formula: We will look at to area formula of a triangle namely

i) Area = $\frac{1}{2}$ ab sin C

ii) Area = $\sqrt{s(s-a)(s-b)(s-c)}$ where $s = \frac{1}{2} (a + b + c)$.

c) Three-dimensional trigonometry: We will solve three dimensional triangulation problems, define angle between straight line and plane, angle between two intersecting plane and calculate the lengths and areas on the horizontal plane.

All of the five sub-topics would consider work related problem. Emphasis will be on solving work related problems.

Topics described will be learned through individual and group projects. The projects concern problems encountered in the disciplines served by this course: Construction and Electrical Engineering.

Assessment:

1) Regular testing, linked to schemes of work. (Continuous)
2) More integrated and “authentic “ approach.
3) There will be two in-class tests.
4) Project work and the tests will count towards your final grade for this unit plus vector.
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**Timeline:**

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<td>1</td>
<td>Introduction. Diagnostic Test (Pre-test)</td>
<td>Radian measure</td>
<td>Radian measure</td>
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<td>2</td>
<td>Radian measure (Real world problems)</td>
<td>Radian measure (Assessment by concept mapping)</td>
<td>Trigonometric Ratio</td>
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<tr>
<td>3</td>
<td>Trigonometric Ratio</td>
<td>Real world problems on Trig ratio</td>
<td>Real world problems on trig ratio</td>
</tr>
<tr>
<td>4</td>
<td>Graph of trigonometric ratio</td>
<td>Graph of trig ratio (real world problems)</td>
<td>Graph of trig ratio (problems, project given)</td>
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<tr>
<td>5</td>
<td>Trigonometric identities</td>
<td>Trigonometric identities</td>
<td>Sine Rule</td>
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<td>Sine Rule</td>
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<td>7</td>
<td>Cosine Rule</td>
<td>Area formula</td>
<td>Area formula</td>
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<td>8</td>
<td>Project</td>
<td>CCEI &amp; Attitude survey</td>
<td>Assessment Test (Post-test)</td>
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Meeting 1:
- Introduction to the whole course.
- Administer diagnostic test (pre-test).

Meeting 2:
- Difference between two-angle measurements. Define radian.
- Convert measurements in degrees (from 0° to 360°) to radians and vice versa.
- Homework – angle investigation. *(Activity 1)*

Meeting 3:
- Discuss homework
- Deduce and use the arc length formula \( S = r\theta \)
- Deduce and use the area of sector formula \( A = \frac{1}{2} r^2 \theta \)
- Give work related problems, apply arc length and sector area formulae to solve them to standards of the occupation/industry.


Meeting 1:
- Discuss problems (jigsaw).
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Meeting 2:
- Continue with problems
- Wrap up radian measure by drawing a concept map to link everything that was learnt.

Meeting 3:
- Calculating the trigonometric rations of angles between 0° and 360° (including the reciprocal ratios) by giving lots of exercises based on certain activities (Activity 2)
- Give homework.

Week 3 (14/1/2002 – 19/1/2002)
Meeting 1:
- Trigonometric ratio (revision)
- Real world problems on trigonometric ratio
Meeting 2:
- More problems on trigonometric ratio
Meeting 3:
- Plot the sine, cosine and tangent curves over one complete cycle.
- Plot the resulting curve over two complete cycles when two sine/cosine functions are added together.
- Give a lot of examples form work-related problems.

Meeting 1:
- Identify the periodic properties of the sine, cosine and tangent waves.
- Apply the graphs of trigonometric ratios to solve a range of work related problems.
- Class exercise.
- Give investigation type of work. (To be discussed in the next class)
Meeting 2:
- Discussion on the investigation problem.
- More solving of work related problems.
Meeting 3:
- More real world problems on trigonometric graphs
- Project given

Meeting 1:
- Deduce and apply $\sin^2 \theta + \cos^2 \theta = 1$ using the right angle triangle.
- Try a lot of deduction exercise (homework).
Meeting 2:
- Real world problems on identities
- Discuss problems
Meeting 3
- Activity on sine rule
- Apply sine rule including the ambiguous case.

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- Deduce and apply $a \sin A = b \sin B = c \sin C = D$ where $D$ is the diameter of the
circumscribing circle of the triangle ABC.
- Class exercise

Meeting 1:
- Apply sine rule to real world problems
- Class Exercise
Meeting 2:
- Activity on cosine rule
- Homework on cosine rule
Meeting 3:
- Worksheet on Cosine Rule
- Solving real world problems in cosine rule

Week 7: (11/2/2002 – 16/2/2002)
Meeting 1:
- **Activity 3** to apply trigonometric identities, sine rule and cosine rule to solve a range of work related problems.
- More real world problems
Meeting 2:
- Calculate the area of triangles using the formula
  $$A = \frac{1}{2}ab \sin \theta$$
- Calculate the area of triangles using the formula
  $$A = \sqrt{s(s-a)(s-b)(s-c)} \quad \text{where} \quad s = \frac{1}{2}(a + b + c).$$
- Class exercise
Meeting 3:
- Apply appropriate methods of calculating the areas of triangles to solve a range of work related problems.
- **Activity 4**

Week 8 (18/2/2002 – 23/2/2002)
Meeting 1:
- Project work
Meeting 2:
- Give actual CCEI questionnaires.
- Some revisions.
Meeting 3:
- Post-test.
Appendices

BACKGROUND OF TRIGONOMETRY:

Trigonometry is an area in mathematics used for determining geometric quantities. It began as the computational component of geometry. For example, one statement of trigonometry states that a side and two angles determine a triangle. This means that given one side of a triangle and two angles in the triangle, then two other sides and angle can be determined.

Trigonometry really means the study of trigons (triangles) in Latin. We can trace it to a long time ago in Babylon. The Babylonians had knowledge of trigonometry, the Pythagorean theorem 1200 years before Pythagoras did, and pi. Unlike the Greeks, who follow 1000 years later, the Babylonians thought in terms of algebra and trigonometry instead of geometry.

Ancient Greek Mathematicians first used trigonometric function with the chords of the circle. The first to publish the chords was Hipparchus in 140 BC. And then another Babylonian, Ptolemy, in terms of chords form the relation \( \sin^2 x + \cos^2 x = 1 \), knew the formulas \( \sin (x + y) = \sin x \cos y + \cos x \sin y \) and what we now know as the sine rule
\[ \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}. \]

The first appearance of the sine of an angle appears in the work of the Hindus. Aryabhata (500 AD), gave tables for sine and used the word jya for sine. The Arabs worked with sines and cosines and by 980 AD, Abu’l-Wafa knew that
\[ \sin 2x = 2 \sin x \cos x. \]

The Arabs used the word jaib (instead of jya) and it means ‘fold’. When Europeans translated Arabic mathematical work into Latin, they used the word sinus meaning fold in Latin. It was only in 1624, Edmund Gunther use the abbreviation sin in a drawing.

Besides Abu’l-Wafa, Al-Biruni also establish trigonometry as a distinct branch of mathematics. The Muslim mathematicians, especially al-Battani, Abu’l-Wafa, Ibn Yunus and Ibn al-Haytham, also developed spherical astronomy and applied it to the solution of astronomical problems.

APPLICATIONS of TRIGONOMETRY

Historically, trigonometry was developed for astronomy and geography, but scientists have been using it for centuries for other purposes too. Besides other fields of mathematics, trigonometry is also used in physics, engineering and chemistry. Within mathematics, trigonometry is used primarily in calculus, linear algebra and statistics. Since these fields are used throughout the natural and social sciences, trigonometry is a very useful subject to know.

Astronomy and Geography

Trigonometric tables were created over two thousand years ago for computations in astronomy. The kind of trigonometry needed to understand position on a sphere is called spherical trigonometry. Spherical trigonometry is rarely taught now since its job has been taken over by linear algebra. As the earth is also a sphere, trigonometry is used in geography and navigation.

Engineering and physics
Appendices

Trigonometry has had greater application to planes. Surveyors have used trigonometry for centuries and engineers (both military and otherwise) too. Physics lay heavy demand on trigonometry. Optics and statics are two early fields of physics that use trigonometry, but all branches of physics use trigonometry since trigonometry aids in understanding space. Related fields such as physical chemistry naturally use it.

Mathematics and its application

Calculus, linear algebra and statistics in particular, use trigonometry and have many applications in all the sciences. Since mathematics is applied throughout the natural and social sciences, trigonometry has many applications.

Let us look at the following problems where trigonometry can be used to solve them.

1. **Airplanes**: An airplane currently flying at an altitude of about 10 km is experiencing a technical difficulty. The pilot could not figure out how far from the airport he should start descending if he wants to descend at a 3° angle. Can you help him?

2. **Bridge**: The main shape of a bridge is an isosceles trapezoid. The length of the short base is 100 m. The height of the bridge is 50 m and the measure of one of the base angles is 56°. Find the length of one of the diagonal cables across the bridge to the nearest tenth of a meter.

3. **The unit circle triangle**: Consider a unit circle with a point P located on the circle in the first quadrant. Point A is the center of the circle and PA is the radius of the circle. A chord AB lies along the positive x-axis and is perpendicular to the x-axis. What is the area of PBA? (Hint: \( \sin 2\theta = 2 \sin \theta \cos \theta \)).

4. **Airplane again**: The peak of Goose bay Mountain is 400 m higher than GBT airstrip. The horizontal distance from the end of the runway to a point directly below the mountain peak is 2025 m. A plane takes off at the end of a runway in the direction of the mountain at an angle that is kept constant until the peak has cleared. If the pilot wants to clear the mountain by 50 m, what should be the angle of takeoff?

5. **The Supermarket Shelf**: In arranging items on supermarket shelf, it is a good idea to put the things you want people to buy at a shelf where it is reachable and where the customers can have a good view of it. Now there are three things you might want to consider:

   1) A typical customer stands about 3 feet away from the shelf when looking at the items.

   2) When a customer looks at an item, his or her head is bent at an angle 15° below the horizontal.

   3) A female customer’s eyes are about 59 inches above the ground, and a male customer’s eyes are about 64 inches above the ground.
Appendices

Based on this information, you have to determine the optimal shelf height. Round your answer to the nearest inch and show work to support your answer.

6. **Measuring mountains**: A surveyor stands on a hill \( h \) feet above a lake. Across the lake is a mountain. The surveyor measures the angle of elevation to the top of the mountain to be \( \alpha \). He also looks down into the lake and sees the reflection of the mountain. The measurement of this angle of depression is \( \beta \). Based on this information, as shown in the diagram, find the height of the mountain in terms of \( h \), \( \alpha \) and \( \beta \).

7. **Measuring River Width**: Given some equipments (e.g. tape measure, equipments of finding angles), describe a way that you can implement to measure the width of a river.

8. **Fishing**: From experience you found that the ideal water depth for fishing is between 15 to 18 feet. Based on markers on the pier, you also know that the high tide depth is typically 24 feet, an the low tide depth is usually 12 feet. It is also a known fact that the high tide occurs every 11 hours 5 minutes. You are going fishing on Friday, 5:00 pm and wonder if the water depth is ideal for fishing. The newspaper says that “record high tide expected” and the high tide is at midnight that night.

   a) Write a trig function that will find the depth of the water in terms of time.

   b) Use your function to determine if the water depth will be ideal for fishing on Friday at 5:00 pm.
Appendix 5B: Recommendation for Teaching this Package

Recommendations for Teaching Trigonometry to National Diploma Year 1

Curriculum

1. More systematic treatment, deal with topics in depth and don’t jump around.
2. Specify clearly the scheme of work for all abilities.
3. More emphasis on work related problems and solve them to the standards of the occupation/industry.

Teaching

1. More emphasis on a clear, precise description of the basic idea or concept being taught.
2. Correct and precise spoken and written mathematics use at all time.
3. Use technology (calculators, computers) widely.
4. Use relevant applications or authentic work examples to motivate the students.

Teaching Style

1. Planned combination of whole-class and individualised teaching.
2. Clear objectives and structure to all lessons.
3. Homework used as a means to encourage practice of skills.
4. Discuss common mistakes with the whole class.
5. Encourage contributions from students.
6. Teachers should start lesson with review of previous work.
7. Teachers should be the main motivational aspect to students and should be friendly to encourage students to ask questions.
8. Use peer and group teaching.
9. Incorporate the constructivist approach.

Assessment

1. Regular testing, linked to schemes of work.
3. Continuous assessment.
4. Variety and non-traditional approach
Lesson 1

Approximate time: 1 hour

Title: Radian measure. (Introduction)
Converting angles in degrees to radian and vice versa.

Overview:
This lesson plans to introduce other units of measuring angle especially the unit radian and why this unit of measurement is important. It emphasizes that angle definition as in degrees is a human creation and radian as an angle is the ratio of the arc-length and the radius. It also tries to explore the relationship between angles in degree and in radian.

Aim/Objective:
1) To introduce angle and various measurement used (degree, radian, radian?)
2) To look at the relationship between degree and radian by first using the:
   a) calculator
   b) defining the angle $\theta = s/r$ (in radian) and $180^\circ = \pi$ radian.
Activity sheet accompanying
3) To convert angles given in degree to radian and vice versa. (Worksheet accompanying)
4) To practice calculator skill especially converting angles in degree, minutes seconds to degree and vice versa.

Key skills:
1) problem solving
2) calculator skills
3) class interaction & co-operation (cooperative learning).

Approach:
1) Launch: Start by posing a question whether they know any other unit of angle measurement. What does it mean when an angle is written as $\pi/4$? Explain that angles can be measured in a few different units, the popular ones being degree, followed by radian and also gradian.

2) Explore: Give out the activity #1 sheet. Work with them along the way to get how to convert degree to radian and vice versa. Give some examples.

Discuss in detail: ‘why in ancient time, 1 degree is 1/360th of a circle?’
The Babylonians invented this based on their Babylonian base 60 numerical system. Hours and minutes are similarly divided into 60's (of course, there are minutes of time and minutes of angle - there are 60 minutes in a degree, and, similarly, there are seconds of time and seconds of degree - there are 60 seconds in a minute, 3600 in a degree). It might also be because they thought that since the earth moves in a circle (although it is elliptical path) around the sun in 360 days, then there was 360 in a circle.

The reason why I asked them this question is to make them aware that it is a creation of ancient time and in fact we can invent another unit of measurement
that we can call a ‘madihah’ in which there are 1234 in a circle. Besides degree, the other unit for angle measurement that is still in use is the gradian – of which there are 400 in a circle (German engineering unit? British military use?) Another one that is of very important use is the radian. The reason why radian is defined to be 2Pi is because the circumference of a circle of radius 1 is 2Pi. So in a circle of radius 1, one radian subtends an arc length of exactly 1. This makes measuring arc length equivalent to measuring angle. The activity sheet tries to build the relationship between degree and radian and how they can easily convert angle from degree to radian and vice versa.

3) Checkpoint: How do you change angles in degree to radian and vice versa?
4) Apply: Once a definite way is found, emphasise this new-found skill with exercises. (worksheet 1)
5) Homework: Give unfinished exercise or additional problems if needed as homework.
Complete the following steps. Collect and record your data as you work through the activity.

**Materials for each group:**
1) Compass   2) String   3) Ruler   4) Protractor   5) Pencil

1. Draw a big circle on a piece of paper using the compass. Each group should have a different radius.
2. Mark a point on the circumference of the circle.
3. Draw a radius connecting the centre point to the point on the circumference.
4. Cut a string of equivalent length to the radius.
5. Place the string on the circumference of the circle, placing one end of the string on the point on the circle. Mark another point on the circle at the other end of the string.
6. Continue mapping the length of the string around the circumference of the circle making sure that you mark the length along the circumference as you go.
8. Draw segments from the center of the circle to each of the marks you made around the circumference of the circle.
9. Label each of the angles beginning with angle #1 and numbering consecutively until all angles are labeled.
10. Use the protractor to obtain the approximate angle measure for each central angle in your circle.
11. Complete the accompanying data sheet for this activity.

**ACTIVITY #1 - DATA SHEET**

1. **MEASUREMENT**

   a. Length of your string. ______________
   b. Approximate measure of each angle in the circle.
   p1= _____ p2= _____ p3= _____ p4= _____ p5= _____ p6= _____ p7= _____

2. **MORE ABOUT THE ANGLES**

   a. How many of your angles are approximately the same in measure? __________
   b. What is the sum of all the angles that are about the same measure? __________
   c. What is the difference between 360 and the sum you found above? __________
   d. What is the measure of the only angle not included in the sum above? __________
   e. What should the sum of all the central angles you drew equal? __________
   f. What is the actual sum of all the angles you measured? __________. If your actual sum is different the answer you gave in Part 2e, what do think caused this to happen? __________

   ___

   g. If you were to cut the circle in half (having only 180°), how many of these angles from part 2a can you draw within the half circle you now have? _______________
h. With your previous observation in mind, how many of these same angles could you then draw within the entire circle?________________________

3. APPLYING WHAT YOU KNOW
a. Based on your knowledge of how the circle and its components were constructed, how might you give an approximate circumference of the circle? (Give an explanation that supports your response.)

________________________

b. Estimate what you think the quotient would be if you divided the circumference of your circle by the length of your shoestring?_______

4. EXTENDING YOUR THOUGHTS
a. How do you think this quotient would change if you used a longer/shorter shoestring? (Support your speculations using knowledge from this activity.)

________________________

________________________

________________________

5. What is the sum of the measures of the angles in the circle? _________
6. What did you expect the sum to be? _________
7. Why is there a difference?

________________________

________________________

________________________

8. As a way of describing the angles, let us NOT measure angles in degrees anymore. Instead, we will measure them in terms of each of these congruent central angles. Since the radius was used to construct the arc length of each angle, we will refer to the measure of each central angle as 1 radian.
9. How many degrees are in 1 radian?_________
10. How many radians are in 1 degree?_________
11. How many radians are in a circle?_________
12. How many radians are in a semicircle?_________
13. What is the significance of the answer to question 12?
Radian Measure of Special Angles: An Application

1. If a half rotation (180°) is equal to \( \pi \) radians, what is the radian measure for 90°? 
   What is the radian measure for 270°?

\[
\begin{align*}
0^\circ &= 0 \\
90^\circ &= \frac{\pi}{2} \\
180^\circ &= \pi \\
270^\circ &= \frac{3\pi}{2} \\
360^\circ &= 2\pi
\end{align*}
\]

2. Given the relationship of 180° and \( \pi \) radians, use the circle provided and label 45°, 135°, 225°, and 315° using radian measure.

\[
\begin{align*}
45^\circ &= \frac{\pi}{4} \\
135^\circ &= \frac{3\pi}{4} \\
225^\circ &= \frac{5\pi}{4} \\
315^\circ &= \frac{7\pi}{4}
\end{align*}
\]

3. Using the same procedure as in #2, use the circle below and label 30°, 60°, 120°, 150°, 210°, 240°, 300°, and 330° using radian measure.

\[
\begin{align*}
30^\circ &= \frac{\pi}{6} \\
60^\circ &= \frac{\pi}{3} \\
120^\circ &= \frac{2\pi}{3} \\
150^\circ &= \frac{5\pi}{6} \\
210^\circ &= \frac{7\pi}{6} \\
240^\circ &= \frac{4\pi}{3} \\
300^\circ &= \frac{5\pi}{3} \\
330^\circ &= \frac{11\pi}{6}
\end{align*}
\]
Appendix 5C1: Lesson Plan 1
MAKTAB TEKNIK SULTAN SAIFUL RUAL
MATHEMATICS DEPARTMENT
RADIAN & DEGREE CONNECTIONS

Given your knowledge of the radian measure of special angles, let's explore the connections between radian and degree measure. Based on your previous exploration, give the degree measure that is equal to each of the following radian measures.

\[
\frac{\pi}{4} = \quad \frac{\pi}{6} = \quad \frac{2\pi}{3} = \quad \frac{3\pi}{4} = \quad \frac{11\pi}{4} = 
\]

Based on the knowledge you now have of radian and degree measure, explain to a student who missed this lab experience how to convert from radian to degree measure and then from degree to radian measure.

To convert from radian to degree measure you should

To convert from degree to radian measure you should

Based on your previous two answers, is there a mathematical formula that supports the procedures you described? If so, what are they?
Appendix 5C1: Lesson Plan 1
MAKTAB TEKNIK SULTAN SAIFUL RIJAL
MATHEMATICS DEPARTMENT
RADIANS AND DEGREES MEASURE BEYOND THE SPECIAL ANGLES

Now that you have made connections between radian and degree measure, and you have discovered how to convert between radians and degrees, you are ready to explore simple conversions for measures that are not special angles.

Using the formulas from the previous exercise, convert each radian measure into degrees, and each degree measure into radians.

Use your calculator in both radian and degree mode to verify your solutions.

\[
115° = \frac{5\pi}{2} =
\]

\[
155° = \frac{7\pi}{12} =
\]

\[
310° = \frac{3\pi}{18} =
\]

\[
75° = \frac{4\pi}{9} =
\]

\[
54° = \frac{2\pi}{15} =
\]
1. Your analog clock shows the passage of 45 minutes.
   
   A. Find the radian angle through which the minute hand moves in that time.
   
   1A. ________

   B. Find the radian angle through which the hour hand moves in that time.
   
   1B. ________

2. The wheel of a bicycle is rotating at a rate of 90 revolutions per minute. Find the angular speed of a spoke of the wheel in radians per minute.

   2. ________

3. An electric hoist is used to lift a piece of equipment. The diameter of the drum on the hoist is 12 inches and the equipment must be raised 15 inches. Find the number of radians through which the drum must rotate?

   3. ________
Lesson 2

Approximate time: 1 hour

Title: Radian measure: Length of arc and area of sector.

Overview:
Now that the students know how to convert degrees to radian and vice versa, they can use this angle to find the length of arc (also from the radian definition) and the area of sector.

Aim/Objective:
1) To revise definition of radian
2) To define arc and sector
3) To deduce and use arc length formula
4) To deduce and use area of sector formula.
5) To solve real world problems in radian measure.

Key skills emphasized:
1) problem solving
2) calculator skills
3) class interaction & co-operation.

Approach:
1) Launch:
   Q1: You are given a choice of running one of the two tracks available today. One track is a quarter of a circle whose radius is 20 m and the other is one third of a circle whose radius is 15 m. You are feeling tired today and would like to choose the shortest possible route. Which one would you choose?
   Q2: A whole pizza with radius 8 cm is cut into six pieces. A piece of that pizza costs $2.00. Another whole pizza with radius 10 cm is cut into eight pieces and a piece of that pizza costs $2.50. Assuming that the ingredients are the same, which one is more value for money?

2) Explore: Give out the activity #2 sheet. Work with them along the way to get to the arc length formula and the area of sector formula. Give some examples.

3) Checkpoint: How do you find the length of arc? How do you find the area of sector?

4) Apply: Once a definite way is found, emphasise this new-found skill with exercises. (worksheet 1)

5) Homework: Give unfinished exercise or additional problems if needed as homework.
1. a. Complete the table below. Find the indicated values of \( s \) and \( t \).

<table>
<thead>
<tr>
<th>( \theta )</th>
<th>( s )</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{2\pi}{2} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \frac{\pi}{2} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \pi )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Use your knowledge of similarity of circles to write an equation that shows the relationship between \( s \) and \( t \). Explain why your equation is valid.

2. Determine the length of arc \( s \) that subtends a central angle of \( 1^\circ \) in a unit circle.

3. Use the calculator and the formula you have discovered to complete the table below:

<table>
<thead>
<tr>
<th>Central angle</th>
<th>45(^\circ)</th>
<th>30(^\circ)</th>
<th>135(^\circ)</th>
<th>270(^\circ)</th>
<th>60(^\circ)</th>
<th>360(^\circ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius</td>
<td>3 cm</td>
<td>1 cm</td>
<td>4 cm</td>
<td>10 cm</td>
<td>3 cm</td>
<td>4 cm</td>
</tr>
<tr>
<td>Length of arc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Use the calculator and the formula you have discovered to complete the table below:

<table>
<thead>
<tr>
<th>Central angle</th>
<th>$\pi/4$</th>
<th>$\pi/6$</th>
<th>$3\pi/4$</th>
<th>$3\pi/2$</th>
<th>$\pi/3$</th>
<th>$2\pi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius</td>
<td>3 cm</td>
<td>1 cm</td>
<td>4 cm</td>
<td>10 cm</td>
<td>3 cm</td>
<td>4 cm</td>
</tr>
<tr>
<td>Length of arc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compare the two tables above and explain your result.

Area of A Sector

5. In the figure below, the smaller of the circles has a radius of 1 unit and the larger a radius of $r$ units. The central angle $\theta$ intercepts an arc of length $t$ on the unit circle and arc of length $s$ on the circle of radius $r$.

In the figure above, let $K(r, \theta)$ represent the area of the sector of the circle of radius $r$ determined by the central angle $\theta$, and $K(1, \theta)$ the area of the unit circle determined by $\theta$.

a. Find the values indicated in the following table in terms of $r$.

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>$K(1, \theta)$</th>
<th>$K(r, \theta)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2\pi$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi/2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
b. Use your knowledge of similarity of circles to write an equation that shows the relationship between the area $K(1, \theta)$ of the sector of the unit circle determined by $\theta$, and the corresponding area $K(r, \theta)$ of the sector of the circle with radius $r$ (in general terms - the value of $r$ is not known). Justify your equation. (Let $K(r, \theta)$ represent the area of the sector of a circle of radius $r$ and corresponding central angle of measure $\theta$.)

c. If $\theta$ is measured in radians, what is the value of $K(1, \theta)$ in terms of $\theta$? Explain.

d. If $\theta$ is measured in radians, what is the value of $K(r, \theta)$ in terms of $\theta$ and $r$? Explain.

e. Do the equations in (b) and (c) hold if $\theta$ is measured in degrees? Why or why not?

Summary:

Circumference of circle = _________
What proportion of the circumference is the arc length $s$ (in terms of angle $\theta$ in radian)? _________
Therefore, arc $s = \text{_______} \times \text{_______}$
\[ s = \text{_______} \]

OR

Angle in radian measure $\theta = s/r$
Therefore radian measure times radius = arc length
And $s = \text{_______}$

Area of the whole circle = _________
In terms of radian, what proportion of the whole circle is the angle $\theta$? _________
Therefore, what is the area of the shaded section?
\[ A = \text{_______} \times \text{_______} \]
\[ A = \text{_______} \]

11. At Mario's Pizza House, pizzas are cut into six equal slices. On the buffet, Mario sells one slice of a 10-inch pizza for $1.00, and one slice of a similar 16-inch pizza for $2.00. Which slice is the better buy? Explain.
Lesson 3

Approximate time: 1 hour

Title: Radian measure: Apply arc length and sector area formula to solve a range of work related problems.

Overview: For students to make sense of the topic, they would be given examples of how radian can be used in solving problems like finding the radius of the earth, the distance travelled by someone on a bicycle after 5.3 revolution of the tyre where the radius of the tyre is 50cm. Students were also given investigative problem to solve in groups in a method called jigsaw.

Aim/Objective:
1) To apply arc length and sector area formula to solve a range of work related problems.
2) To enhance student problem solving strategies and increase student ability to solve deductive reasoning problems. To bring a sense of fun and accomplishment to math and science class problem solving via jigsaw.
3) To develop students’ cooperation through discussing how to solve problems and develop their confidence in presenting their solution to the class using jigsaw.
4) To make student aware of the everyday nature of mathematics and that mathematics is widely used in the real world.
5) To summarize the topic on radian measure in a concept map.

Key skills emphasized:
1) problem solving
2) calculator skills
3) class interaction & co-operation.

Approach:
1) The students have divided themselves into four groups of four for ND/ELE/10 and three groups of four for ND/RTE/08
2) Give examples of real life problems and solve.
   a) Eratosthenes problem
   b) Area of segment problem
3) Give a sheet of exercises and divide the problems among the groups. One problem to each person in a group.
4) Each student assigned to problem 1 form a group, problem 2 another group and so on.
5) Let the new-formed group discuss on how to solve the problems among themselves with the teacher facilitating the class.
6) After 20 mins, each member will go back to their original group and present their solution to the group members.
7) Practice: Let the students do other problems on the sheet individually.
8) Homework: Give unfinished exercise or additional problems if needed as homework.
Example:

a) Measuring the circumference of the earth

Eratosthenes (240 B.C), was the first mathematician to measure the circumference of the earth. Assuming that the earth is round and the sun's rays are parallel, he measured the cast shadow of the vertical post. He found that at noon during the summer solstice in Alexandria, Egypt, the post cast a shadow and the angle made was 7.2° but at the same time in Syene, a town directly south, the post cast no shadow. The distance from Alexandria to Syene was found to be 787 km.

\[
\frac{7.2}{360} = \frac{787}{x} \Rightarrow x = \frac{360 \times 787}{7.2} \\
\Rightarrow x = 39350 \text{ km}
\]

We can therefore find the radius of the earth since

\[39350 = 2 \times \pi \times r\]

and \[r = 39350 / (2 \times \pi) = 6263 \text{ km}\]

b) Cross Section of the Pipe

A pipe of diameter 3 cm as in the diagram is filled with water at the level shown. Find the wetted arc length and the area of cross section of water that filled the pipe?

\[
\cos \theta = \frac{0.2}{1.5} \Rightarrow \theta = 1.437 \Rightarrow 2\theta = 2.874 \\
wetted arc = 1.5 \times 2.874 = 4.311 \text{ cm}
\]

Area = Area of sector – area of triangle

\[
= 0.5 \times r^2 \times \theta - 0.5 \times r^2 \times \sin \theta \\
= 0.5 \times (1.5)^2 \times (2.874 - 0.2644) \\
= 2.936 \text{ cm}^2.
\]

Assessment:

As an assessment for this whole topic students are encouraged to come up with a concept map that will link everything that they have learnt in this topic. Each group were given 2 day (homework) for discussion and then hand in their work.
INVESTIGATIVE TYPE EXERCISES

(1) For dessert, John has been served a wedge of pie that is one-eighth of the whole pie. He decides to share it with Mary by cutting it into two pieces with the same area. Most people would cut the wedge to form two congruent wedge shapes. However, for reasons known only to John, he decides to make a cut perpendicular to the cut that most people would make. (See the diagram below.)

How far from the corner of the wedge, C, should his cut be so that the two resulting pieces will have the same area? Give your answer as the ratio between the distance to the cut and the radius of the pie, using only a reasonable number of significant digits.

Bonus: Who holds the world record for reciting from memory the most digits of pi? Please state your source to receive credit for the bonus.

(2) Last weekend I ordered a 12-inch deep-dish pizza at my favourite pizza place. My little brother decided to cut the pizza differently than usual, so he cut off a slice from point D to B in the diagram below.

I was very interested in figuring out how much pizza he had left behind on the left-hand side of the pizza, so I placed a 5-inch piece of straw beside the pizza so that the end of the straw was tangent to the pizza at point C, where BC is a diameter. Knowing that the straw is 5 inches long and the diameter of the pizza is 12 inches, how can I determine the area of the pizza region DBC? What is the area of that region to the nearest square inch?

(3) Thousands of years ago, the most revered item of the ancient culture of Dalvek was the Seal of Dalvek, a flat clay disk that hung over the door of their sacred temple. When civil unrest struck the Dalvek, the sacred Seal was accidentally sheared in two by a wayward sword blow; although the cut was perfectly straight, it did not pass through the center of the disk (and thus the two pieces were not of equal size).

The leaders of the two warring factions were so shocked by this event that they called for an immediate cessation of hostilities. Each took a fragment, and they commemorated the
peace by coating the faces of their fragments in gold and lining the edges in silver. (By "edge," I mean both the curvy part that was part of the original circle, and the straight edge formed by the cut. See picture.)

Fast forward to the year 2001, where the passage of time has all but erased the history of the Dalvek, but the larger piece of the Seal rests beneath glass display case in Seattle's Museum of Lost Civilizations. On the current world market, the silver on the larger piece of the Seal is worth $10,000 and the gold is worth $100,000.

Unbeknownst to the museum, an unscrupulous archeologist is trying to sell off in the black market the smaller fragment of the Seal of Dalvek, which she has just uncovered in an expedition. The black marketeer has a good knowledge of silver and knows that the silver in the smaller piece is worth $5,000; however, her knowledge of gold is not as great, and she does not know how much the gold portion of the smaller fragment is worth.

Given that the total dollar value of the larger fragment is $110,000, find the total dollar value of the smaller fragment.

(4). My brother is always looking for challenging math problems that he thinks I won't be able to solve. Well, after I solved last week's pizza problem, he thought of a second pizza problem that he was sure would be too tough for me.

We went out to dinner and ordered another 12-inch-diameter deep-dish pizza. When the pizza arrived at our table, my brother made two cuts in the pizza, as shown in the diagram below. Neither cut went through the center of the pizza. Luckily, the pizza was on a special pizza plate designed to help people cut the pizza into eighths. As I looked at the pizza, I noticed that points G and D were located so that arc GD was an eighth of the pizza's circumference. Next, my brother handed me a ruler and told me to find the area of the pizza slice GHD by making only two measurements and using mathematics. How could I have solved this problem?
Homework Sheet

1. Reno, Nevada, is approximately due north of Los Angeles. The latitude of Reno is 40°N, while that of Los Angeles is 34°N. If the radius of Earth is 6400 km, find the north-south distance between the two cities.

2. A rope is being wound around a drum with radius 10 feet. How much rope will be wound around the drum if the drum is rotated through an angle of 40°?

3. Two gears are adjusted so that the smaller gear drives the larger one. If the smaller gear (radius 2.5 cm) rotates through 225°, through how many degrees will the larger gear (radius 5 cm) rotate?

4. A section of road follows a circular arc with a central angle of 37.2°. The radius of the inside of the curve is 172.0 m and the road is 15.2 m wide. There is a guardrail 0.7 meter from the outside each of the road. How long is the guardrail?

5. In the application above, suppose that the area of the circle inside the road is to be covered with grass. What area will be covered?

6. A lawn sprinkler can water up to a distance of 25 m. It turns through an angle of 135°. What area can it water?

7. A drum has a diameter of 0.94 m. A crate must be lowered 14.2 m, using rope wound around the drum. Through what angle will the drum turn?

8. Part of a road follows a circular arc with a central angle of 35°. The radius of the arc of the inner circle is 37.3 m and the road is 13.2 m wide. How much longer is the outer edge of the road?
Lesson 4

Approximate time: 1 hour

Title: Trigonometric Function

Overview: The students have studied trigonometry before (in secondary school). The revision on Pythagoras is to recall and examine how much they know the topic before I start off with the lesson.

Aim/Objective:

1) To revise on Pythagoras’ Theorem
2) To define and demonstrate the six trigonometric functions.
3) To use the calculator to find sine, cosine, etc of angles.
4) To address the common misconception:
   a) Problems in identifying which are opposite, adjacent and hypotenuse in a triangle.
   b) Problems in algebraic manipulation e.g. \( \tan 50^\circ = \frac{20}{x} \)
      \[ \Rightarrow x = 20 \tan 50^\circ \]

5) To solve simple right-angled triangle problems and the problems in context.

Key skills:

1) problem solving
2) calculator skills
3) class interaction & co-operation.

Strategy:

1) Discuss the Pythagorean Theorem. Given a right-angled triangle, identify the hypotenuse, the adjacent side and the opposite side to the angle.
2) Demonstrate the Pythagorean Theorem. 
   http://www.pbs.org/wgbh/nova/proof/puzzle/theorem.htm
3) Discuss the trigonometric functions.
4) Calculate various variables – Trigonometric puzzle (Homework)
   5) (a) Launch: How would you measure the heights of buildings, trees and hills without having to climb them? Similarly, how would you measure the width of a river without having to cross it?
   Demonstrate a Real life problem by measuring the height of the wall of the classroom using the tangent function.
   (b) Explore: Activity #3, Sine and Cosine Ratios in Right Triangles
   (c) Checkpoint: In a right-angled triangle, Pythagoras theorem can solve the third side given two sides and trigonometric relationship can be used to solve the triangle if a side and an angle or two sides are given.
6) (d) Practice: THE ROOF sheet (homework)
   (e) Homework: For any unfinished exercise.
Shade all the regions which display correct trigonometric ratios to find the hidden animal.
Activity #3

Sine and Cosine Ratios in Right Triangles

**Review of Prerequisites:**

1. The **unit circle** is the circle in the plane centered at the origin with a radius of one. By the Pythagorean Theorem, if \( P(x,y) \) is any point on the unit circle, \( x^2 + y^2 = 1 \).

2. The **sine of** \( P \), \( \sin P \), is the value of the \( y \)-coordinate of the point \( P(x,y) \) that is the intersection of the unit circle and the terminal side of the angle with vertex at the origin, initial side along the positive \( x \)-axis, and measure \( P \). The **cosine of** \( P \), \( \cos P \), is the value of the \( x \)-coordinate of this point.

![Diagram showing unit circle and sine and cosine values](image)

\[ \sin P = y \]
\[ \cos P = x \]

**Examples:**

a. In the figure to the right,

\[ \sin \theta = 0.6 \]
\[ \text{and} \quad \cos \theta = 0.8 \]

The example could be extended to include \( P \) in the second quadrant.
3. If \(-1 \leq x \leq 1\), the **arcsine of** \(x\), denoted \(\arcsin x\) or \(\sin^{-1} x\), is the measure \(\theta\) of the angle between \(-\frac{\pi}{2}\) and \(\frac{\pi}{2}\) for which the value of the sine function is \(x\). In other words, for \(-1 \leq x \leq 1\) and \(-\frac{\pi}{2} \leq \theta \leq \frac{\pi}{2}\), \(\arcsin x = \theta\) if and only if \(\sin \theta = x\).

Likewise, if \(-1 \leq x \leq 1\), the **arccosine of** \(x\), denoted \(\arccos x\) or \(\cos^{-1} x\), is the measure \(\theta\) of the angle between \(0\) and \(\pi\) for which the value of the cosine function is \(x\). In other words, for \(-1 \leq x \leq 1\) and \(0 \leq \theta \leq \pi\), \(\arccos x = \theta\) if and only if \(\cos \theta = x\).

**Examples:**

a. \(\arcsin 0 = 0\) since \(\sin 0 = 0\)

b. \(\arcsin 1 = \frac{\pi}{2}\) since \(\sin \frac{\pi}{2} = 1\)

c. \(\arccos -1 = \pi\) since \(\cos \pi = -1\)

d. \(\arccos 0 = \frac{\pi}{2}\) since \(\cos \frac{\pi}{2} = 0\)

4. **Tangent** is defined as opposite over adjacent. Therefore from our previous work

\[
\tan x \text{ can be defined as } \frac{\sin x}{\cos x}.
\]

From here we can see that \(\tan x\) can take the value from \(-\infty\) to \(+\infty\).

If \(-\infty \leq x \leq \infty\), the **arctangent of** \(x\), denoted \(\arctan x\) or \(\tan^{-1} x\), is the measure \(\theta\) of the angle between \(-\frac{\pi}{2}\) and \(\frac{\pi}{2}\) for which the value of the tangent function is \(x\). In other words, for \(-\infty \leq x \leq \infty\) and \(-\frac{\pi}{2} \leq \theta \leq \frac{\pi}{2}\), \(\arctan x = \theta\) if and only if \(\tan \theta = x\).
Cooperative Group Activity:

1. In the figure below, \( \Delta ABC \) represents an arbitrary right triangle in which \( a \) is the measure of the leg opposite \( \angle A \), \( b \) is the measure of the leg opposite \( \angle B \), and \( c \) is the measure of the hypotenuse (the side that is opposite the right angle).

A set of coordinate axes has been superimposed on the triangle so that the origin coincides with \( \angle A \). A unit circle with its center at the origin has been constructed on the axes. Point \( P \) is the point of intersection of the circle with the hypotenuse. \( \overline{PQ} \) is perpendicular to the \( x \)-axis.

Use your knowledge of the coordinate plane to label the coordinates of the vertices of \( \Delta ABC \) in terms of the lengths of its sides \( a \), \( b \), and \( c \). What is the relationship between \( \Delta APQ \) and \( \Delta ABC \)? Why?

\[
A = \quad B = \quad C = \quad
\]

Use your knowledge of the geometry of similar triangles to rewrite the definitions of \( \sin A \) and \( \cos A \) (or \( \sin \theta \) and \( \cos \theta \)) in terms of the lengths of the sides \( a \), \( b \), and \( c \) of \( \Delta ABC \). Explain how you reach your conclusion.
In right $\triangle ABC$, the side of length $a$ is opposite ($\text{opp}$) $\angle A$; the side of length $b$ is adjacent ($\text{adj}$) to $\angle A$; the side of length $c$ is the hypotenuse ($\text{hyp}$). Rewrite the definitions of $\sin A$ and $\cos A$ in terms of these verbal descriptions of $a$, $b$, and $c$.

2. The Pythagorean Theorem can be used to show that, if point $P(x,y)$ is a point on a unit circle, $x^2 + y^2 = 1$. Rewrite this relationship in terms of $\sin \theta$ and $\cos \theta$ where $\theta$ is the measure of the corresponding central angle with initial side along the positive $x$-axis and terminal side passing through $P$. (This equation is appropriately called the Pythagorean identity for sine and cosine.)

Use algebra and the characterizations of sine and cosine as ratios of appropriate sides of a right triangle to show that the Pythagorean identity holds for $\sin A$ and $\cos A$ in the right triangle, $\triangle ABC$, as shown in the figure.

3. For practice use the calculator to evaluate each of the following to four decimal places.

$$\sin 30^\circ \approx \quad \sin 75^\circ \approx \quad \sin 45^\circ \approx$$

$$\cos 30^\circ \approx \quad \cos 75^\circ \approx \quad \cos 45^\circ \approx$$
Appendix 5C4: Lesson Plan 4
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\[
\sin^2 30^\circ + \cos^2 30^\circ = \quad \sin^2 50^\circ + \cos^2 50^\circ =
\]

4. For practice use the TI-82 calculator to find the following angles, if they exist, measured to the tenth of a degree. If an angle does not exist, explain why.

\[
\sin^{-1} 0.3452 = \quad \sin^{-1} 1.7021 =
\]

\[
\sin^{-1} 0.4545 = \quad \cos^{-1} 0.3452 =
\]

\[
\cos^{-1} 0.7021 = \quad \cos^{-1} 1.4545 =
\]

5. Find the sine and cosine of \( \angle A \) in each of the following right triangles to four decimal places. Use the value of sine or cosine to determine the measure of \( \angle A \) to the nearest tenth of a degree.

\[A \quad 24 \quad C\]

\[B \quad \quad 7\]

\( \angle A \approx \)

\[A \quad 15 \quad \quad B\]

\[15 \quad 7\]

\( \angle A \approx \)

6. Use the characterizations of sine and cosine as ratios of appropriate sides of a right triangle, and the Pythagorean identity to find the indicated missing parts of the right triangles below.
Appendix 5C4: Lesson Plan 4

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7. Use the Pythagorean identity to find the value of the sine of the angle when its cosine is known or the value of the cosine of the angle when its sine is known.

If \( \sin \theta = \frac{\sqrt{2}}{2} \), \( \cos \theta = \) _________

If \( \cos \theta = \sqrt{0.2} \), \( \sin \theta = \) __________

If \( \sin \theta = \frac{\sqrt{3}}{3} \), \( \cos \theta = \) __________

If \( \cos \theta = 0.7022 \), \( \sin \theta = \) __________
8. Describe a right triangle for which the sine and cosine of one of its acute angles have the same value. Explain why your triangle satisfies this condition.

9. Sailors on small boats lacking sophisticated electronic equipment still use trigonometry to determine their location and course. In navigation, the course of a craft is the angle measured in degrees clockwise from the north to the direction in which the craft is traveling. The bearing of a particular location \( P \) from an observer at \( O \) is the angle \( \theta \) measured in degrees clockwise from the north to \( \overrightarrow{OP} \). The figure below shows two cases. In the first case the bearing of the boat is NE; in the second the bearing is SW.

Suppose a navigator on a ship, sailing on a course of 345° at 20 knots (nautical miles per hour), sights a lighthouse due north of the ship. Fifteen minutes later the lighthouse is due east of the ship. How far from the lighthouse is the ship at that time?
QUESTION ONE

Ali is looking at the new design for the roof section of his new house. He has a picture of one end of the building.
(a) Drawn below is a sketch of the roof section

```
      B
     /|
A---C
     |
     |
     D
```

5.4 m
5 m

The width of half of the roof section AC, is 5.0 m. The length of the roof, AB, is 5.4 m.

(i) Calculate the height of the roof section BC.
Height of roof = m

(ii) The angle (θ) that a roof makes with the horizontal is called the pitch. Calculate the pitch (θ) of this roof using the diagram below.

```
      B
     /|
A---C
     |
     |
     D
```

Pitch =
(b) Ahmad would prefer a different design for the roof section and says the height should be 1.7 m. The width of half of the roof section, AC, remains at 5.0 m. Calculate the roof length, AB, for Ahmad’s design.

1.7m

Roof length = _______ m

(c) Helmi has another design for the roof section and says the pitch of the roof should be 23°.
The width of half of the roof section, AC, remains at 5.0 m.
Calculate the height of the roof, BC, for Helmi’s design.

Height of the roof = _______ m

QUESTION TWO

Aishah has a design plan of her own for the roof section.
The total width of the roof section, AD, in Aishah’s design is 11.4 m.
Assume that the spouting-ridge length is the same for both sides.
(a) Aishah decides that the pitch of her roof will be 15°.
Roofing iron comes in sheets that are 6.0 m long. Would one sheet of roofing iron be enough to go from the spouting (at A) to the ridge (B) on one side of the roof? Justify your answer using trigonometry.
Appendix 5C4: Lesson Plan 4

(b) Aishah then finds that the pitch of a roof must be at least 17.5° to satisfy building requirements. She decides that the roof length must be 6.0 m long so that sheets of roofing iron do not need to be cut. Will the use of the 6.0 m lengths of roofing iron ensure that the roof section meets the building requirements?

The total width of the roof section, AD, remains 11.4 m.

Justify your answer using trigonometry.

QUESTION THREE

Osman has another design in mind for the roof section.
The total width of Osman's meeting house roof section is to be 9.8 m.
The 6.0 m long sheets of roofing iron must be used for each side without being cut.
Calculate the inside angle (θ) at the ridge of Osman's meeting house

QUESTION FOUR

Hamidah has to connect the existing aerial at A on top of the dining hall to the TV plug at point E on the front corner of the lean-to with very expensive cable.
For safety reasons the cable must be in contact with the outside surface of a wall or the roof at all times.
Point E is 0.8 m above the floor level.
Calculate the shortest length of cable needed to join the aerial at A and the TV plug at E.
Your working needs to be logical and well presented.
If you decide your first attempt is not the shortest length, try using a different strategy.
Lesson 5

Approximate time: 1 hour

Title: Solving various trigonometric function and application to the real world.

Overview: The students have studied trigonometric function in the previous class. This lesson is to address some difficulties and misconception identified from the previous lesson and also to look at and solve more work related problems in trigonometry.

Aim/Objective:

1) To change student’s tendency to think of \( \sin^{-1} x \) as equal to \( \frac{1}{x} \sin x \)
2) To emphasize that given \( \sin \theta \) = 0.8965, \( \theta \) would not have a unique value but another value in the second quadrant and other values of the form \( 2n\pi + \theta \) for \( n = 1, 2, 3, \ldots \)
3) To give other real-world application and work related examples.
4) To solve other work related examples.
5) To assess students understanding of the subject matter by individually assessing their solutions to problems.

Key skills emphasized:

1) problem solving
2) calculator skills
3) class interaction & co-operation.

Strategy:

1) When you are given an angle \( X \), trigonometry is used to compute \( \sin(X), \cos(X), \) and \( \tan(X) \). When the value of \( \sin(X) \) is given, for example \( \sin(X) = 0.2 \), the inverse sine function provides the value of \( X \). \( \sin^{-1}(X) \) is known as the inverse sine function and it is NOT equal to \( 1/\sin(X) \).

2) \( X = \sin^{-1}(0.2) = 11.5^\circ \)

This function is not single valued. In the range of \( 0^\circ \) to \( 360^\circ \), the Sine function is positive in the first and second quadrant. So, \( X = 11.5^\circ \), but it also equals \( 180^\circ - 11.5^\circ \) which is \( 168.5^\circ \). For more information, you should inspect the inverse graphs page. The same is true for:

\( X = \cos^{-1}(0.2) = 78.5^\circ \)

This function is also not single valued, and since cosine is positive in the first and fourth quadrants, the other value would be \( 360^\circ - 78.5^\circ \) which is \( 281.5^\circ \) and for

\( X = \tan^{-1}(0.2) = 11.3^\circ \)

However, this function is not single valued, and since the tangent function is positive in the first and third quadrants, the other value would be \( 180^\circ + 11.3^\circ \) which is \( 191.3^\circ \).
3) (a) Launch: How would you measure the heights of buildings, trees and hills without having to climb them? Similarly, how would you measure the width of a river without having to cross it?

(b) Examples: If the distance of a person from a tower is 100 m and the angle subtended by the top of the tower with the ground is 30°, what is the height of the tower in meters?

Steps:

- Draw a simple diagram to represent the problem. Label it carefully and clearly mark out the quantities that are given and those which have to be calculated. Denote the unknown dimension by say $h$ if you are calculating height or by $x$ if you are calculating distance.

- Identify which trigonometric function represents a ratio of the side about which information is given and the side whose dimensions we have to find out. Set up a trigonometric equation.

- Substitute the value of the trigonometric function and solve the equation for the unknown variable.

Solution:

- $AB =$ distance of the man from the tower = 100 m
- $BC =$ height of the tower = $h$ (to be calculated)
- The trigonometric function that uses AB and BC is $\tan A$, where $A = 30^\circ$.

\[
\tan 30^\circ = BC / AB = h / 100
\]

Therefore height of the tower $h = 100 \tan 30^\circ = (100) \frac{1}{\sqrt{3}} = 57.74$ m.

(b) Practice: A lot on inverse function and work related problems.
(c) Homework: For any unfinished exercise.
Exercises:

1. Find the exact value (between 0° and 360°) for the following.

a. Arccot 1

b. Arcsin \( \frac{1}{\sqrt{3}} \)
c. Arccos \( \frac{1}{2} \)

d. Arcsec 2

e. Arctan \( \sqrt{3} \)
f. Arcscsc \( \sqrt{2} \)

g. Arccos \( \frac{1}{2} \) (Quad IV)

h. Arccot \( \frac{1}{\sqrt{3}} \) (Quad III)
i. Arctan - 1 (Quad II)

j. Arcsec \( \sqrt{2} \)

k. Arcsin \( \frac{1}{2} \) (Quad III)
l. Arcsec \( \frac{2}{\sqrt{3}} \)

2. A ship of height \( h = 24 \text{ m} \) is sighted from a lighthouse. From the top of the lighthouse, the angle of depression to the top of the mast and the base of the ship equal 30° and 45° respectively. How far is the ship from the lighthouse?

3. Two men on opposite sides of a TV tower of height 32 m notice the angle of elevation of the top of this tower to be 45° and 60° respectively. Find the distance between the two men.

4. You are stationed at a radar base and you observe an unidentified plane at an altitude \( h = 2000 \text{ m} \) flying towards your radar base at an angle of elevation = 30°. After exactly one minute, your radar sweep reveals that the plane is now at an angle of elevation = 60° maintaining the same altitude. What is the speed of the plane?

5. A little boy is flying a kite. The string of the kite makes an angle of 30° with the ground. If the height of the kite is \( h = 24 \text{ m} \), find the length of the string that the boy has used.
6. A pole of height \( h = 50 \) ft has a shadow of length \( l = 50.00 \) ft at a particular instant of time. Find the angle of elevation of the sun at this point of time.

7. Two men on the same side of a tall building notice the angle of elevation to the top of the building to be \( 30^\circ \) and \( 60^\circ \) respectively. If the height of the building is known to be \( h = 120 \) m, find the distance between the two men.

8. The angle of elevation to the top of the Empire State Building in New York is found to be \( 11^\circ \) from the ground at a distance of 1 mile from the base of the building. Using this information, find the height of the Empire State Building.

9. A pilot flying at an altitude of 1200 feet is starting his approach. He is 4500 feet along his flight path from the runway.
   (a) What is his horizontal distance (\( x \)) from the runway?
   (b) What is his angle of approach (\( \theta \))?
Lesson 6
Approximate time: 1 hour
Title: Trigonometric Graphs. (Introduction)

**Aim:**

1) To learn the basic shape of each trigonometric graph and consider the effect of changing the various variables such as:
2) Identify the periodic properties of the trigonometric curves.
3) To be able to give the equation of a plotted trigonometric graphs.
4) By the end of the lesson, students should be able to predict the resulting graph from any single change of variable in the trigonometric function.
   - Demonstrate effect of change in variables on the amplitude and frequency of graphs of trigonometric functions.
   - Students can recognize similarities of graphs of trigonometric functions by changing a sine wave equation into a cosine wave equation.
   - Students will demonstrate their command of related vocabulary (amplitude, frequency, vertical and horizontal stretch, reflections, and phase shifts) in writing at the end of each lesson.
5) To teach responsibility and cooperation in a group work and to find out their opinion on collaborative learning.

**Key skills:**

1) Graph plotting
2) calculator skills
3) class interaction & co-operation.

**Approach:**

1) Launch: Start by posing a question whether they know the equation of a sinusoidal graph from the real world example (e.g. a measure of temperature during a 24-hour period). Explain the benefits of knowing the equation. Show more examples of graphs from graph for heartbeat, sound waves, radio frequencies etc. Show how sine and cosine graph can be obtained by tracing the path of someone running around the circle seen from the top and left.

2) Explore: Give out the activity #4 sheet taken partly from [http://www.nsa.gov/programs/mepp/hs/trig01.pdf](http://www.nsa.gov/programs/mepp/hs/trig01.pdf) and the Cooperative Learning Activity sheet. Work with them along the way. This is because students don’t work with graphic calculator. I could only show the examples of graph simulations once on the computer but they were encouraged to go to the internet using their home computers to see the graph simulations on the following URLs:

   - [http://id.mind.net/~zona/mmts/trigonometryRealms/trigonometryRealms.html](http://id.mind.net/~zona/mmts/trigonometryRealms/trigonometryRealms.html)
   - [http://www.np.edu.sg/msclIntMaths/TrigGrph/1_GrSC.htm](http://www.np.edu.sg/msclIntMaths/TrigGrph/1_GrSC.htm)

3) Checkpoint: Define amplitude, frequency, period and phase shifts.
4) Apply: Application will be done in the next lesson.
5) Reflection: Each group is to discuss about cooperative learning and fill in the required information on the sheet – Cooperative Learning Activity Report

**Activity #4**

GROUP NAME: __________________________

GROUP EXPLORATION SHEET

AMPLITUDE

\[ y = A \sin x \]

Sketch the graph of:
\[ y = \sin x \]

Sketch the curve which results from graphing each function:
\[ y = 3 \sin x \]
\[ y = -3 \sin x \]
\[ y = 4 \sin x \]
\[ y = -4 \sin x \]

Sketch the graph of:
\[ y = \cos x \]

Sketch the curve which results from graphing each function:
\[ y = 5 \cos x \]
\[ y = -3 \cos x \]
\[ y = 4 \cos x \]
\[ y = -4 \cos x \]

Summarize how a change in the AMPLITUDE changes the graph of a trigonometric function.
GROUP NAME: ____________________________

GROUP EXPLORATION SHEET
FREQUENCY
\[ y = A \sin Bx \]

Sketch the curve which results from graphing each function:

\[
\begin{align*}
  y &= \cos 2x \\
  y &= \cos 3x \\
  y &= \cos 4x \\
  y &= \sin 2x \\
  y &= \sin 3x \\
  y &= \sin 4x
\end{align*}
\]

Summarize how a change of FREQUENCY changes the graph of a trigonometric function. Another property of a trigonometric function is its PERIOD. The period of a sine or cosine function is calculated by dividing \( 2\pi \) by the frequency of the trigonometric function. The period of a trigonometric function represents the width of one cycle of the curve. Period is crucial to know when you are graphing with paper and pencil. It is less crucial to calculator-assisted graphs.

Give the period of each of the following functions:

\[
\begin{align*}
  y &= 3 \sin 2x \\
  y &= -6 \cos 4x \\
  y &= 4 \sin 1/2x
\end{align*}
\]
GROUP EXPLORATION SHEET

PHASE SHIFT

\[ y = A \sin B(x + C) \]

Sketch the curve which results from graphing each function:

\[
\begin{align*}
  y &= \sin (x + \pi/4) \\
  y &= \sin 3(x + \pi) \\
  y &= \sin 3(x + \pi/4) \\
  y &= \sin 3(x - \pi) \\
  y &= \sin 3(x - \pi/4) \\
  y &= \cos (x + \pi/4) \\
  y &= \cos 2(x + \pi/3) \\
  y &= \cos 2(x + \pi/4) \\
  y &= \cos 2(x - \pi/3) \\
  y &= \cos 2(x - \pi/4)
\end{align*}
\]

Summarize how a change in the parameter added to/subtracted from \( x \) affects the graph of the function. Can you determine how that parameter affects the DISTANCE that the graph is shifted?

EXTRA

Can you describe the relationship between \( y = \sin x \) and \( y = \cos x \) which is exhibited by the following functions?

Graph each pair of functions and compare the resulting curves:

\[
\begin{align*}
  y &= 2 \sin x \\
  y &= 2 \cos (x - \pi/2) \\
  y &= 3 \cos x \\
  y &= 3 \sin (x - \pi/2)
\end{align*}
\]
GROUP NAME:_____________________

GROUP EXPLORATION SHEET
VERTICAL SHIFT
$y = A \sin Bx + D$

Sketch the curve which results from graphing each function:

\[ y = \sin x + 1 \]
\[ y = \sin x + 1 \]
\[ y = \sin x + 2 \]
\[ y = \sin x + 3 \]
\[ y = \sin x - 1 \]
\[ y = \sin x - 2 \]
\[ y = \sin x - 3 \]

\[ y = \cos x + 1 \]
\[ y = \cos x + 1 \]
\[ y = \cos x + 2 \]
\[ y = \cos x + 3 \]
\[ y = \cos x - 1 \]
\[ y = \cos x - 2 \]
\[ y = \cos x - 3 \]

Summarize how a change in the constant affects the graph produced.
GROUP NAME:________________________

GROUP REPORT SHEET

Given the following trigonometric function:

\[ y = 3 \sin 4(x + \pi/4) + 1 \]

write out, in your own words, what would happen to the graph of this function when:

the AMPLITUDE is changed from 3 to 4

the AMPLITUDE is changed from 3 to −2

the FREQUENCY is changed from 4 to 2

the FREQUENCY is changed from 4 to 8

\((x + \pi/4)\) is changed to \((x + \pi/3)\)

\((x + \pi/4)\) is changed to \((x - \pi/3)\)

the CONSTANT is changed from 1 to 3

the CONSTANT is changed from 1 to −2

Sketch the graph of the original function: \[ y = 3 \sin 4(x + \pi/4) + 1 \]
Appendix 5C6: Lesson Plan 6
MAKTAB TEKNIK SULTAN SAIFUL RIJAL
MATHEMATICS DEPARTMENT
Cooperative Learning Activity Report

Date: __________________________ Title of Activity: __________________________

Group Members (Your signature indicates your involvement and understanding of the report to which this form is attached. Do not sign it for someone else.)
(Note: In groups of three, the roles of materials manager and resource person are combined.)

Coordinator: ________________________________
Record: ________________________________
Materials Manager: ________________________________
Resource Person: ________________________________

Did each member of the group contribute to the discussion? ______________

Did each member of the group participate in the activities? ______________

Did each member fulfill his/her responsibility? ______________

Did your group complete all assigned activities? ______________

1. What mathematical concept was addressed by this activity?

2. Address the strengths and weaknesses of this activity. Use the back of this sheet if necessary.

3. What could have been done to make your group interaction more effective?
Lesson 7

Approximate time: 1 hour
Title: Application of Trigonometric Graphs.

Aim:
1) To apply the graphs of trigonometric ratios to solve a range of work related problems.
2) To make students aware that they can use trigonometric functions to model high and low tides.
3) To encourage students to explore other applications of this topic, such as FM broadcasting channels and household circuits.
4) To give out project on “Trigonometric Waveforms Around Us”

Key skills:
1) Graph plotting
2) calculator skills
3) class interaction & co-operation.
4) Problem solving skill

Approach:
1) Launch: Have a graph of radio frequency wave and ask them if they can give the equation of this graph
2) Examples: Give out examples on how to solve certain problems.

Example 1:
The typical voltage $V$ supplied by an electrical outlet in the U.S. is a sinusoidal function that oscillates between -165 volts and +165 volts with a frequency of 60 cycles per second. Obtain an equation for the voltage as a function of time $t$.

Solution:
What we are looking for is a function of the form

$$V(t) = A\sin[\omega (t-\alpha)] + C.$$ 

Referring to the above figure, let us look at the constants one-at-a-time.

Amplitude $A$ and Vertical Offset $C$: Since the voltage oscillates between -165 volts and +165 volts, we see that $A = 165$, and $C = 0$.

Period $P$: Since the electric current oscillates 60 times in one second, the length of time it takes to oscillate once is 1/60 second. Thus, the period is $P = 1/60$.

Angular Frequency $\omega$: This is given by the formula

$$\omega = 2\pi/P = 2\pi(60) = 120\pi.$$ 

Phase Shift $\alpha$: The phase shift $\alpha$ tells us when the curve first crosses the t-axis as it ascends. Since we are not given this information, we can choose $\alpha$ to be an arbitrary number, so let us simply take $\alpha = 0$.

$$V(t) = A\sin[\omega (t-\alpha)] + C = 165\sin(120\pi t),$$ 

where $t$ is time in seconds.

Example 2:
Appendix 5C7: Lesson Plan 7
MATFAB TEKNIK SULTAN SAIFUL RIJAL
MATHEMATICS DEPARTMENT
An economist consulted by your temporary employment agency indicates that the demand for temporary employment (measured in thousands of job applications per week) in your county can be modeled by the function
\[ d = 4.3\sin(0.82t + 0.3) + 7.3, \]
where \( t \) is time in years since January, 1995. Calculate the amplitude, the vertical offset, the phase shift, the angular frequency, and the period, and interpret the results.

Solution:
To calculate these constants, we write
\[ d = A\sin(\omega (t - \alpha)) + C = A\sin(\omega t - \omega \alpha) + C \]
\[ = 4.3\sin(0.82t + 0.3) + 7.3, \]
and we see right away that \( A = 4.3 \) (the amplitude), \( C = 7.3 \) (vertical offset) and \( \omega = 0.82 \) (angular frequency). We also have
\[ \omega \alpha = 0.3, \]
so that
\[ \alpha = 0.3/\omega \approx 0.3/0.82 \approx 0.37 \]
(rounding to two significant digits; notice that all the terms were given to two digits.) Finally, we get the period using the formula
\[ \omega = 2\pi/P \]
\[ 0.82 = 2\pi/P, \]
so that
\[ P = 2\pi/\omega \approx 7.7. \]

We can interpret these answers in the form of the following little report:
The demand for temporary employment fluctuates in cycles of 7.7 years about a baseline of 7,300 job applications per week. Every cycle, the demand peaks at 12,000 applications per week (4,300 above the baseline) and dips to a low of 3,000. In April, 1995 (\( t = 0.37 \)) the demand for employment was at the baseline level and on an upward cycle.

http://people.hofstra.edu/faculty/Stefan_Waner/trig/trig1.html

3) Explore: Give out the worksheet.
4) Apply: Distribute project paper “Trigonometric Waveforms around Us”
5) Homework: Give unfinished exercise or additional problems if needed as homework.
Application Questions

(1) A graph is given as:

\[ S(t) = 10 \cos(\pi/6) \ t, \]

where \( t \) = time, in months from 0 to 12.

a. Sketch a graph of the function over a 12-month interval \([0,12]\).

b. What is the period of the function?

c. What is the minimum value and when does it occur?

d. What is the maximum value and when does it occur?

(2) The voltage, \( V \), of an electrical outlet in a home is given as a function of time, \( t \) (in seconds), by

\[ V = V_0 \cos (120\pi \ t). \]

a. What is the period of the oscillation?

b. What does \( V_0 \) represent?

c. Sketch the graph of \( V \) against \( t \). (Take \( V_0 \) to be some unknown positive quantity.) Label the axes.

d. If \( V_0 \) is 0.5 volts, what is the voltage at time \( t = 30 \)?

e. If \( V_0 \) is 0.5 volts, what is the first time when the voltage is 0.25 volts?

(3) The depth of water at the end of a pier varies with the tides through out the day. Today, January 23, the high tide occurs at 4:15 A.M. with a depth of 5.2 meters. The low tide occurs at 10:27 A.M. with a depth of 2.0 meters.

A. Find a trigonometric equation that models the depth of the water \( t \) hours after midnight, and graph it.

B. Find the depth of the water at noon.

C. A large boat needs at least 3 meters of water to moor at the end of the pier. During what time period after noon can it safely moor? Show this point on a graph in red.

D. What is the first time after midnight on February 1 when high tide occurs? Show this point on your graph in blue. (Hint: set your time scale on the x-axis to run from midnight on Jan. 23 to noon on Feb. 1.)

(4) You enjoy fishing on the back bay and have realized from numerous fishing adventures that the ideal water depth for fishing is between 15 feet and 18 feet. Based on markers on the pier, you also know that the high tide depth is typically 24 feet, and the low tide depth is usually 12 feet. It is also a
known fact around your seaside town that high tide occurs once every 11 hours 5 minutes. You would like to go fishing this Friday, and figure you can get to the pier at 5:00 P.M.

"I wonder if the water depth will be ideal for fishing then," you wonder aloud as you pick up the Sunday paper. On the front of the paper is a headline that reads "Record High Tides Expected." You skim the article and conclude that there will be a high tide at midnight that night.

1. Write a trig function that will find the depth of the water in terms of time.

2. Use your function to determine if the water depth will be ideal for fishing on Friday at 5:00 P.M.
Educational Program with PowerPoint/FrontPage

Trigonometric Waveforms Around Us

♦ What to do?

This project you will be working on for the next couple of weeks will be worth one phase test grade. The title is “Trigonometric Waveform Around Us’

You must choose a periodic phenomenon encountered in everyday life. You must gather the data generated by this phenomenon, use the data to plot the graph and derive its equation. You must also apply the equation for further investigation.

You can think of varieties of periodic phenomenon; e.g. radio waves, sound waves, music waves, light waves, lasers, pendulums, car engine piston displacements, tsunami waves, change of temperature in a day or all year round, change of prayer time all year round, dissection of a cylinder, lawn sprinkler and so on.

I encourage you to select a topic that is unique or the one that you find particularly interesting.

♦ How to do

You will work in a group of four. You and your friends will have to produce an educational program/web-page using Power Point/ Front Page. It can be in any format of presentation, however, the final product should be clear and direct to the point. You should submit it in diskettes with a program summary on A4 paper in less than 30 words. You should submit two sets: one set stays in Brunei and the other goes to Australia.

♦ How do we grade

The following are the grading criteria:

• Introduction: Give some background or historical information on the topic you have chosen, and explain any technical terms or concepts. There should be a clear indication that you have done some research in this section.

• Data: Explain how data was measured and gathered. It may be in a tabular form on the screen.

• Graph: Based on the data plotted on a pair of labelled axes, use Excel to get a smooth curve that will best fit your data.

• Equation Derivation: From the curve plotted, derive the equation of the curve. State or derive the amplitude, phase shift, translation and period of the waveform. Explain clearly where each number comes from.

• Verification: Check your equation by predicting the behaviour of the phenomenon via two cases to show that your equation works: a) in one case,
choose a nontrivial values for the independent variable and solve for the
dependent variable; b) in another case, choose a nontrivial values for the
dependent variable and solve for the independent variable. Since the curve is
periodic, obtain at least three independent variables.

- **Error Analysis:** Discuss some of the sources of error that may prevent your
equation from accurately predicting the actual behaviour of the phenomenon.

- **Technical Correctness:** Your project must meet the specified requirements. Edit
the program to remove irrelevant information and include a bibliography at the end.

- **Creativity and Effort:** make sure you put time and thought into selecting an
original topic or come up with some untraditional ideas. Use any pictures, clip
arts, video clips, voice clips and so on to make this project more interesting to
watch. (Remember: You are creating an educational program)

- **Summary Sheet:** Write a short summary of your project in less than 300 words
on A4 paper. This summary should introduce the phenomenon you choose and
how data is gathered. You should also include a conclusion and what viewer can
learn from the program.

- **Extra Credit:** Extra credit will be given to unusual projects that provide deeper
insights or that goes beyond the mathematical scope of what was done in class.

♦ **Advice**

Browse through various resources: books in the library, textbooks, websites
or any educational program available to you.

Hold appropriate number of team meeting before starting the project. Make sure that
every member of your team have a consensus of how to carry out the project.

Divide responsibilities fairly, and once you are assigned to a task, be responsible to
accomplish your duty. Work as a team.

Submit us a proposal of your project that includes a timeline before you actually start
on 24 January 2002. A weekly progress report should be submitted on Thursdays so
that your progress can be monitored.

Do not hesitate to seek advice/assistance from any instructors in the college. We
would be please to assist you in any way or another.

♦ **When to submit**

You must submit two sets of your diskettes and report by 09 February 2002:
one will go to Curtin University and the other to your mathematics instructor in
MTSSR. The later you submit, the less mark you will get. Submission after 16
February 2002 will not be awarded any marks. So be careful and good luck.
Lesson 8
Approximate time: 1 hour
Title: Trigonometric Identities.

Overview: Some of the identities are extremely helpful, if not absolutely necessary, in order to solve the problems. These identities makes problem solving in trigonometry easier. They can be used to verify statements or to determine a specific value.

Aim:
1) To introduce identity and what it means
2) To derive other identities from the basic $\cos^2 \theta + \sin^2 \theta = 1$
3) To use identities to solve work related problems.

Key skills:
1) class interaction & co-operation.
2) Problem solving skill

Approach:

1) Launch: Do you know that $\cos^2 \theta + \sin^2 \theta = 1$? Why is that so?
2) Explore: Give out the activity #5 sheet. Students to work in groups
3) Checkpoint: Ask students to list the identities they have derived.
4) Apply: Give an example of application of trigonometric identities.

Example:

Simplify: a) $(\sin 35^\circ + \cos 35^\circ) \times (\sin 35^\circ - \cos 35^\circ) + 2 \sin^2 55^\circ$

Solution:

\[
(\sin 35^\circ)^2 - (\cos 35^\circ)^2 + 2 \sin^2 55^\circ = \sin^2 35^\circ - \cos^2 35^\circ + 2 \sin^2 55^\circ \\
= \sin^2 35^\circ - \cos^2 35^\circ + 2[\sin(90^\circ - 35^\circ)]^2 = \sin^2 35^\circ - \cos^2 35^\circ + 2 \cos^2 35^\circ \\
= \sin^2 35^\circ + \cos^2 35^\circ = 1
\]

Give out investigation sheet investigation as given.

5) Homework: Give unfinished exercise or additional problems if needed as homework.
We are already familiar with the following ratios:

\[
\begin{align*}
\sin \theta &= \frac{1}{\csc \theta} & \cos \theta &= \frac{1}{\sec \theta} \\
\tan \theta &= \frac{1}{\cot \theta} & \cot \theta &= \frac{1}{\tan \theta} \\
\sec \theta &= \frac{1}{\cos \theta} & \csc \theta &= \frac{1}{\sin \theta}
\end{align*}
\]

You would also notice that all of the trig functions can be written in terms of \( \sin \theta \) and \( \cos \theta \). This means we can determine the value of each as long as we can determine the value of the two of them.

We also remember earlier on that from the figure below:

\[ x = \cos \theta \]
\[ y = \sin \theta \]

\[ x^2 + y^2 = 1 \] from the Pythagoras theorem
Therefore, \((\cos \theta)^2 + (\sin \theta)^2 = 1\)
i.e. \ \ \ \ \ \ \ \ \ \ \ \ \cos^2 \theta + \sin^2 \theta = 1

What do you get when you divide through by \( \cos^2 \theta \)?

What about dividing through by \( \sin^2 \theta \)? What do you get?
Can you work out how to get the following cofunction property?

\[
\begin{align*}
\sin (90^\circ - \theta) &= \cos \theta \\
\cos (90^\circ - \theta) &= \sin \theta \\
\tan (90^\circ - \theta) &= \cot \theta
\end{align*}
\]

**Identities Investigation**

1. Express \(\frac{(1 - \cos^2 \phi) \cot \phi}{\sin \phi}\) in its simplest form.

2. Use the identities to show that \(\tan^2 x = \sec x (\sec x - \cos x)\)

3. If \(\sec x = \frac{13}{5}\) and \(x\) is in the first quadrant, find \(\sin x\), \(\cos x\), \(\tan x\), \(\csc x\) and \(\cot x\).

4. Express \(\sin 73^\circ + \cos^2 17^\circ\) in terms of \(k\) if \(\sin 73^\circ = k\)
Lesson 9
Approximate time: 1 hour
Title: Sine Rule
Aim:

1) To introduce the Law of Sines. This activity sheet asks students to do some measurements to “notice” the Law of Sines and then to prove it. A few traditional practice problems follow.
2) To solve a few problems using sine rule.

Prerequisites:
(1) Students will need a ruler with centimeters and a protractor.
(2) Students should be familiar with right triangle trigonometry.

Key skills:
1) calculator skills
2) class interaction & co-operation.
3) Problem solving skill

Approach:

1) Launch: Trigonometric ratios were used when the triangle is a right-angled triangle. What should be done if the triangle given is not a right-angled triangle?
2) Explore: Give out the activity #6 sheet. Give some examples before they start on the worksheet
3) Checkpoint: State the sine rule
4) Apply: Once a definite way is found, emphasise this new-found skill with exercises in the activity sheet
5) Homework: Give unfinished exercise or additional problems if needed as homework.

Example:
Can you find the length of AB in the following triangle?

```
A

10

110°

30°

B

C
```

- 355 -
Appendix 5C9: Lesson Plan 9
MAKTAB TEKNIK SULTAN SAIFUL RUAL
MATHEMATICS DEPARTMENT

Activity #6
Mathematical Investigations
Trigonometry - Beyond the Right Triangles
Law of Sines

To “solve a triangle” usually means to find the lengths of all three of its sides and the measures of all three of its angles.

Below, using a ruler and a protractor, each person in the group should lay out one of the following four triangles listed, all of which have a base side, AB, of 10.0 cm. The first person should use a triangle with \( \angle A = 40^\circ \), the second person should use a triangle with \( \angle A = 80^\circ \), the third person should use a triangle with \( \angle A = 140^\circ \), and the fourth person should use a triangle with \( \angle A = 90^\circ \). Since one side and one angle do not uniquely determine a triangle, each person is to choose the other dimensions of his/her triangle.

Draw your triangle:

\[ \begin{array}{c}
\text{A} \\
\text{C} \\
\text{B}
\end{array} \]

Using the data from your triangle and that from the other members of your group, complete the following table.

<table>
<thead>
<tr>
<th>( m\angle A )</th>
<th>( m\angle B )</th>
<th>( m\angle C )</th>
<th>( a )</th>
<th>( b )</th>
<th>( c )</th>
<th>( \frac{a}{\sin(\angle A)} )</th>
<th>( \frac{b}{\sin(\angle B)} )</th>
<th>( \frac{c}{\sin(\angle C)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>40°</td>
<td></td>
<td></td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80°</td>
<td></td>
<td></td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140°</td>
<td></td>
<td></td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90°</td>
<td></td>
<td></td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Round to 2 sig. digits

Comment on any observations you notice:
Now it is time to formally prove the Law of Sines.

Consider the triangle $ABC$, with $h$ as the altitude to side $BC$ and $k$, the altitude to $AC$.

\[ \sin B = \frac{h}{c} \quad \Rightarrow \quad h = \]
\[ \sin C = \frac{h}{b} \quad \Rightarrow \quad h = \]

Set the two expressions for $h$ equal.

Then,
\[ \frac{\sin B}{b} = \quad \text{and} \quad \frac{\sin C}{c} = \]

In conclusion, in one triangle $\triangle ABC$, we have the Law of Sines:

The Law of Sines

In any triangle the ratio of the sine of an angle to the length of the side opposite it is a constant.

or

\[ \frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c} \]

Note that the reciprocals of these fractions are also equal. That is:

\[ \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \]

Generally, we use whichever form is more convenient.

This formula is called the sine rule in a triangle $ABC$. Say $R$ is the radius of the circle with centre $O$ through the points $A$, $B$ and $C$. Let $B'$ be the second intersection point of $BO$ and the circle. The angle $B'$ in triangle $BB'C$ is equal to $A$. In the right-angled triangle $BB'C$ we see that $a = 2R \sin(B') = 2R \sin(A)$. Thus, the fractions in the sins rule are all equal to $2R$ where $R$ is the radius of the circumcircle.
Use the Law of Sines to solve the following triangles: Draw a figure if none is given.

1. \( \triangle ABC \), \( \angle A = 42^\circ \), \( \angle B = 28^\circ \), \( AB = 10 \)

2. \( \triangle PQR \), \( \angle Q = 29^\circ \), \( \angle P = 18^\circ \), \( r = 20 \)

\[ m\angle A = \quad m\angle R = \]

\[ AB = \quad q = \]

\[ BC = \quad p = \]

3. \( \triangle KLM \), \( \angle K = 82^\circ \), \( m = 12 \), and \( k = 15 \)

4. \( \triangle CDE \), \( c = 15 \), \( e = 25 \), and \( \angle C = 85^\circ \)

\[ m\angle M = \quad m\angle E = \]

\[ m\angle L = \quad m\angle D = \]

\[ l = \quad d = \]

5. \( \triangle FGH \), \( \angle F = 18^\circ \), \( f = 8 \), and \( g = 12 \).
[Note: There are two solutions.]

\[ m\angle G = \]

\[ m\angle H = \]

\[ h = \]
6. In $\triangle ABC$, $\angle B = 44^\circ$ and $a = 12$. Determine the values of side $b$ for which $\angle A$ has:
   a. One value
   b. Two values
   c. No values

Extra Activity

Fact the size of the indicated angle in each of the following diagrams – use the sine rule.
Lesson 10
Approximate time: 1 hour

Title: Cosine Rule

Aim:
1) To introduce and prove the Law of Cosines. This activity sheet will lead students through a derivation of the Law of Cosines, first for a specific case and then in the general case. Several basic exercises follow the derivations.
2) To apply cosine law to work related problems.

Prerequisites:
(1) Students should be familiar with the standard labeling of triangles and triangle trigonometry.
(2) Students should be familiar with the Law of Sines.

Key skills:
1) calculator skills
2) class interaction & co-operation.
3) Problem solving skill

Approach:
1) Launch: We use sine rule when at least one angle and its opposite side is known besides having another angle or side given. Can we solve a triangle if only three sides or two sides and an included angle were given?
2) Explore: Give out the activity sheet. Give some examples before they start on the activity sheet.
3) Checkpoint: State the six forms of cosine rule.
4) Apply: Once a definite way is found, emphasise this new-found skill with exercises. (worksheet #1)
5) Homework: Give unfinished exercise or additional problems if needed as homework.
Activity #7

Mathematical Investigations
Trigonometry - Beyond the Right Triangles
Law of Cosines

Name: __________________________

Solving a Triangle (second view)

Given \( \triangle ABC \) with side \( b = 7 \) cm, side \( a = 8 \) cm and angle \( C = 47^\circ \), find side \( c \).

Try the Law of Sines:

Any problem?

Using the angle \( C = 47^\circ \) and the side \( b = 7 \), and right-triangle trigonometry, find the coordinates of \( A(CK, KA) \). Leave answers in exact form e.g. \( 7 \cos 47^\circ \) instead of 4.774

\[
A = (\quad , \quad )
\]

Now, what are the coordinates of \( K \)?

\[
K = (\quad , \quad )
\]

What's the length of \( KB \)?

\( KB = \quad \)

It is now possible to use the Pythagorean theorem on \( \triangle AKB \), to find \( c \). Do the algebra below, but save the "arithmetic" (actual calculations) until the very end.

\[
c^2 = AK^2 + KB^2 = (\quad)^2 + (\quad)^2 \text{ substitute}
\]

\[
c^2 = \quad \text{ mull out and collect terms}
\]

\[
\text{hint? } 49(\sin(47^\circ))^2 + 49(\cos(47^\circ))^2 = ?
\]

\[
c^2 = \quad \text{ with nothing "calculated"}
\]

\[
c^2 = \quad \quad \text{ or } \quad \quad c = \quad \text{ (now calculate)}
\]

Now finish "solving the triangle" by finding the angles: \( \angle A = \quad \quad \angle B = \quad \quad \)

On the next page, we will generalize the preceding idea by following a similar procedure using all variables rather than specific values.

The Law of Cosines:
Find the coordinates of points A and K in terms of side b and \( \angle ACB \).

A = \\
K = \\

Find the length of KB.

Use the Pythagorean theorem on AB.

\[ a^2 = \]

Multiply out and simplify, using a trigonometric identity.

\[ a^2 = \]

What you have developed is called the Law of Cosines.

The Law of Cosines

In any triangle, \( c^2 = a^2 + b^2 - 2ab \cos(C) \)

This might also be called the "Super Pythagorean Theorem" (SPT). Why?

Consider what would happen if we were to relabel the figure at the top of this page, replacing A with B, B with C, and C with A, and then reprove the Law of Cosines. We could derive the law for \( a' \) instead of \( c' \). Doing this would yield:

\[ a'^2 = \]

Similarly, we could relabel and derive the law for \( b' \). If we do, this would yield:

\[ b'^2 = \]

What happens to the formula above if the included angle is 90°?

Now it's your turn.
Worksheet

1. $\triangle XYZ$, $x = 6$, $y = 8$, and $\angle Z = 150^\circ$. Find the exact value of $z$.

2. Find $\angle B$

3. $\triangle JKM$, $j = 19$, $k = 14$, and $m = 17$. Find $\angle K$.

4. A surveyor needed to find the distance across an elliptical pond, labeled $AK$ in the diagram. From one point on the side of the pond, the distances of 123 ft and 134 ft were found and the angle measured 64 degrees. What is the required distance?

5. Given lengths of 15, 9, and 25, use the Law of Cosines to find one angle. Explain any "difficulties" encountered.
6. A spotlight on top of Jordan Towers makes an ellipse with a major axis of 28 feet on the ground. The angles to the top of the building from the top and bottom of the ellipse, were measured using a transit. Find the height of the building.

7. Find \((x, y)\).

8. A lighthouse is at the top of a vertical cliff. The top of the lighthouse is 60 m above the ground at the base of the cliff. Maria walks away from the base of the cliff along horizontal ground until she comes to a post. She measures the angle of elevation from the ground to the top of the lighthouse as 69°. She then walks in the same direction until the angle of elevation is 40° and stops. How far from the post did she walk?
Extra Activity

**WHAT IS A STUPID ANT?**

CALCULATE THE INDICATED DISTANCE IN EACH OF THE FOLLOWING SITUATION

<table>
<thead>
<tr>
<th>Distance</th>
<th>148 m</th>
<th>650 m</th>
<th>42.9 m</th>
<th>29.3 m</th>
<th>24 m</th>
<th>27 m</th>
<th>150 m</th>
<th>18.5 m</th>
<th>24 m</th>
<th>9.9 km</th>
</tr>
</thead>
</table>
Appendix 5C11: Lesson Plan 11

Lesson 11
Approximate time: 1 hour
Title: Area Formula

Aim:
1) To introduce and prove the two area formula.
   This activity sheet will lead students through a derivation of the Area
   formula, first for area given two sides and an included angle and the second
   for area given all three sides.
2) To apply area formula to work related problems.

Prerequisites:
(1) Students should be familiar with the normal area formula
(2) Students should be familiar completing the square

Key skills:
1) calculator skills
2) class interaction & co-operation.
3) Problem solving skill

Approach:
1) Launch: How would a surveyor calculate the area of any given triangular
   piece of land?
2) Explore: Give out the activity sheet. Give some examples before they start on
   the activity sheet.
3) Checkpoint: When is it appropriate to use each area formula?
4) Apply: Give out assignment sheet that was based on a worksheet from
   http://www.tki.org.nz/r/ncea/maths2_8Av3_30Jan03.doc
5) Homework: Give unfinished exercise or additional problems if needed as
   homework.
Area of a triangle

![Diagram of a triangle with labeled sides and angles]

The area of the triangle is \( \frac{ah}{2} \).

But in triangle BAH, we have \( \sin(B) = \frac{h}{c} \).

Hence the area of the triangle is \( \frac{abc}{2} \).

Similarly, we have that the area of the triangle

\[ \frac{bc\sin A}{2} = \frac{ac\sin B}{2} \]

| Area of triangle ABC | \[ \frac{abc}{2} = \frac{bc\sin A}{2} = \frac{ac\sin B}{2} \] |

Another proof uses the Pythagorean Theorem for the area where

\[ A = \sqrt{(s-a)(s-b)(s-c)} \quad \text{where} \quad s = \frac{a+b+c}{2} \]

Drop from A is a perpendicular to side a. Let its length be \( h \). Let the side \( a \) be divided by it into parts of lengths \( x \) and \( a - x \). Then using the Pythagorean Theorem on the two small triangles, and the usual formula for area of a triangle:

\[ b^2 = h^2 + x^2 \]
\[ c^2 = h^2 + (a - x)^2 \]

Area = \( \frac{ah}{2} \)

Then by subtracting the second equation from the first:

\[ b^2 - c^2 = 2ax - a^2 \]
\[ x = (a^2 + b^2 - c^2)/(2a) \]

Substituting this back into the first equation:

\[ h^2 = b^2 - \frac{(a^2 + b^2 - c^2)^2}{4a^2} \]

Now using the third equation:

\[ (Area)^2 = \frac{a^2h^2}{4} = \frac{a^2}{4} \left[ b^2 - \frac{(a^2 + b^2 - c^2)^2}{4a^2} \right] \]
\[ = \frac{a^2b^2}{4} \left( a^2 + b^2 + c^2 \right)^2 \]
\[ = \frac{16a^2b^2 - (a^4 + b^4 + c^4 + 2a^2b^2 - 2a^2c^2 - 2b^2c^2)}{16} \]
Appendix 5C11: Lesson Plan 11

MATHEMATICS DEPARTMENT

\[
\frac{-(c^4 + [-2b^2 - 2a^2]c^2 + [a^4 - 2a^2b^2 + b^4])}{16}
\]

We factor this by completing the square on \(c^2\), then using the difference of two squares three times, then \(a + b + c = 2s\):

\[
(Area)^2 = \frac{-(c^4 + [-2b^2 - 2a^2]c^2 + [a^2 + b^2]^2 - 4a^2b^2)}{16}
= \frac{-(c^2 - a^2 - b^2)^2 - [2ab]^2}{16}
= \frac{-(c^2 - a^2 - 2ab - b^2)[c^2 - a^2 + 2ab - b^2]}{16}
= \frac{-(c^2 - [a + b]^2)(c^2 - [a - b]^2)}{16}
= \frac{-(c - [a + b])(c + [a + b])(c - [a - b])(c + [a - b])}{16}
= \frac{(a + b + c)(a + b - c)(a - b + c)(-a + b + c)}{16}
= \frac{2s(2s - 2c)(2s - 2a)(2s - 2b)}{16}
= s(s-a)(s-b)(s-c)
\]

Area = \(\sqrt{s(s-a)(s-b)(s-c)}\)
Assignment

Teacher Guidelines:
The following guidelines are supplied to enable teachers to carry out valid and consistent assessment using this internal assessment resource.

Formulae for the sine and cosine rules, areas of triangles, sectors, and segments, and arc length must be supplied to the students. These may be on the front of the assessment or a level 2 formula sheet may be issued.

Context/setting:

SECTION A
Students will be required to choose and apply a model to find the area of an irregularly shaped quadrilateral. They will use an alidade, orienteering compass, plane table or similar, as an aid to completing a radial survey. They will take measurements to calculate lengths and angles in order to find the total area and perimeter of the shape. They will only be instructed to take measurements to find the area. If students can complete this task without being told which measurements that they need to take they are eligible for the award of Achievement with Merit or Excellence. If the help sheet (Student Resource Sheet 2) is given, then Achievement is the highest level that can be awarded. Students will need to work in pairs to take measurements. Ensure that students with the help sheets work together, and those following their own plans work together, to obtain their required measurements. Where the teacher marks the initial point, X, this must not be on a side or a diagonal of the quadrilateral.

SECTION B
Students will be required to use their measurements from Section A to perform calculations.

Conditions:
Time allocation - this activity will take one period for practical measurements and a further class period for Section B.

The first period could be allocated to take practical measurements. Students could complete their calculations during the second period, or overnight. [Students will take varied times to complete their measurements and calculations]. Section B is a written assessment and is likely to take one class period at most to complete.

For Section A each pair of students should have a different allocated position from which to carry out the radial survey.

Additional information:
Alternatives to the alidade would require the use of a magnetic compass or theodolite to enable measurement of the angles from the central point.

Marking
Set up a spreadsheet that will allow you to enter the 4 angles and the 4 lengths and output the area, the length of the diagonals, and the 4 interior angles. This will allow you to easily check students' answers.

**Resource requirements:**

Section A - Students will need a 30 metre tape, a simple alidade (essentially a sighting device made from a ruler with a nail or pin at each end) and a flat desk or stool for use as a plane table or a magnetic compass.

A suitable irregular-shaped open space with an unobstructed view of each corner from the centre. Most school fields or tarmac surfaces would fit this description. Non-rectangular is essential.

**Finding the Land Area**

**Student Instructions Sheet**

There are two parts to this assessment. The first requires fieldwork using a **radial survey** and the second part is the calculations.

---

### Some Useful Formulae

- **Sine Rule:** \( \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \)
- **Cosine Rule:** \( \cos C = \frac{a^2 + b^2 - c^2}{2ab} \)
- **Arc length:** \( s = r\theta \)
- **Cosine Rule:** \( c^2 = a^2 + b^2 - 2ab\cos C \)
- **Area of Triangle:** \( A = \frac{1}{2} ab \sin C \)
- **Area of sector:** \( A = \frac{1}{2} r^2\theta \)
- **Area of segment:** \( A = \frac{1}{2} r^2\theta - \frac{1}{2} r^2 \sin \theta \)
This may provide evidence for any level of achievement.

1. Find the area of a part of your school grounds that is allocated to you by your teacher.
   Take measurements to complete a radial survey.
   - Equipment available - tape measure, trundle wheel, magnetic compass, alidade.
   - The shape you need to measure is a quadrilateral.

2. Draw and label a sketch of the quadrilateral

3. Mark with an X, on your diagram, the point from which you will take your measurements. This must not be on a straight line that joins 2 of the corners (side or diagonal).

4. On your diagram indicate the measurements that you will need to take to calculate the area of the quadrilateral. When you go into the school grounds and take the measurements you must record these on your diagram.

THIS MUST BE CHECKED BY YOUR TEACHER BEFORE YOU GO OUT TO TAKE THE MEASUREMENTS.

If the measurements you indicate will not allow you to complete the task you will be given a Student Resource Sheet 2 telling you which measurements you need to take. In this case the highest grade you will be able to be awarded will be Achievement.
Section A - Student Resource Sheet 2

Instructions to be given to students for ACHIEVEMENT ONLY

You have been asked to find the area of a piece of the school grounds, labelled ABCD.
(refer to the example sketch shown).

You need to:
1. Go to the area you are going to measure.
   - Get the table and place it in a level position above the point X allocated by your teacher.
   - Mark a central point on a fresh piece of paper and label it X.
   - Use your alidade or compass to help you draw lines (spokes) from X towards each corner of the area you are surveying.
   - Name each corner with a different letter. A, B, C, D
2. Use the long tape (or accurate, consistent pacing) to measure the actual distance from your central point on the ground to each corner.
   \[ XA, XB, XC, XD \]
3. Record these measurements on your diagram.
4. You will need to measure and record the sizes of the angles \( \angle AXB, \angle BXC, \angle CXD, \angle DXA \).
5. Subdivide the area on the diagram into triangles.
SECTION B
YOU WILL NEED TO USE YOUR SKETCH AND MEASUREMENTS FROM SECTION A TO COMPLETE THIS SECTION OF YOUR TASK. YOU DO NOT NEED ANY OTHER MEASUREMENTS TO COMPLETE THE TASK.

1. The school caretaker wants to sow grass seed in the area of the school grounds that you were allocated to measure. Calculate the total area of the quadrilateral. (This may involve calculating the area of separate triangles first)

2. A pipe is to be laid diagonally across the quadrilateral. The caretaker needs to know the length of this pipe. Calculate the shortest distance between the pairs of opposite corners (the 2 diagonals) of your quadrilateral.

3. A garden is to be put in one corner of the area you have been given to measure. To plan the garden you are asked to find the size of any one of the interior angles of the quadrilateral.

5. Write a report on the accuracy of your measurements. You should name at least three possible sources of error in your measurement.
Table: *The syllabus of the package developed in the area of Trigonometry were as follows: Source - (Programme-Guide, 1999)*

<table>
<thead>
<tr>
<th>Sub Topic</th>
<th>Performance Objectives</th>
<th>Enabling Objectives</th>
<th>Performance Standard</th>
<th>Recommended Number of hours</th>
</tr>
</thead>
</table>
| 1) Radian measure         | To apply arc length and sector area formulae to solve work related problem               | - Convert angular measurements
  - define radian
  - convert measurements in degrees (from $0^\circ$ to $360^\circ$) to radians and vice versa
  - convert multiples of $\pi$ radians and vice versa
  Deducing and use
  - the arc length formula $S = r\theta$
  - the area of sector formula $A = \frac{1}{2}r^2\theta$
  Apply arc length and sector area formulae to solve a range of work related problems. | Given work related problems, apply arc length and sector area formulae to solve them to the standards of the occupation/industry. | 4 |
| 2) Graphs of Trigonometric Ratio | To apply the graphs of trigonometric ratios to solve work related problem               | - Calculate the trigonometric ratios (including the reciprocal ratios) of angles between $0^\circ$ and $360^\circ$
  - Plot - the sine, cosine and tangent curve over one complete cycle
  - the resultant curve over two complete cycles when two sine and/or cosine functions are added together
  Identify the periodic properties of the sine, cosine and tangent curves
  Apply the graph of trigonometric ratios to solve a range of work related problems | Given work related problems, apply graphs of trigonometric ratios to solve them to the standards of the occupation/industry. | 6 |
3) Identity, Sine and Cosine Rules and the area formula

<table>
<thead>
<tr>
<th>To apply trigonometric identities to solve work related problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduce and apply</td>
</tr>
<tr>
<td>- the identity ( \sin^2 \theta + \cos^2 \theta = 1 ) using the right angle triangle</td>
</tr>
<tr>
<td>- the sine rule for ( \Delta ABC ): ( \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} ), including the ambiguous case</td>
</tr>
<tr>
<td>( \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = D ) where ( D ) is the diameter of the circumscribing circle of the ( \Delta ABC ).</td>
</tr>
<tr>
<td>- The cosine rule ( a^2 = b^2 + c^2 - 2bc \cos A ) for ( \Delta ABC )</td>
</tr>
<tr>
<td>- Apply trig identities to solve a range of work related problems</td>
</tr>
<tr>
<td>Calculate the area of triangles using the formula</td>
</tr>
<tr>
<td>- Area = ( \frac{1}{2} ab \sin C )</td>
</tr>
<tr>
<td>- Area = ( \sqrt{s(s-a)(s-b)(s-c)} ) where</td>
</tr>
<tr>
<td>( s = \frac{1}{2}(a+b+c) )</td>
</tr>
</tbody>
</table>

Given work related problems, apply trigonometric identities to solve them to the standards of the occupation/industry. 6

Given work related problems, apply appropriate area formulae to solve them to standards of the occupation/industry 2

The topics on area formula and three Dimensional Trigonometry were also developed but were not implemented due to time constraint

Table 5.3: The syllabus of the package developed in the area of Trigonometry were as follows: Source - (Programme-Guide, 1999)
Lesson 1 (03/01/02)

APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

- Seating arrangement, easy access to teacher and discussion and for group work.
  - Not easy for discussion, long tables are better if fixed
  - Mental Maths
    - Revision of topics covered in previous units
    - Revision of main points or unit already covered
    - Revision of content covered in previous lesson

- Homework reviewed
  - Pupils showing own solution on board
  - Teacher using mistakes as teaching points
  - Teacher showing solution on board if necessary

- Spoken maths clear, precise and correct.

- Maths on blackboard or OHP correct, clear, precise and well laid out.

- New concepts introduced
  - Interactive discussion
  - Example worked on board with the whole class
  - Immediate revision of forgotten/misunderstood topics
  - Relevant/real life examples and problems given to students

- Individual work (exercise/activities)
  - Teacher continually taking note of what everyone is doing
  - Class kept together working through exercises
  - Solutions reviewed with whole class
  - Mistakes immediately pointed out to the whole class
  - Pupils offer their solutions to class for discussion

- Whole class on task throughout lesson

- Whole class progression

- Enthusiasm  (not 50)

- Good pace  (not 50)

- Calculators used
  - correctly
  - effectively

- Homework clearly set
  - extending concepts learn in lesson
  - link with next lesson

- Summary of main points at end of lesson

Some one questioned why we are doing the activity sheet. We help them complete them. Interested in always about being independent. One student commented that she doesn’t like measuring. Makes her feel like a small kid. But the question on π = 360° of a circle starts the students to think and talk about it. They say that they would try to find the answer through the internet.
APPENDIX 6A
LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
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☐ Revision of main points of unit already covered
☐ Revision of content covered in previous lesson

☐ Homework reviewed
☐ Pupils showing own solution on board
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☐ New concepts introduced
☐ Interactive discussion
☐ Example worked on board with the whole class
☐ Immediate revision of forgotten/misunderstood topics
☐ Relevant real life examples and problems given to students

☐ Individual work (exercise/activities)
☐ Teacher continually taking note of what everyone is doing
☐ Class kept together working through exercises
☐ Solutions reviewed with whole class
☐ Mistakes immediately pointed out to the whole class
☐ Pupils offer their solutions to class for discussion

☐ Whole class on task throughout lesson — two boys doesn’t seem to be on task

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
☐ correctly
☐ effectively

☐ Homework clearly set
☐ extending concepts learn in lesson
☐ link with next lesson

☐ Summary of main points at end of lesson

The discussion about which flower is of more value was heated full of enthusiasm. Problems to be discussed the next lesson.

Given out all questions — 1 group left. No student came up with an answer for the question. I had to do some explanation. Students listened attentively. After class, girl to talk to two girls. They say that now, maths lesson are not dry and boring.
Appendix 6A: Samples of Observation Field Notes

LESSON 4 (10/10/02)
(14/10/02)

APPENDIX 2

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
  ☐ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☐ Teacher showing solution on board if necessary

☐ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☐ Interactive discussion
  ☐ Example worked on board with the whole class
  ☐ Immediate revision of forgotten/missunderstood topics
  ☐ Relevant/real life examples and problems given to students

☐ Individual work (exercise/activities)
  ☐ Teacher continually taking note of what everyone is doing
  ☐ Class kept together working through exercises
  ☐ Solutions reviewed with whole class
  ☐ Mistakes immediately pointed out to the whole class
  ☐ Pupils offer their solutions to class for discussion

☐ Whole class on task throughout lesson

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☐ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learned in lesson
  ☐ link with next lesson

☐ Summary of main points at end of lesson

The pupils did the mind puzzle although I think it's a bit too young for them. A lot of homework were given including the proof of Pythagoras. It reminded the students to go to the websites for interactive proof of Pythagoras.
APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☑ Revision of topics covered in previous units
  ☑ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☐ Teacher showing solution on board if necessary

☐ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☐ Interactive discussion
  ☐ Example worked on board with the whole class
  ☐ Immediate revision of forgotten/misunderstood topics
  ☐ Relevant/real life examples and problems given to students

☐ Individual work (exercise/activities)
  ☐ Teacher continually taking note of what everyone is doing
  ☐ Class kept together working through exercises
  ☐ Solutions reviewed with whole class
  ☐ Mistakes immediately pointed out to the whole class
  ☐ Pupils offer their solutions to class for discussion

☐ Whole class on task throughout lesson

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☐ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learnt in lesson
  ☐ link with next lesson

☐ Summary of main points at end of lesson

---

Did many problems on the ratios today. Not much discussion, students just worked quietly. They complain of too much to do. I told them just try to do as much as they can. Give out project today.
APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
  ☐ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☐ Teacher showing solution on board if necessary

☐ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☐ Interactive discussion
  ☐ Example worked on board with the whole class
  ☐ Immediate revision of forgotten/misunderstood topics
  ☐ Relevant/real life examples and problems given to students

☐ Individual work (exercise/activities)
  ☐ Teacher continually taking note of what everyone is doing
  ☐ Class kept together working through exercises
  ☐ Solutions reviewed with whole class
  ☐ Mistakes immediately pointed out to the whole class
  ☐ Pupils offer their solutions to class for discussion

☐ Whole class on task throughout lesson

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☐ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learnt in lesson
  ☐ link with next lesson

☐ Summary of main points at end of lesson

In a rush. Formulas for area is given. A few examples students try to complete. "Finding the area of a pool laid" problem quickly as have little time with them. Have to give them some figures since we don't have time to measure (do field work). Post-Test given.
APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

- Seating arrangement, easy access to teacher and discussion and for group work.
- Mental Maths
  - Revision of topics covered in previous units
  - Revision of main points of unit already covered
  - Revision of content covered in previous lesson
- Homework reviewed
  - Pupils showing own solution on board
  - Teacher using mistakes as teaching points
  - Teacher showing solution on board if necessary
- Spoken maths clear, precise and correct.
- Maths on blackboard or OHP correct, clear, precise and well laid out.
- New concepts introduced
  - Interactive discussion
  - Example worked on board with the whole class
  - Immediate revision of forgotten/misunderstood topics
  - Relevant/real life examples and problems given to students
- Individual work (exercise/activities)
  - Teacher continually taking note of what everyone is doing
  - Class kept together working through exercises
  - Solutions reviewed with whole class
  - Mistakes immediately pointed out to the whole class
  - Pupils offer their solutions to class for discussion
- Whole class on task throughout lesson
- Whole class progression
- Enthusiasm
- Good pace
- Calculators used
  - correctly
  - effectively
- Homework clearly set
  - extending concepts learn in lesson
  - link with next lesson
- Summary of main points at end of lesson

Students choose to complete the - 382 -

Making them question accepted phenomena and say lesson not boring
Appendix 6A: Samples of Observation Field Notes

Lesson 3 (15/01/02)

APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
  ☐ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☐ Teacher showing solution on board if necessary

☐ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☐ Interactive discussion
  ☐ Example worked on board with the whole class
  ☐ Immediate revision of forgotten/misunderstood topics
  ☐ Relevant/real life examples and problems given to students

☐ Individual work (exercise/activities)
  ☐ Teacher continually taking note of what everyone is doing
  ☐ Class kept together working through exercises
  ☐ Solutions reviewed with whole class
  ☐ Mistakes immediately pointed out to the whole class
  ☐ Pupils offer their solutions to class for discussion

☑ Whole class on task throughout lesson %

☑ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☐ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learn in lesson
  ☐ link with next lesson

☐ Summary of main points at end of lesson

Discussion was interesting. Especially about the measuring of the radius of the Earth. Assuming she are familiar with trigonometry and measuring three, the problems on area of segments, teachers are not done that well and similar example was shown.
APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☑ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
  ☐ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☐ Teacher showing solution on board if necessary

☑ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☑ Interactive discussion
  ☑ Example worked on board with the whole class
  ☑ Immediate revision of forgotten/misunderstood topics
  ☑ Relevant/reallife examples and problems given to students

☑ Individual work (exercise/activities)
  ☑ Teacher continually taking note of what everyone is doing
  ☑ Class kept together working through exercises
  ☑ Solutions reviewed with whole class
  ☑ Mistakes immediately pointed out to the whole class
  ☑ Pupils offer their solutions to class for discussion

☑ Whole class on task throughout lesson

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☑ correctly
  ☐ effectively

☑ Homework clearly set
  ☑ extending concepts learnt in lesson
  ☑ link with next lesson

☐ Summary of main points at end of lesson

---

Students seem to enjoy the puzzle phenomenon of Greek geometry. The visual interest students. They were冠军
to do it at home using their own computer by giving them the URL. The real-life problem to measure the wall and is good to make students motivated to learn about trig.
Appendix 6A: Samples of Observation Field Notes

LESSON 9 (31/01/02)

APPENDIX 6A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
  ☑ Revision of main points of unit already covered
  ☐ Revision of content covered in previous lesson

☐ Homework reviewed
  ☐ Pupils showing own solution on board
  ☐ Teacher using mistakes as teaching points
  ☑ Teacher showing solution on board if necessary

☐ Spoken maths clear, precise and correct.

☐ Maths on blackboard or OHP correct, clear, precise and well laid out.

☐ New concepts introduced
  ☑ Interactive discussion
  ☐ Example worked on board with the whole class
  ☐ Immediate revision of forgotten/misunderstood topics
  ☑ Relevant/real life examples and problems given to students

☐ Individual work (exercise/activities)
  ☑ Teacher continually taking note of what everyone is doing
  ☐ Class kept together working through exercises
  ☐ Solutions reviewed with whole class
  ☐ Mistakes immediately pointed out to the whole class
  ☐ Pupils offer their solutions to class for discussion

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☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☑ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learn in lesson
  ☐ link with next lesson

☐ Summary of main points at end of lesson

Students enjoy doing the exam activity. Some could
wait to solve the puzzle although I gave them an hour
students need to be reminded of the existence of solutions
and seems to be cheating again like the honest, in
ahead of others
APPENDIX A

LESSON CHECKLIST

This checklist is to remind teachers of the style of teaching recommended. Not all aspects are expected to be covered in one lesson. But this should serve as a reminder before the start of each lesson.

☐ Seating arrangement, easy access to teacher and discussion and for group work.

☐ Mental Maths
  ☐ Revision of topics covered in previous units
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☐ Whole class on task throughout lesson

☐ Whole class progression

☐ Enthusiasm

☐ Good pace

☐ Calculators used
  ☐ correctly
  ☐ effectively

☐ Homework clearly set
  ☐ extending concepts learn in lesson
  ☐ link with next lesson

☑ Summary of main points at end of lesson

The main points at end of lesson:

- Working on real-life problem assignment.
- Time to reflect on brainstorming method and enough time given.
- Formulas of area given and examples shown on board.
- Activity cannot be completed since I have to employ an area formula to surveyors and go through the
  exercise.

Since not enough time, no measuring was done.

Have 3 different areas and its measurements in four different groups, and ask them to find the area.
Appendix 6B: The concept map produced by a group of students in RTE class
Appendix 6B: Samples of Students’ Work (Concept Map)

Appendix 6B2: A concept map produced by a group of students in ELE.
Appendix 6B3: A concept map produced by a group of students in RTE
Appendix 6B4: A concept map produced by a group of students in ELE
WHAT IS SINE WAVE?

The application of trigonometry where the sine and cosine ratios were regarded as functions of time. We introduced the identities in practical problems. Sine waves functions have such widespread importance in all branches of science and engineering that it essential to gain an understanding of their basic properties and characteristics. For example, almost all countries in the world generate and distribute electricity in alternating current (AC) form, radio wave, light wave, vibrational wave, the change of temperature and etc.
## THE TEMPERATURE DATA

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<td>26.2</td>
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<tr>
<td>48</td>
<td>27</td>
<td>25.7</td>
<td>1.3</td>
</tr>
</tbody>
</table>
THE ACTUAL TEMPERATURE DATA GRAPH

Fig. 1
THE EQUATION

Average period = $\frac{1}{2} [(33 \cdot 10) + (38 \cdot 14)]$
= 23.5 hour/cycle

Average Frequency = $\frac{1}{23.5}$
= 0.042553191 cycle/hour

Average Angular Velocity = $(2\pi)(0.042553191)$
= 0.267 rad/hour

So the Equation is,

\[ Y = 29 + 5 \sin [0.267 (t - 10)] \]

Where,

Y is the ambient temperature in °C
T is the time hours from the start of recording
0.267 (t - 10) is in radians.
TO PROVE THE EQUATION BY SUBSTITUTE TIME [t]....

For example,

1. \[ Y = 29 + 5 \sin (0.267 (t - 10)) \]
   \[ Y = 29 + 5 \sin (0.267 (2 - 10)) \]
   \[ = 24.8 \degree C \]

2. \[ Y = 29 + 5 \sin (0.267 (t - 10)) \]
   \[ Y = 29 + 5 \sin (0.267 (24 - 10)) \]
   \[ = 26.2 \degree C \]

3. \[ Y = 29 + 5 \sin (0.267 (t - 10)) \]
   \[ Y = 29 + 5 \sin (0.267 (26 - 10)) \]
   \[ = 24.5 \degree C \]

4. \[ Y = 29 + 5 \sin (0.267 (t - 10)) \]
   \[ Y = 29 + 5 \sin (0.267 (48 - 10)) \]
   \[ = 25.7 \degree C \]
EXPLANATION

8 Temperature is the degree of the hotness or coldness of the atmosphere and is measured in degrees Celsius (°C) or degrees Fahrenheit (°F).

8 From our graphs that we plotted, it forms Sine Wave.

8 The peak amplitude (A) is reach up to 34 °C. It is happen because the hotness of the solar radiation in the earth surface.

8 The lowest amplitude that shown on the graph is around 23 °C. It also happen because the hotness will fall down. Then the coldness occur.

8 It also have one complete cycle, at 4 am until 2 pm in the next days.

8 The peak amplitude (A) of a sine wave is the maximum swing in the value of Y from zero in either the positive or the negative direction.

8 The frequency of a periodic wave, such as a sine wave is equal to the number of cycles which occur in one second. Then the time for one cycle is T, known as the periodic time.
CONCLUSION

From our two days practical, we have found the decrease and increase of the temperature are forms. As are result, in a Day the heat of the sun will produces, while in the night the coldness of atmosphere occurs. Its were shown in Figure 1.
REFERENCES

1 ] Understanding Geography
   - Tham Yoke Chun
   - Page 18 to 20

2 ] Electrical and Engineering Mathematics
   - Volume 1
   - Richard Meadows
   - Page 283 to 285

3 ] Electrical and Engineering Mathematics
   - Volume 3
   - Richard Meadows
   - Page 131 to 134
Appendix 6C1: Sample of project Presentation by Group 1

ACTIVITY

1. What is your periodic waveform?
   Ans: About the temperature data of Brunei Darussalam

2. How do you collect data?
   Ans: By using Thermometer

3. What software will you use?
   Ans: PowerPoint and Microsoft Word

4. When and where do you meet together?
   Ans: Every Friday night at HERITAGE CAFE

5. Do you have any reference book?
   Ans: Yes, that shown at the back of the booklet
Trigonometric Waveforms Around Us

ACKNOWLEDGEMENTS

We would like to take this opportunity to thank our Math instructor, Mr. Masaaki Takahasi from the Math department, for his advice in this project. Had it not been for his patience and constructive comments, this project would not have been what it is.

Our sincere thanks also goes to Mrs. Hjh Madiahah Khalid, for providing us with valuable information that is needed for this study.

Indeed we like to express our appreciation to Mr. Sinfronio T.Ferrolino, our electronic instructor for the useful comments on the topic.

Last but not least special thanks and gratitude to our colleagues for the help and support rendered to us during this study.
Trigonometric Waveforms Around Us

ABSTRACT

The study reports on ‘Sinusoidal AC Voltage Waveforms’. This topic is chosen because of its relevancy to our course of study and also the importance it has in our daily lives.

In this report, we included brief information on AC voltage supplies and its waveforms together with several technical terms for the convenience of our readers.

This report provided an equation that proves the AC’s sine properties. A graph showing the AC voltage on an oscilloscope is also shown in this report.

The study concludes with the proof that the sinusoidal graph shown on the oscilloscope actually fits the equation given.
Appendix 6C2: Sample Project Presentation by Group 2

Trigonometric Waveforms Around Us

<table>
<thead>
<tr>
<th>TABLE OF CONTENT</th>
<th>Pages</th>
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<tbody>
<tr>
<td><strong>Chapter 1</strong></td>
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<tr>
<td>- Project Aims</td>
<td>4</td>
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<td><strong>Chapter 2</strong></td>
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<tr>
<td>- Brief Background</td>
<td>5-6</td>
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<td>- Technical Terms</td>
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<td><strong>Chapter 3</strong></td>
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<td>- Project Content</td>
<td>7-8</td>
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<td>- Plotted Graph on Oscilloscope</td>
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<td>- Proving the Equation</td>
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<tr>
<td><strong>Chapter 4</strong></td>
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<tr>
<td><strong>Appendix</strong></td>
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</table>
Trigonometric Waveforms Around Us

**Chapter 1 - Project Aims**

One of the main aims of this project is to discover the relationship of trigonometric function and AC voltage. This study undertakes to plot a graph, which shows that there is a significant relationship between the trigonometric function as against the AC voltage.

Secondly, this project also tries to enhance the knowledge and understanding of AC voltage waveforms, which relates to our daily lives.

Apart from having to produce a piece of assignment accurately, this project also gives students a chance to work together as a team. By so doing, the students would be able to learn on time management and cooperation.
Appendix 6C2: Sample Project Presentation by Group 2

Trigonometric Waveforms Around Us

Chapter 2 – Brief Background

Alternating current (AC) is current which flows back and forth along a conductor. (In contrast, direct current (DC) is current which flows in one direction only). Alternating current is the result of an alternating voltage (force) pushing electric charges back and forth.

The diagram shows an AC generator capable of producing an alternating voltage. It is basically a loop of wire rotating between the poles of a magnet.

The diagram also shows a graph of the voltage \( v \) produced by the generator as a function of time \( t \) as the loop \( L \) rotates through one complete circle. This curve is called a sinusoidal waveform. It has the formula:

\[
V = E_p \sin \omega t
\]

Where

- \( V \) is the voltage,
- \( t \) is the time,
- \( \sin \) is the function that gives the curve its wave shape,

\( E_p \) and \( \omega \) are parameters that describe the details of the curve:

- \( E_p \) is called the **amplitude** and is the maximum height that the curve reaches,
Trigonometric Waveforms Around Us

- $\omega$ is called the **angular velocity** and describes how rapidly the curve oscillates (it is actually the rate of rotation of the generator measured in radians per second).

When $v$ is positive (at the top or crest of the wave) this means that the upper terminal has a greater voltage than the lower terminal. And when $v$ is negative then the lower terminal has a greater voltage than the upper terminal. An oscilloscope is capable of displaying such waveforms.

**Technical Term**

- Period (t) – time in 1 whole oscillation/cycle
- Frequency (f) – no. of cycle per second (Hz)
- Amplitude/peak value (Ep) – max value on y-axis
- Oscilloscope – An instrument that displays a changing voltage over time
- Signal generator – Device that generates AC signals
Chapter 3 – Project Content

For Practical, since we did not have access to an ‘electronic Laboratory’, we resulted in using a software program namely called Circuit Maker and Electronics Workbench. It is here that we conducted our practical.

In this stage, we had with us several components namely an oscilloscope, a signal generator set to 10 volts, 1 Hz and a ground connection. Here, we took the resultant graph and studied it taking its given values provided by the oscilloscope.

Circuit Diagram (derived from electronic workbench software)
Appendix 6C2: Sample Project Presentation by Group 2

Trigonometric Waveforms Around Us

Data table

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<td>2.205</td>
<td>9.602936856769</td>
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</table>

Plotted Graph on oscilloscope

[Graph showing oscillations on an oscilloscope]
From the Graph,

Given that supply voltage = 10V
Frequency \((f)\) = 1 Hz

Equation can be derived like so,

\[ V = E_p \sin \omega t \]

\[ \omega = 2\pi f \]

\[ = 2\pi \times 1 \]

\[ = 6.2832 \text{ radian/second} \]

Let \( t = 2.08 \text{ s} \)

\[ V = 10 \sin (6.2832 \times 2.08) \]

\[ V = 4.8175 \text{ V} \]
Chapter 4 – Conclusion

It is found that, the answer obtained in the equation have met the voltage of the given time of the graph shown.

In conclusion, we concluded that the graph is in fact a sinusoidal graph and fits the equation given. By using the equation, we are able to find the voltage points of the alternating voltage at given values of time.
Appendix 6C2: Sample Project Presentation by Group 2

Trigonometric Waveforms Around Us

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http://www.ibiblio.org/obp/electricCircuits/AC/AC_1.html

http://6tecnct.dcccd.edu/stan/iac/acinu3.htm

Fundamentals of Electrical Engineering & electronics, B.L. Theraja

Electrical Principals for Technicians, vol.1, waterworth, G

Electronic Workbench and Circuit Simulation software

Microsoft PowerPoint

Microsoft Word
Appendix 6C2: Sample Project Presentation by Group 2

Trigonometric Waveforms Around Us

Appendix

This is the report of the investigation entitled "Trigonometric Waveform around Us". The members are Mohd. Azizan Haji Zainal Abidin (group leader), Ak. Mohd. Khadiman Pg. Hj. Othman, Noorhaisam Abd. Hamid, and Khanafie Apong. For this investigation we had tried several topics but had met only failure each time. At first we tried the Human Heartbeat as our topic. We drew a graph of the number of heartbeats against time per minute. We had a linear curve as a result. After that, each of us proposed a topic. Azizan proposed the topic "Length of a Shadow". To our surprise, the result was a tangent curve. Khadiman proposed "Train Schedules". Sadly there were no train schedules that met our criteria. Noorhaisam and Khanafie each suggested "Engine Piston Crankshaft Movement" and "Waveform in Electronic (guitar) Sound Effects". In theory, both were likely to be sinusoidal waves, but there was a lack of technical knowledge and skill, which were required so we were forced to look for another topic. Finally, we had chosen "Sinusoidal Wave in AC voltage" as our topic. Our reason for this was that the topic was relevant to our course study, and it was commonly known and yet the most frequently misunderstood.

We started to do our project on the January 19th 2002. Meetings and discussions followed on the 21, 22 25 and 28th January, 2, 4, 9, 10, 12th of February. Tasks were distributed as follows; Azizan was responsible for calculations, graph drafting on Excel and typing tasks. Khadiman was responsible for the presentation of the project on Microsoft power point and 'practical' on circuit simulation and electronic workbench. Noorhaisam was responsible for the research and appropriate material selection and Khanafie was responsible for producing the report draft and checking the language and grammar.

A major hindrance on doing this project, were the shortage and more seriously, the unavailability of an Electronic Laboratory. The main cause for the unavailability was the impending final year examination for the final year.
Appendix 6C2: Sample Project Presentation by Group 2

Trigonometric Waveforms Around Us

students. The instructors were practically preoccupied at all times. We decided to
give the priority to our seniors. We opted to use our knowledge of "Electrical
Workbench" and "Circuit Simulation" software as an alternative to a real life
practical.

We conducted several meetings in the school library and Khadiman's home.
There and then we made thorough research on the topic through reference
books and the Internet. Noorhaisam was mainly in charge of doing this whilst the
rest us helped out. Then comes khadiman where he took charge of the 'practical'
in the program electrical workbench and circuit simulation (everybody else
observed). This was done on a separate computer to ease things up a bit. He
also took the responsibility of making the presentation. I had the task of guiding
and ensuring smooth progress of the project. I was too, responsible for drawing
the graph (as I had more experience on this field) and some typing tasks. Before
any printed result we handed the job to Khanafie where he would check for
grammar and spelling mistakes. He also wrote most of the report and as
assurance, hands the result to other members for double-checking and
verification.
Appendix 6D: Rubrics for Grading Project

**Rubrics for Grading the Project**

The project was graded according to the criteria given in the activity sheet. The final product was to contain: an introduction and details of data, graph, equation derivation, verification, error analysis, technical correctness, creativity and effort along with a summary sheet.

**Outstanding/Insightful Completion – awarded 85% - 100%**
- Complete response with clear, coherent, unambiguous, and elegant explanation
- Includes clear and simple diagram
- Shows understanding of the question's mathematical ideas and processes
- Identifies all the important elements of the question
- Includes examples and counter examples
- Gives strong supporting arguments
- Goes beyond requirements of the problem

**Good Completion – awarded 70% - 84%**
- Good solid response with some of the characteristics above, but probably not all
- May be less elegant, less complete
- Does not go beyond requirements of the problem

**Fair Completion – awarded 55% – 69%**
- Reasonably complete response, but the explanation may be muddled or incomplete
- Diagrams may be inappropriate or unclear
- Seems to understand mathematical ideas, but may not be able to express clearly

**Unsatisfactory Completion – awarded 40% - 54%**
- Omits significant parts or all of the question and response
- Makes major errors
- Uses inappropriate strategies
Appendix 6E: Reflection on Students Reaction to Project

**Reflection on Students Reaction to Project.**

The project on “Trigonometric Waveforms Around Us” was given on the 21st of January 2002. They had just completed the topic on trigonometric graphs where they were taught how to draw graphs given various equations of different amplitudes, frequencies and phase shifts.

1st meeting: Students were not bothered with the project. They just put it away in their files. Anyway, the project was given at the end of a class. They were in a hurry to go for lunch.

2nd meeting: Asked them about their progress on project. They have many things to do, they said. Although they were encouraged to submit a proposal of what they propose to do, nobody seemed to care.

3rd meeting: Group 1 girls asked whether they could do the project on temperature change in one particular location over 48 hours at 2 hours interval. I said sure you can. They even had the readings (data) ready. I looked through them and encourage them to continue.

4th meeting: I still had not received any proposals. Reminded the students again. They said that they had to prepare for a test. The girls had plotted their data and were struggling to get the equation of the graph obtained. Helped them a bit by reminding them of what had been taught in class.

5th meeting: I was getting worried. Students were initially given three weeks to complete the project but many of them have not even started. They asked for extension. I had to discuss it with their class teacher. After meeting with them, I asked the teacher if he is willing to extend the dateline. He says fine. As long as the students learn.

6th meeting: Had to say goodbye to the students. Going back to Australia because of other commitments. The class teacher would take over the handling of the project from me and keep me posted with the progress.

Through emails, class teacher informed that the students are having problems with the project. At first they are not sure of how to commence, what title to choose and in organizing for meeting among them. I asked the teacher to remind the students to keep a journal of what they experience during the project so that I know what was going on. Each group produced a one page summary of what they went through at the end of the project report but not really the journal writing I was expecting. Class teacher again posted me with the progress. Now that they had their data, they were not sure of how to present them as they are not familiar with power-point or front-page. Again, they had to be taught how to use it.
Appendix 6E: Reflection on Students Reaction to Project

1st July 2002. I had to go back to Malaysia because my father passed away. After a week in Malaysia and since it was also school holidays at that time, I stopped over in Brunei. I took this opportunity to visit the college and students. By this time they had submitted their project to the class teacher and the teacher handed me my copy at that time. I took this opportunity to interview them on what they went through during the project. Whether they think the project is of any benefit to them and so on. This was just an informal interview with three of the students in a group.

Student 1: The project was a lot of hard work. But we got to understand trigonometric graphs very well. We were stressed out during the project. Now that we had finished it, we wonder what the stressed was all about. I think because of the project, I now know more about trig graphs, about how to find resources, through the internet and books, and we got to meet almost everyday. We would meet at a café to discuss about the project every Friday night besides ongoing discussions when we meet in class.

Student 2: Not only do we become better at searching information on the internet, we learn how to use power-point and draw graphs using Excel too. We get help from many teachers and our interaction with them also became better. We had projects before and writing the report was always difficult. But if we keep doing this and given more guidance on how to write a report, we can get better. I am beginning to see the benefit of projects now.

Student 3: Now I see the application of trigonometric graph in everyday life. It made me interested in learning mathematics. At least we don't just solve problems that have no meaning at all in mathematics. I think working together in groups like with this project, we became closer and learn how to manage time. It will benefit us when we work. Of course it was hard work trying to complete the project, but now that it is over, the benefits out-weights the hardship. I don't mind doing this kind of project again.
Appendix 7A: Interview with Teachers Transcript (Post Implementation)

**Post Interview**

1. What do you think of the package?
2. Do you notice any difference in student attitude and achievement after using the package?
3. How would you rate the package?

**Teacher 1:**

Q1: Impressive. But you have the time to look up for this kind of material since you are doing research full time. I don’t think we have that kind of time.

Q2: Not noticeable. I have just entered one or two classes after you handed back the class to me. I guess you really have to ask their opinion on this matter. Students just don’t volunteer information. But one girl did say that the problems in your worksheet are interesting problems and she enjoys them.

Q3: Can’t really say. But it’s good. Certainly more than 7/10. Depends on what you are looking at. I think the activities are interesting, problems are varied and you have done your best to include real-life problems. But some of them are quite hard to solve.

On the whole I think if you can really get the students to follow the package, the result will be good. Anything to increase students motivation is fine with me. Oh, I think your investigation sheet on the roof is interesting. It will be suitable for my construction students.

**Teacher 2:**

Q1: The package is very good. I thought that you have research a lot and did a lot of reading to get the material. If properly implemented, it could improve students understanding and attitude. I wonder where you get your materials for your package from because I also have done a lot of thinking into putting together a suitable package with activities to make students enjoy maths and understand it better. I congratulate you for that.

Q2: I had not had the opportunity to really test the students yet but I think they don’t exhibit much difference in attitude as far as I can see. I don’t know about understanding yet. These kind of things (understanding of mathematics) will appear later. My students had always been supportive of me and they are a joy to teach. So, I can’t give you a definite answer there.

Q3: By the look of it? 8/10? I am sure you can keep improving on it as you keep teaching the topic year on year. When I give an 8/10, that is a very good rating. I don’t give anything higher than that until I am very sure that they are really effective.

But do you really have the time to implement that? Here, we are still very traditional. Chalk and board is still the fastest way to convey knowledge or teach the students.
Appendix 7B: Interview with Students Transcript (Post Implementation)

Post Interview

For students (02/02/02 & 04/02/02)

1. Do you like mathematics? Why?
2. Do you think mathematics is important? Why?
3. What do you think of the classroom environment for mathematics lessons now? Do you think is the current mathematics classroom is conducive to learning? How do you feel about the class so far?
4. Do you like the way mathematics is taught now?
5. Can you see the relevance to your chosen profession?
6. Has there been any improvement in the way mathematics is taught and in the environment?
7. Has the attempted improvement been successful?
8. What else can be done to improve mathematics understanding?

Student 1: (ELE – above average)

Q1: I have always like maths. Since I was small. In fact everybody except one in my family like maths.

Q2: I think maths is important and because it is related to every day life.

Q3: I think the environment now is conducive for studying. I like the group work and thinks that it is important because we can discuss among friends.

Q4: I like the way mathematics is taught now. I can see the links and relate it to everyday life.

Q5: I can see a lot of use in my chosen profession like the project that we did.

Q6: There have been a lot of improvement since then. I especially like the jigsaw.

Q7: Some success. I think that the project made me more knowledgeable and more skilled in using the internet, Power-Point; in working as a group; in time management; in drawing graphs using Microsoft Excel; in writing reports, and even with their interaction with instructors

Q8: Make mathematics more fun. More field work and activities.

Student 2: (ELE - average)

Q1: I don’t like maths since primary. I think it is a lot of memorisation. I now understand that mathematics doesn’t mean memorisation.

Q2: I am very certain that it is very important because we need math to pursue almost every course.

Q3: I think physically, the environment is not very comfortable. I think group work and discussion helps a lot and I like the way that students are able to communicate now.
Appendix 7B: Interview with Students Transcript (Post Implementation)

Q4: I like the way maths is taught now.

Q5: I can see the relevance to my course. Some of them like the wiring problem, the trigonometric graphs and the use of law of sine and cosine to solve triangles.

Q6: Yes, a lot

Q7: Thinks so

Q8: More applications should be emphasized

**Student 3**: (ELE - weak)

Q1: I don't really mind maths since primary school. Now that I have left studying for sometime (being an in-service student), I really have to work hard to catch up and improve. But I am beginning to feel at ease with it.

Q2: Yes, maths is important and we need to do well especially to pursue for further studies.

Q3: I think the way math is learned is different now compared to before. I like the peer learning (cooperative learning) that was emphasized and thinks that the classroom is conducive for learning.

Q4: I like the way maths is taught now. More practical applications can be seen. At first I thought that the way is a bit strange and unfamiliar but I learn to like it.

Q5: I can see the relevance. I know that maths is important in engineering.

Q6: Yes, but still trying to accommodate self to the new style.

Q7: Not sure

Q8: More field work.

**Student 4**: (RTE – above average)

Q1: I don't like maths in school. Now after leaving school (now 31 yrs old, in service student) and studying at this college, I am beginning to like it but I still have to work hard.

Q2: Yes maths is important because it is used in everyday life.

Q3: The environment is good. Friends’ and teachers’ help make it easier to go through hard problems. I like the group work. Overall, I enjoyed the class but sometimes we really have to rush.
Appendix 7B: Interview with Students Transcript (Post Implementation)

Q4: I really like the way mathematics is taught now and also before this. Our teacher before has also done a lot in making us interested in mathematics. He tries very hard to make things clear for us.

Q5: Before this we learn how to do a problem and remember the formula. But it’s hard to remember when you don’t know which one to use. Now the approach is more to suit our course.

Q6: This class is also hard work, but you learn a lot as you're working so there is an improvement in the way math is taught and in the environment.

Q7: This class is fun, exciting, creative and makes people use their mind and common sense to solve problems that you might face in real life situations. So, I think the improvement has been successful.

Q8: Friendly teachers who take interest in whether we understand or not.

Student 5: (RTE - average)

Q1: I like maths and now I like it better because it is a challenge for me.

Q2: Yes because maths is used in almost everything.

Q3: The environment is okay. At least classes are not so formal and we can talk among us.

Q4: We learn a lot about real life problems. Before this, math is quite boring. It keeps you more interested and wanting to learn. Also when you get the answer, you feel good about knowing what to do.

Q5: The problems and examples were real and you could imagine the problems as you did them. That made the problems easier for me.

Q6: There were a lot of changes in the way maths was taught. I think it is for our own good.

Q7: I like being able to work together to figure things out. At least that is successful.

Q8: Don’t give to much homework, ha, ha.

Student 6: (RTE - weak)

Q1: I’ve always liked maths because I like to solve problems.

Q2: Yes, because even to go shopping and calculate the discount, we need to use maths.

Q3: Yes. I am quite happy doing things alone but if I am stuck I’ll refer to the better students and teachers.
Appendix 7B: Interview with Students Transcript (Post Implementation)

Q4: Yes, I remember my F5 teacher also tried activities with us. They are interesting.

Q5: Yes, you have included many examples that are relevant.

Q6: Yes, I guess.

Q7: I am not so sure. But since I have always liked maths, more improvements to the way it is taught is better.

Q8: More projects as I think I learn a lot when doing projects.
Cooperative Learning Activity Report

Date: 31/01/2002  Title of Lab Activity: Amplitude and Frequency

Group Members (Your signature indicates your involvement and understanding of the report to which this form is attached. Do not sign it for someone else.)

(Note: In groups of three, the roles of materials manager and resource person are combined.)

Coordinator:  Roshidah
Recorder:  Siti Ropidah
Materials Manager:  Suryani
Resource Person:  3 person

Did each member of the group contribute to the discussion?  Yes
Did each member of the group participate in the activities?  Yes
Did each member fulfill his/her responsibility?  Yes
Did your group complete all assigned activities?  Yes

1. What mathematical concept was addressed by this activity?
   Amplitude and Frequency

2. Address the strengths and weaknesses of this activity. Use the back of this sheet if necessary.
   Advantages — More understanding by increase our knowledge about the differences between amplitude and frequency.
   Disadvantages — The graph was complicated and difficult to see

3. What could have been done to make your group interaction more effective?
   a. Team Work
   b. Understanding

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Cooperative Learning Activity Report

Date: 14 - 01 - 02 Title of Lab Activity: Graph sketching (Amplitude & Frequency)

Group Members (Your signature indicates your involvement and understanding of the report to which this form is attached. Do not sign it for someone else.)

(Note: In groups of three, the roles of materials manager and resource person are combined.)

Coordinator: 
Recorder: Zulizzi
Materials Manager: 
Resource Person: 

Did each member of the group contribute to the discussion? 

Did each member of the group participate in the activities? 

Did each member fulfill his/her responsibility? 

Did your group complete all assigned activities? 

1. What mathematical concept was addressed by this activity?
   
   Trigonometric ratios. Graph sketching on the changes of amplitude and frequency.

2. Address the strengths and weaknesses of this activity. Use the back of this sheet if necessary.
   
   The strengths are that it helps us to understand more effectively and note us communicate better between each other.

3. What could have been done to make your group interaction more effective?
   
   Everyone could do different work on the activity rather than completing each individual assigned activities.
Appendix 7C: Samples of Cooperative Learning Activity Report

Cooperative Learning Activity Report

Date: 17-01-2002  
Title of Lab Activity: GRADE 5TH 6TH 7TH (RESPONSES & RESULTS)

Group Members (Your signature indicates your involvement and understanding of the report to which this form is attached. Do not sign it for someone else.)

(Note: In groups of three, the roles of materials manager and resource person are combined.)

Coordinator: ____________________________
Recorder: ________________________________  Group Members
Materials Manager: ________________________
Resource Person: _________________________

Did each member of the group contribute to the discussion? Yes
Did each member of the group participate in the activities? Yes
Did each member fulfill his/her responsibility? Yes
Did your group complete all assigned activities? Yes

1. What mathematical concept was addressed by this activity?
   Mapping the trigonometric function and looking for the amplitude and the frequency.

2. Address the strengths and weaknesses of this activity. Use the back of this sheet if necessary.
   It is useful to understand the difference and the change of amplitude and frequency.

3. What could have been done to make your group interaction more effective?
   It may be good effective if a group could have sitting face to face together than sitting in a row.
Cooperative Learning Activity Report

Date: 1/29/02
Title of Lab Activity: Graph Sketching (Amplitude & Frequency)

Group Members (Your signature indicates your involvement and understanding of the report to which this form is attached. Do not sign it for someone else.)

Coordinator: Ayman
Recorder: Noorhasam
Materials Manager: Khanalie
Resource Person: Khadmam

Did each member of the group contribute to the discussion? Yes
Did each member of the group participate in the activities? Yes
Did each member fulfill his/her responsibility? Yes
Did your group complete all assigned activities? Yes

1. What mathematical concept was addressed by this activity?
   The higher the amplitude the higher the graph. The higher the frequency, the higher the period of the more oscillations.

2. Address the strengths and weaknesses of this activity. Use the back of this sheet if necessary.
   Team work, provided more understanding. All students to interact with each other. Needed to do more work done.

3. What could have been done to make your group interaction more effective?
   Provide more make up work. Every work done should be shown or explained with each other.