MICROSCALE CHEMISTRY EXPERIMENTS FOR UPPER SECONDARY SCHOOLS IN MALAYSIA

MASHITA BINTI ABDULLAH

UNIVERSITI SAINS MALAYSIA

2011

MICROSCALE CHEMISTRY EXPERIMENTS FOR UPPER SECONDARY SCHOOLS IN MALAYSIA

By

MASHITA BINTI ABDULLAH

Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

January 2011

ACKNOWLEDGEMENTS

I express my great gratitude to Allah for blessing me with the opportunity and willpower to endure this worthy experience.

My sincere expression of thanks and gratitude to my main supervisor, Prof. Dr. Norita Mohamed and to my co-supervisor Assoc Prof. Dr Zurida Hj Ismail for their supervision, guidance, assistance and the encouragement that were patiently and graciously given through the process of completing this research. I am indeed blessed with such supervisors who have strong work ethics, are meticulous and committed and not forgetting, pleasantly warm in nature.

I would like to extend my gratitude to Ministry of Education, Malaysia for giving the opportunity and providing the PhD scholarship to undergo this degree.

This research would not have been possible without financial support from Universiti Sains Malaysia short term grant and Escience Fund from MOSTI. This research also would not have been possible without permission from Educational Planning and Research Division (EPRD), Ministry of Education, Malaysia, Penang State Education Department and cooperation from the principals of the school involved in the study. Many thanks to the teachers and students who have participated in this study. Your cooperation and willingness to participate had enabled me to gather the needed data and carried out the research successfully.

Finally, I wish to thank my friends, especially members of my PhD support group, lab assistants, colleagues and other individuals who have been directly or indirectly supportive, patient and understanding.

Dedicated to my family, my husband, Rosli Bin Samot, my parents and siblings and the rest of family members….you all are my sources of inspiration.

May Allah bless you all for your kindness.

TABLE OF CONTENTS

Acknowledgements……………………………………………………………………… ii

Table of Contents…………………………………………………………………….. iii

List of Tables………………………………………………………………………….. ix

List of Figures………………………………………………………………………… xii

Abstrak……………………………………………………………………………….…. xiv

Abstract…………………………………………………………………………….… xvi

CHAPTER ONE – INTRODUCTION

1.1 Background of the Study……………………………………………………... 1

1.2 Statement of Problem……………………………………………………….. 4

1.3 Microscale Chemistry…………………………………………………………. 5

1.4 Research in Microscale Chemistry…………………………………........... 9

1.4.1 Development of Experimentation…………………………………….. 9

1.4.2 Impact of Microscale Experiments Towards Learning……………… 16

1.5 Scope and Objective of the Study…………………………………………… 19

1.5.1 Development of Microscale Chemistry Experimentation for Secondary Schools……………………………………………….…… 20

1.5.2 Teachers' Feedback…………………………………………………. 21

1.5.3 School Treatment……………………………………………………. 22

1.6 Significance of the Study……………………………………………………. 23

1.7 Definition of Terms ………………………………………………………… 24

CHAPTER TWO – DEVELOPMENT OF EXPERIMENTATION FOR SECONDARY SYLLABUS

2.1 Introduction……………………………………………………………….. 27

2.2 Methodology……………………………………………………………… 40

2.3 Microscale Chemistry Apparatus…………………………………..…... 41

2.4 Form Four Microscale Chemistry Experiments…………………………... 42

2.4.1 Empirical formula of magnesium oxide and copper(II) oxide………. 42

2.4.2 Electrolysis of molten compounds and aqueous solution………… 49

2.4.3 Acid base titration………………………………………………. 51

2.4.4 Identification of gases…………………………………………… 54

2.4.5 Decomposition of carbonate salts……………………………..... 60

2.4.6 Confirmation tests of cations in aqueous salt solutions…………… 62

2.5 Form Five Microscale Chemistry Experiments…………………………….. 63

2.5.1 Rate of reaction…………………………………………………….. 63

2.5.2 Preparation of ethanol and esters………………………………….. 65

2.5.3 Oxidation and reduction…………………………………………… 67

2.5.4 Thermochemistry………………………………………………………. 69

2.5.5 Soap preparation process…………………………………………….. 71

2.6 Cost-benefit Analysis…………………………………………………….. 73

2.6.1 Analysis of chemical usage, waste produced and time spent………. 73

2.6.2 Cost for student equipment for the Malaysian chemistry curriculum… 74

2.7 Conclusions……………………………………………………………… 76

CHAPTER THREE – DEVELOPMENT OF EXPERIMENTATION FOR FOOD ANALYSIS

3.1 Introduction………………………………………………………………… 79

3.2 Titrimetric Analysis…………………………………………………………. 80

3.2.1 Sugar Analysis: Lane-Eynon (AOAC Official Method 930.36)…… 81

3.2.2 Salt Analysis: Volhard (AOAC Official Method 937.09)………….. 82

3.2.3 Benzoic Acid Analysis: Direct Solvent Extraction (AOAC Official Method 963.19)……………………………………………………. 83

3.2.4 Sulphur Dioxide Analysis: Direct Titration (AOAC Official Method 892.02)……………………………………………………………… 83

3.3 Materials and Methods………………………………………………………. 84

3.3.1 Sugar Analysis………………………………………………………. 84

3.3.2 Salt Analysis……………………………………………..……… 88

3.3.3 Benzoic Acid Analysis…………………………………..……… 91

3.3.4 Sulphur Dioxide Analysis……………………………………….. 94

3.4 Results & Discussion……………………………………………………… 97

3.4.1 Comparison in terms of amount of chemicals used for food analysis experiments………………………………………………………. 97

3.4.2 Comparison in terms of waste produced per 30 students for food analysis experiments…………………………………………..….. 101

3.4.3 Comparison in terms of time spent per student for food analysis experiments……………………………………………………… 104

3.4.4 Precision for food analysis experiments…………………………….. 107

3.4.5 Comparison between results of chemical methods and instrumental methods……………………………………………………..… 110

3.5 Conclusions…………………………………………………………..…. 113

CHAPTER FOUR – TEACHERS' EVALUATION

4.1 Introduction………………………………………………………………… 115

4.2 Methodology……………………………………………………………….. 116

4.3 Results and Discussion…………………………………………………… 120

4.4 Analyses of Open Comments……………………………………………… 131

4.5 Focussed Group Discussion……………………………………………….. 131

4.5.1 Feasibility of implementation……………………………………..…. 132

4.5.2 Impact of microscale chemistry…………………………………..…. 134

4.5.3 Barriers/Challenges…………………………………………………..… 135

4.6 Conclusions……………………………………………………………….. 136

CHAPTER FIVE – STUDENTS' FEEDBACK

5.1 Introduction……………………………………………………….………. 137

5.2 Purpose of study…………………………………………………….……….. 137

5.3 Methodology………………………………………………………….………. 138

5.3.1 Research design……………………………………………….……... 138

5.3.2 Implementation of the study……………………………………….. 139

5.3.3 Data collection………………………………………………....... 141

5.3.4 Data analysis………………………………………………………….. 145

5.4 Results and Discussion…………………………………………………… 146

5.5 Teacher Feedback on the Microscale Chemistry Experiments……….……… 155

5.5.1 Feasibility…………………………………………………………… 155

5.5.2 Problems…………………………………………………………….……. 157

5.6 Students' Feedback………………………………………………………… 157

5.6.1 Questionaires……………………………………………………. 157

5.6.2 Analyses of open comments……………………………………….. 160

5.6.3 Interviews…………………………………………………………... 161

5.6.3.1 Understanding of chemistry concepts……………………… 161

5.6.3.2 Handling of apparatus……………………………………..... 162

5.6.3.3 Interest in doing experiments………………………………. 162

5.6.3.4 Students' preferences…………………………………….…. 163

5.6.3.5 Problems……………………………………………………. 163

5.7 Conclusions………………………………………………………………. 164

CHAPTER SIX - CONCLUSIONS AND SUGGESTIONS

6.1 Conclusions………………………………………………………………. 166

6.2 Limitations of the Study …………………………………………………. 168

6.3 Recommendations for Future Research……………………………………… 169

REFERENCES……………………………………………………………… 170

APPENDIX A: Form four manual

APPENDIX B: Quantity of chemical used, waste reduction & time duration for form four experiments

APPENDIX C: Form five manual

APPENDIX D: Quantity of chemicals used, waste reduction & time duration for form five experiments

APPENDIX E: The worksheets for the experiments conducted in the workshop

APPENDIX F: The evaluation questionnaire for teachers

APPENDIX G: Chemistry concept test (Pre-test)

APPENDIX H: Chemistry concept test (Post-test)

APPENDIX I: Attitude inventory (Pre-test)

APPENDIX J: Attitude inventory (Post-test)

APPENDIX K: Motivation inventory pre-test & post-test

APPENDIX L: Students' Comments

APPENDIX M: The permission letter

LIST OF PUBLICATIONS

LIST OF TABLES

		Page
Table 2.1	Topics in Form Four chemistry syllabus	28
Table 2.2	Topics in Form Five chemistry syllabus	28
Table 2.3	List of experiments in Form Four KBSM chemistry syllabus	28
Table 2.4	List of experiments in Form Five KBSM chemistry syllabus	30
Table 2.5	List of experiments in Form Four and Modifications/Adaptations	32
Table 2.6	List of experiments in Form Five and Modifications/Adaptations	36
Table 2.7	List of components in the kit	44
Table 2.8	Other apparatus that have been used	45
Table 2.9	Chemicals used, waste produced (per 30 students) and time duration (per student) for form four experiments	75
Table 2.10	Chemicals used, waste produced (per 30 students) and time duration (per student) for form five experiments	75
Table 2.11	Comparison in terms of cost for student equipment for chemistry curriculum between traditional and microscale setting	77
Table 3.1	Comparison in terms of amount of chemicals used for sugar analysis experiments per 30 students	98
Table 3.2	Comparison in terms of amount of chemicals used for salt analysis experiments per 30 students	98
Table 3.3	Comparison in terms of amount of chemicals used for benzoic acid analysis experiments per 30 students	100
Table 3.4	Comparison in terms of amount of chemicals used for sulphur dioxide analysis experiments per 30 students	100
Table 3.5	Comparison in terms of waste produced per 30 students for sugar analysis experiments (duplicate)	102
Table 3.6	Comparison in terms of waste produced per 30 students for salt analysis experiments (duplicate)	102

Table 3.7	Comparison in terms of waste produced per 30 students for benzoic acid analysis experiments (duplicate)	102
Table 3.8	Comparison in terms of waste produced per 30 students for sulphur dioxide analysis experiments (duplicate)	103
Table 3.9	Comparison in terms of time spent per students for sugar analysis experiments (duplicate)	105
Table 3.10	Comparison in terms of time spent conducting salt analysis experiments per students (duplicate)	105
Table 3.11	Comparison in terms of time spent conducting benzoic acid analysis experiments per students (duplicate)	106
Table 3.12	Comparison in terms of time spent conducting sulphur dioxide analysis experiments per students (duplicate)	106
Table 3.13	Precision between the traditional and microscale approach for the sugar analysis experiments	108
Table 3.14	Precision between the traditional and microscale approach for the salt analysis experiments	108
Table 3.15	Precision between the traditional and microscale approach for the benzoic acid analysis experiments	109
Table 3.16	Precision between the traditional and microscale approach for the sulphur dioxide analysis	109
Table 3.17	Sugar analysis using three different methods	111
Table 3.18	Salts analysis using three different methods	111
Table 3.19	Benzoic acid analysis using three different methods	112
Table 3.20	Sulphur dioxide analysis using three different methods	112
Table 4.1	List of schools in Penang involved in the workshop	117
Table 4.2	Evaluation of worksheet	121
Table 4.3	Evaluation of the microscale kit	121
Table 4.4	Evaluation of microscale experiments	123

Table 4.5	Chemistry teachers' overall evaluation	128
Table 4.6	Evaluation feasibility of microscale experiments	130
Table 4.7	Mean average and Standard deviation for all the construct	130
Table 4.8	List of schools of expert teachers involved in the workshop	133
Table 5.1	Microscale chemistry experiments conducted	140
Table 5.2	Reliability Estimates for Attitude and Motivation	144
Table 5.3	Comparison of the pre test scores for experimental and control groups	148
Table 5.4	Comparison of the post test scores for experimental and control groups	148
Table 5.5	Comparison of the post test scores for experimental and control groups for the topics of electrochemistry and acid and bases	151
Table 5.6	Mean values for the attitude inventory for experimental and control groups	151
Table 5.7	Mean factor values for the attitude inventory between pre and post test for experimental group	153
Table 5.8	Mean factor values for the motivation inventory for experimental and control groups	153
Table 5.9	Mean factor values for all the motivation inventory between pre and post test for experimental group	156
Table 5.10	Students'perception towards microscale chemistry Experimentation	159

LIST OF FIGURES

		Page
Figure 1.1	Apparatus for the electrolysis of water with separate collection of oxygen and hydrogen	12
Figure 1.2	The equipment that constitutes our microscale gas chemistry kit	12
Figure 1.3	Preparation and study on the chemical reactions of chlorine gas in a plastic petri dish	14
Figure 1.4	Small scale and low-cost gas apparatus by Kvittingen & Verley	14
Figure 2.1	Microscale chemistry apparatus	43
Figure 2.2	Empirical formula of Magnesium oxide	48
Figure 2.3	Empirical formula of copper(II) oxide	48
Figure 2.4	Electrolysis of molten Lead (II) bromide	50
Figure 2.5	Electrolysis of aqueous solution	50
Figure 2.6	Acid base titration	53
Figure 2.7	Production of oxygen	56
Figure 2.8	Production of hydrogen	56
Figure 2.9	Production of carbon dioxide	57
Figure 2.10	Production of ammonia	57
Figure 2.11	Production of chlorine	58
Figure 2.12	Production of hydrogen chloride	58
Figure 2.13	Production of sulphur dioxide	59
Figure 2.14	Production of nitrogen dioxide	59
Figure 2.15	The effect of heat on carbonate salts	61
Figure 2.16	Acetate sheet	64
Figure 2.17	Rate of reaction	66

Figure 2.18	Preparation of ethanol	66
Figure 2.19	Transfer of electrons at a distance	68
Figure 2.20	Heat of precipitation	72
Figure 2.21	Preparation of Soap	72
Figure 3.1	Traditional Procedure of Sugar Analysis	86
Figure 3.2	Microscale Procedure of Sugar Analysis	87
Figure 3.3	Traditional Procedure of Salt Analysis	89
Figure 3.4	Microscale Procedure of Salt Analysis	90
Figure 3.5	Traditional Procedure of Benzoic Acid Analysis	92
Figure 3.6	Microscale Procedure of Benzoic Acid Analysis	93
Figure 3.7	Traditional Procedure of Sulphur Dioxide Analysis	95
Figure 3.8	Microscale Procedure of Sulphur Dioxide Analysis	96
Figure 5.1	Study procedures	147

EKSPERIMEN KIMIA BERSKALA MIKRO BAGI SEKOLAH PERINGKAT MENENGAH ATAS DI MALAYSIA

ABSTRAK

Kerja amali adalah penting demi membantu pelajar untuk memperoleh kemahiran saintifik dan berfikir dan pengalaman serta menghargai kimia dalam kehidupan seharian. Pelajar memerlukan kerja amali secara 'hands-on' dan pengalaman sebenar. Kelas amali kimia secara tradisional di Malaysia biasanya dikendalikan kebanyakannya secara berkumpulan (2 atau lebih pelajar), sebagai demonstrasi ataupun tidak dijalankan langsung. Tambahan pula dengan pertambahan bilangan pelajar mengarahkan kepada peningkatan kos untuk mengendalikan kerja amali serta peningkatan dalam bahan buangan menyebabkan pencemaran alam sekitar. Objektif kajian ini adalah untuk membina eksperimen-eksperimen kimia yang berskala mikro peringkat sekolah menengah yang sama dengan eksperimen-eksperimen tradisional dan membuat perbandingan antara dua teknik ini dari segi ketepatan dan kepersisan data yang diperolehi, amaun bahan kimia yang digunakan, peralatan yang diperlukan, masa yang diperlukan dan amaun bahan buangan yang dihasilkan. Kajian ini juga dijalankan untuk menentukan keberkesanan pendekatan secara individu melalui eksperimen berskala mikro terhadap pemahaman konsep kimia pelajar, sikap dan motivasi dan juga menyiasat pendapat dan masalah guru dan pelajar dalam penggunaan teknik berskala mikro ini. Sebanyak lima puluh eksperimen kimia berskala mikro bagi silibus tingkatan 4 dan tiga puluh lima eksperimen kimia berskala mikro bagi silibus tingkatan lima telah dibangunkan menggunakan kit kimia skalamikro (RADMASTE, South Africa) dan peralatan kaca berisipadu kecil. Untuk eksperimen yang telah dibangunkan, penyiasatan awal telah dijalankan untuk menentukan bahan kimia yang bersesuaian dan isipadu dan kepekatan bahan kimia juga telah dioptimumkan bagi setiap eksperimen. Dapatan kajian ini menunjukkan bahawa pendekatan kimia berskala mikro ini boleh diadaptasikan bagi kebanyakan eksperimen kimia tingkatan empat dan lima dalam sillibus kimia peringkat menengah di Malaysia. Pendekatan ini boleh mengurangkan kos, masa dan bahan buangan disebabkan pengurangan bahan kimia yang ketara berbanding eksperimen kimia secara tradisional. Teknik ini dapat mengurangkan bahan buangan sehingga 73%, penggunaan bahan kimia sehingga 73% dan menjimatkan masa sebanyak 75% untuk menjalankan eksperimen-eksperimen tingkatan empat. Teknik ini juga dapat mengurangkan bahan buangan sehingga 72%, bahan kimia sehingga 59% dan menjimatkan masa sehingga 53% untuk menjalankan eksperimen-eksperimen tingkatan lima. Eksperimen-eksperimen berskala mikro ini boleh dikendalikan oleh pelajar secara individu. Rekabentuk kajian**,** ‘quasi-experimental pre test-post test control group design’ telah digunakan untuk menentukan keberkesanan kaedah ini terhadap pelajar. Dapatan kajian menunjukkan bahawa dengan pendekatan ‘hands-on’ ini, pelajar memperoleh pemahaman konsep kimia yang signifikan tetapi tidak memberi kesan terhadap sikap dan motivasi mereka dalam pembelajaran kimia. Pendekatan skala mikro boleh meningkatkan pemahaman konsep kimia pelajar tetapi tidak mempengaruhi sikap mereka terhadap kerja amali dan motivasi mereka dalam mempelajari kimia. Maklum balas daripada guru (66) dan pelajar (83) menunjukkan bahawa mereka memberikan respon yang positif terhadap pendekatan ini.

MICROSCALE CHEMISTRY EXPERIMENTS FOR UPPER SECONDARY SCHOOLS IN MALAYSIA

ABSTRACT

Laboratory work is essential to assist students in acquiring scientific and thinking skills and experience, as well as appreciate chemistry in real life. Students require the hands-on practical and personal laboratory experience. Chemistry practical classes in Malaysian secondary schools are conducted mostly in groups (2 or more), as demonstrations or not conducted at all. Increase in the number of students leads to increased costs of conducting laboratory experiments and also to increase in chemical wastes generated which contributes to environmental pollution. The objectives of the study include developing microscale chemistry experiments for upper secondary chemistry students that correspond to traditional macroscale experiments and comparing microscale and macroscale experiments in terms of accuracy and precision of results obtained, amount of chemicals used, apparatus required, time needed and amount of waste produced. This study also was conducted to determine effectiveness of an individualized approach through microscale chemistry experiments on students' understanding of chemistry concepts, attitude and motivation and also investigate students' and teachers' opinions and problems on using the microscale technique. Fifty microscale chemistry experiments for Form Four syllabus and thirty five microscale chemistry experiments for Form Five syllabus were developed using the Microchemistry Kit (RADMASTE, South Africa) and small volume glassware. For the experiments developed, preliminary investigations were carried out to determine the appropriate chemicals to be used and the volume and concentration for the chemicals were also optimized for each experiment. Findings of this study indicate that the microscale chemistry approach can be adapted for most of the Form Four and Form Five chemistry experiments in the Malaysian secondary school chemistry syllabus. This approach can reduce cost, time spent and chemical wastes generated since it uses much smaller quantities of chemicals compared to the traditional scale experiments. This technique can reduce wastes up to 73%, chemicals used up to 73% and save up to 75% time spent for experiments in the form four syllabus. This technique also can reduce wastes up to 72%, chemicals used up to 59% and save up to 53% time spent for experiments in the form five syllabus. Experiments can also be conducted individually by students. The research design**,** a 'quasi-experimental pre test-post test control group design' was employed to determine the effectiveness of this approach towards students. The findings showed that with its hands-on approach, the students received significant gains in their understanding of the chemistry concepts. The microscale approach can increase students understanding of chemistry concepts as traditional-scale practical work but did not affect their attitude towards chemistry practical work and motivation in learning chemistry. Feedback from teachers (66) and students (83) on the microscale chemistry experiments indicate that teachers and students also gave positive responses towards this approach.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The philosophy of science education in Malaysia is to nurture a science and technology culture by focusing on the development of individuals who are competitive, dynamic, robust and resilient, and able to master scientific knowledge and technological competency. In consonant with this philosophy, the aim of science education is towards developing the potential of individuals in an overall and integrated manner so as to produce Malaysian citizens who are scientifically and technologically literate, competent in scientific skills, practice good moral values, capable of coping with scientific and technological advances and able to manage nature with wisdom and responsibility for the betterment of mankind (Curriculum Development Center, 2006). Science is a core subject in the school curriculum for students from primary to secondary schools. The science curriculum comprises three core science subjects and four elective science subjects. The core subjects are science at the primary school level, science at the lower secondary level and science at the upper secondary level. Elective science subjects are: biology, chemistry, physics and additional science; they are offered at the upper secondary level.

The core science subjects for the primary and lower secondary levels are designed to provide students with basic scientific knowledge, to prepare students to be literate in science, and enable students to continue their science education at the upper secondary level. Core science at the upper secondary level is designed to produce students who are literate in science, innovative and able to apply scientific knowledge in decision making and problem solving in everyday life. The elective science subjects prepare students who are more scientifically inclined to pursue the study of science at the post-secondary level.

Chemistry is offered to students at the upper secondary level beginning in Form Four (equivalent to Grade 10, in the US system). Students who have followed the chemistry curriculum will have a basic foundation in chemistry to enable them to pursue formal and informal further education in science and technology. The curriculum content is organized based on the following themes:

- Introduction to chemistry.
- Matter around us.
- Interactions between chemicals.
- Production and management of manufactured chemicals.

Part and parcel of learning chemistry is carrying out laboratory practicals. From an educational point of view, chemistry without laboratory work is seen as a body of factual information and general laws which conveyed nothing of lasting power to the mind (Layton, 1990). Central to the teaching-learning approach in the chemistry curriculum is practical work geared towards the mastery of scientific skills, which comprise process skills, manipulative skills and thinking skills. Hofstein and Mamlok-Naaman (2007) stated that for more than a century: "*laboratory experiences have been purported to promote central science education goals, including the enhancement of students' abilities; scientific practical skills and problem solving abilities; scientific* *'habits of mind'; understanding of how science and scientists work; interest and motivation"* (p. 105). Practical work in chemistry gives students opportunities to gain these skills through scientific investigations and hands-on activities and has the potential to significantly enhance learning and development of conceptual understanding. It may offer a unique learning environment that can help students construct their knowledge, develop logical and inquiry-type skills and develop psychomotor skills. It can also promote positive attitudes and provide students with opportunities to develop skills regarding cooperation and communication (Hofstein, 2004).

As suggested by one of the constructivist teaching models, integrating hands-on activity can stimulate the students and allow them to be creative (Faire and Cosgrove, 1988). The basic principle is that the activities should encourage learners to (re)construct scientific knowledge, since according to Scott (1987), a constructivist view of learning, *"perceives students as active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences"*. From the constructivist perspective, students need to be active participants in the learning process in constructing meaning and developing understanding (Jenkins, 2000). The teacher's role is to be a facilitator who will provide the appropriate opportunities for the learners to undertake the construction.

Bradley (2001) reported that practical work should involve active student participation. Taraban *et al.* (2006) also found that for two topics in high school biology, students gained significantly more content knowledge and knowledge of process skills using active-learning labs than in traditional instruction, which is relatively more dependent on lecture and textbooks. The active-learning labs include using hands-on, inquiry-oriented activities and organizing students into collaborative learning groups that analyze problem-oriented scenarios.

1.2 Statement of Problem

The chemistry curriculum aims at producing active learners. To this end, students are given ample opportunities to engage in scientific investigations through hands-on activities and experiments. The inquiry approach, incorporating thinking skills, thinking strategies and thoughtful learning, should be emphasized throughout the teaching-learning process. The science laboratory has always been regarded as the place where students should learn the process of science. Ideally, each student should be wholly responsible for conducting the experiments from start to finish.

While practical work in chemistry is considered essential in chemical education, it is frequently absent from the real curriculum in schools around the world (Bradley *et al*., 1998). In studies conducted on science education in Malaysia, Sharifah and Lewin (1993) observed that practical work is often conducted in groups rather than individually or in pairs. Of the teachers surveyed, 54 percent reported group sizes of 4 or 5 students per group. Direct observation of classes noted a range of 1 to 7 students per group. Such practices limit active work to two to three students while the other members tend to be passive observers. This resulted in low level acquisition of scientific skills and knowledge among the students. Students require the hands-on practical and personal laboratory experiences to acquire the science process skills.

Furthermore, a keen emphasis on public examinations by teachers has led to teaching being mainly geared towards passing these examinations. Practical work and experimentation are often sacrificed, since these do not contribute a significant percentage to the overall marks. Thus, teaching and learning in the classroom in some context becomes largely teacher-centred, thereby ignoring the development and mastery of scientific and thinking skills among students, as required by the curriculum. In studies by Tsaparlis and Gorezi (2007) on the addition of a project-based component to a conventional expository physical chemistry laboratory, working in fours seemed acceptable to the majority of the students. However, 30% of the students reported that unequal contribution of members in a group was the most serious problem of group work.

Other problems associated with practical work in schools include the lack of facilities. A case study revealed that in general, equipment was adequate for group work in all schools for group sizes of 4 to 5 students (Sharifah & Lewin, 1993). Research on implementation of laboratory work assessment, PEKA (Pentaksiran Kerja Amali) indicate that the constraints which hinder the effectiveness of implementing the PEKA programme in classrooms were lack of apparatus and materials, students' negative attitudes, passive and lack of cooperation (Mingan, 2001). This type of assessment requires students to gain manipulative skills by doing practical work.

1.3 Microscale Chemistry

Microscale chemistry is an alternative approach to overcome some of the problems associated with practical work, since it provides hands-on activities and personal experiences for students using reduced amounts of chemicals, miniature labware, safe, easy manipulative techniques and high quality skills. Precision or accuracy of experiments is not compromised and teachers can also use it as a tool to design new laboratory acitivities (Cooper *et al*., 1995, Bradley, 1999, Singh *et al.*, 1999, Tallmadge *et al.*, 2004). It is recognized as Smallscale Chemistry by the International Union of Pure and Applied Chemistry (IUPAC). This laboratory-based approach can improve students skills in handling equipment, encourage them to do experiments, and also stimulate them to do experiments carefully and patiently. Kelkar and Dhavale (2000) reported that undergraduate students performed experiments with more care and their skills in handling the equipment were markedly improved after adoption of this technique in their laboratory.

The microscale concept was introduced through the work of Emish and Pregl, who had received the Nobel Prize in 1923 (Pike *et al*, 1996). Emish had published the *Lehrbuch der Mikrochemie*, which dealt with methods of chemical experimentation using milligram quantities of material. Pregl also had developed methods to determine carbon, hydrogen and other elements in organic compounds with 3 to 5 mg samples. Feigl had also discovered extremely sensitive chemical reactions by which micrograms to nanograms of a substance in very dilute solution can be detected (MA & Horak, 1976). Microscale chemistry had been introduced in the organic chemistry laboratory at Bowdoin College, Maine. This was later expanded to cover general, inorganic, analytical and environmental chemistry.

The National Microscale Chemistry Center was established at Merrimack College in 1992 – 1993 as the first center to offer formal microscale chemistry training to teachers and chemists at all levels from elementary schools to universities. There are also other centres such as the Centre for Research and Development in Mathematics, Science and Technology (RADMASTE Centre) in Africa, Australian Microscale Chemistry Center, Chinese Microscale Chemistry Center, Microscale Chemistry in Israel, Nordic Microscale Chemistry Center, Austrian Microscale Chemistry Center, Swedish Microscale Chemistry Center and Mexican Microscale Chemistry Centre.

With this microscale approach, students should be able to improve their understanding of concepts, attitude and motivation towards chemistry as well as laboratory work. Many researchers have reported that laboratory experiences can improve student attitudes and interest in chemistry and personal involvement in chemistry laboratory promotes students' interest in studying chemistry (Ben-Zvi *et al*., 1976; Hofstein and Lunetta, 1982; Okebukola, 1986; Hofstein, 2004). Hence, microscale chemistry experiments are seen as a viable alternative to encourage teachers as well as students to want to do practical work in chemistry.

Among the benefits of microscale chemistry are improved safety, cost and time savings, environment-friendliness, pollution prevention, more adaptable equipment and also enhanced chemistry learning. In particular, benefits of microscale chemistry which include the following (McGuire *et al*., 1991, National Microscale Chemistry Centre, 1993, Cooper *et al*., 1995, Bradley, 1999, Singh *et al.*, 1999, Kelkar & Dhavale, 2000, Vermaak & Bradley, 2003, Tallmadge *et al.*, 2004):

(i) Safety

This technique can improve laboratory safety with its usage of smaller quantities of chemicals, lessened toxicity and danger to students and teachers.

Chances of fire, explosion and serious injury are greatly reduced and perhaps almost eliminated.

(ii) Cost savings

By using the smaller quantities of chemicals, the cost of chemicals and equipment would be greatly reduced. Hence a wider variety of chemicals can also be used for experiments which would not have been affordable previously.

(iii) Equipment more adaptable

Since most items in the microscale kits are made up of plastic, it is easy to handle them and there would be further cost savings with minimal initial and recurrent breakages.

(iv) Time savings

By doing the experiments using this technique, shorter experiment times are required. Preparation time is also shortened and the experiment can be repeated if required. Clean up times are reduced and more time is available for reflection/discussion sessions with students.

(v) Environment-friendly

This technique promotes environmental friendly experiments with less waste produced. Chemical disposal problems are almost eliminated and it can instill culture of saving and caring for the environment.

(vi) Pollution prevention

This technique builds pollution prevention, waste minimization and student safety at the design stage rather than controlling it at the disposal stage by promoting reduction of chemical wastes at source.

(vii) Enhanced learning

This technique also advocates hands-on learning experience by allowing students to share responsibility for their own learning. It also fosters creative, inquiry-based problem solving abilities among the students.

1.4 Research in Microscale Chemistry

Most research in microscale chemistry have focused on developing microscale experiments for high school and undergraduate level and some have focused on feasibility of using this technique among students.

1.4.1 Development of Experimentation

Initially, the development of microscale experiments was carried out for organic chemistry due to numerous amounts of organic solvents used in macroscale experiments. Many researchers developed small scale organic chemical equipment and techniques to perform experiments without sacrificing any of the objectives of macro method (Cheronis, 1939, Gilow, 1992, Ellervik & Grundberg, 1999, Russo & Meszaros, 1999, Williamson, 1999, Wesolowski *et al*., 1999). Mahamulkar *et al*. (2000) utilized capillaries in an innovative way as reaction vessels and for the qualitative detection of functional groups. The low cost of capillary tubes coupled with low reagent consumption, makes this technique attractive for use in any undergraduate or postgraduate laboratory.

For high school or elementary school, Gupta (2007) developed a simple W-shaped apparatus by bending glass tubing to contain all of the chemicals involved and to limit the quantities to microscale. It can be used for testing the presence of carbon dioxide, sulphur dioxide or other gases. W-tubes were tested by teachers and students from schools to demonstrate its great utility and convenience. Willemsen (2000) developed an appropriately sized stirring device for carrying out microscale experiments. The device consisted of items such as a squirrel fan, a stirring magnet, a piece of PVC pipe, silicone adhesive, hose adapters, a PVC adapter and a thermos insulated snack jar that can be assembled in less than a half an hour.

Begtrup (2001) conducted small-scale filtration using a modified plastic syringe. It is a simple procedure for pressure filtration that does not require pumps where both filtrate and residue can be collected. The filtration is performed in a commercially available, inexpensive plastic syringe, which is slightly modified to allow unproblematic repeated piston movements. Joling *et al*. (2002) designed a low-cost, fast electric heater to replace expensive hot-plates used in microscale chemistry laboratory. It is essentially a soldering iron whose tip is replaced by an aluminium block with a drilled hole.

The secondary school chemistry syllabus include electrochemistry which was considered difficult and misconceptions about electrochemistry were abundant (Johnstone, 1980; Finley *et al*., 1982; Garnett and Treagust, 1992). As students have problems understanding voltage and current as well as the relation between these two concepts, Eggen *et al*. (2006) constructed two small, simple and illustrative galvanic cells that can be made by most students in any laboratory or most classrooms. Materials used to construct these two apparatus include a culture plate (12 or 24 wells or small vials), disposable polyethene pipets, small crocodile clips, graphite rod or pencil leads, galvanized nails or zinc strips, magnesium ribbon, silver wire, floral foam, light diodes and saturated solutions of copper(II) sulphate and sodium sulphate.

Since central to most chemistry curricula is the measurement of reduction potential, Eggen *et al.* (2007) described how to construct three simple and inexpensive electrodes: a hydrogen, a chlorine and a copper electrode. The robust copper electrode is made from a plastic pipet which is partly filled with 1.0 M copper(II) sulphate where the tip is blocked with solidified agar-agar in 1.0 M potassium nitrate. The copper wire has been pushed through the bulb and into the copper(II) solution.

The study of production of gases is a significant and important part of the curriculum in secondary schools. A variety of microscale gas chemistry methods have been developed (Alyea, 1992, Kilroy, 1994, Slater & Rayner-Canham, 1994, Choi, 2002, Obendrauf & Koehler-Kruetzfeldt, 2003, Wang & Zhao, 2003, Eggen & Kvittingen, Kvittingen & Verley, 2004, Ibanez *et al*., 2005a, Ibanez *et al*., 2005b). A variety of apparatus used to prepare and collect gases by the above researchers include a disposable plastic syringe (Alyea, 1992), a small test tube with soft latex stoppers or septa and blunt needles (Obendrauf and Koehler, 2003), 24-well plates and pipet bulbs (Slater & Rayner-Canham, 1994), a centrifuge tube and thin stem pipet (Kvittingen & Verley , 2004), Petri dish (Choi, 2002), a test tube and Beral pipet with slits cut into the bulb (Kilroy, 1994), a Kipp generator (Wang & Zhao, 2003). Eggen & Kvittingen (2004) produced gases using electrochemical methods and microscale methods using one or two pipet bulbs (Figure 1.1). Ibanez *et al*. (2005a, 2005b) produced ozone and chlorine dioxide gases *in situ* using a Beral pipet as the generation chamber.

The Alyea-Mattson ‘in-syringe’ method was used to prepare different gases (Figure 1.2). This method was originally described by Alyea (1992) where the method featured the generation of gases by reacting two chemicals, typically one solid and one

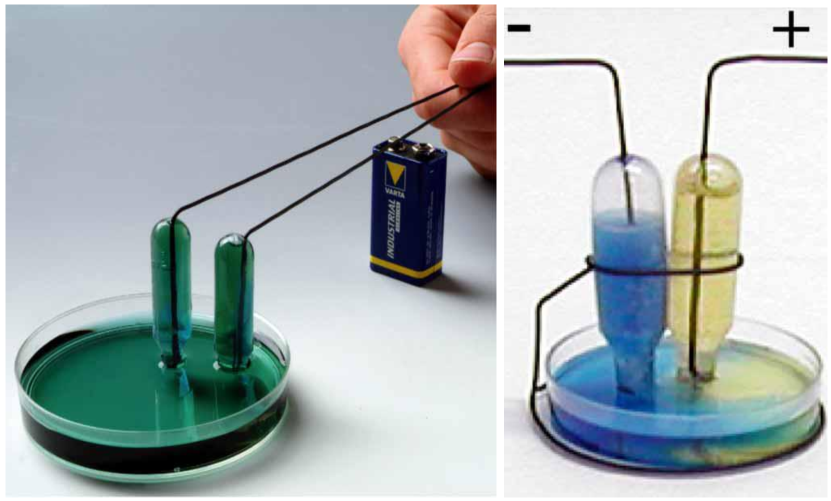

Figure 1.1: Apparatus for the electrolysis of water with separate collection of oxygen and hydrogen (bromothymol blue was added to the solution). (A) Shows one-hand grip of the apparatus (two hands are more stable) before the electrolysis has started. (B) A close-up illustrating the gas volumes, changes of indicator color, and a stand of floral wire (color changes from green in A to blue at the negative electrode and yellow at the positive electrode; photo RoarØhlander).

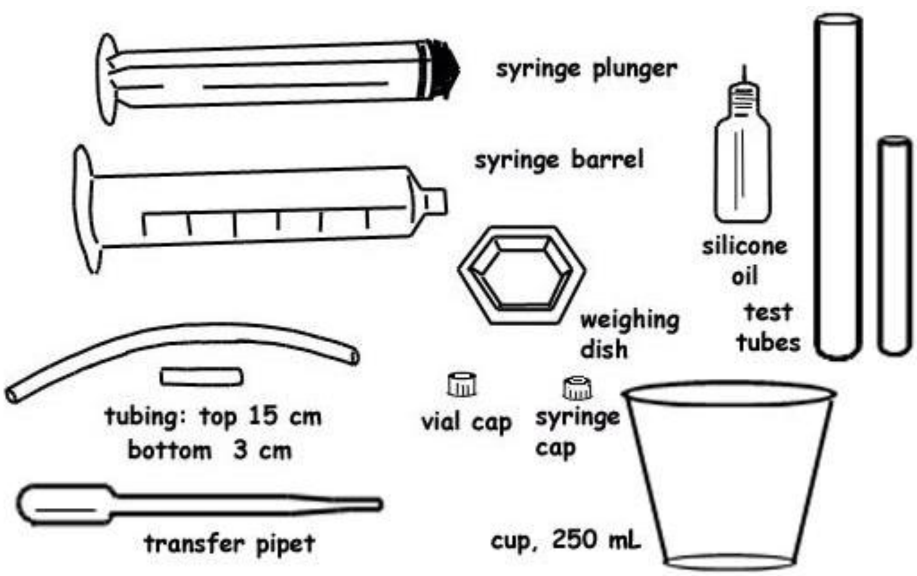

Figure 1.2: The equipment that constitutes microscale gas chemistry kit.

aqueous liquid, inside a plastic syringe. Mattson (2005) contributed to develop a safe and easy way to bring the two reagents together inside the syringe but was separated so they cannot react until the plunger is in place and the syringe is sealed (closed system).

Choi (2002) demonstrated some of the chemistry of chlorine on a microscale level at the size of a water droplet. Chlorine gas was prepared from an acidified bleach solution in a plastic Petri dish (Figure 1.3). The chlorine gas generated in situ reacted with other chemical reagents in the dish by diffusion. Some of the oxidizing properties and bleaching power of chlorine gas were shown visually and could be observed within 10 minutes. These experiments provide suitable hands-on experience for students at the secondary school level.

Kvittingen & Verley (2004) used disposable polyethene transfer pipets (Beral pipets) and polypropene microcentrifuge tubes and floral wire to construct simple small scale and low-cost gas apparatus (Figure 1.4). Microcentrifuge tubes are used as the reaction vessel; the stems of pipets are formed into tubing and stopper and pipet bulbs with a shortened stem as the dropping funnels to collect the gas over water. Stands are fashioned from floral wire and culture plates also can be used as open reaction vessels and stands. This simple gas apparatus can be made by students either in the laboratory or the classroom.

In analytical and general chemistry, many titrations are performed routinely. Singh *et al*. (1998) described the construction of a versatile microburet that offers superior manipulation, ensuring a rapid, precise and accurate method for microscale titiration. Singh *et al.* (2000) carried out a comparative study of microscale and standard

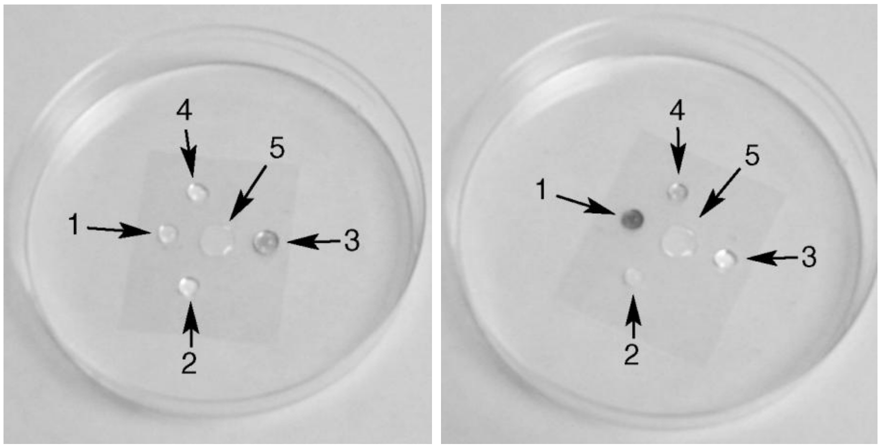

Figure 1.3: Preparation and study on the chemical reactions of chlorine gas in a plastic petri dish. (A) Before chemical reactions: 1, a drop of Fe(II) solution; 2, a drop of Na_2SO_3 solution; 3, a drop of grape juice; 4, a drop of KI solution; 5, a drop of bleach solution. (B) Ten minutes after addition of sulfuric acid, and then other reagents:1, drops of Fe(II) and KSCN solutions; 2, drops of Na_2SO_3 and $BaCl_2$ solutions; 3, a drop of grape juice; 4, a drop of KI solution; 5, drops of bleach and H_2SO_4 solutions.

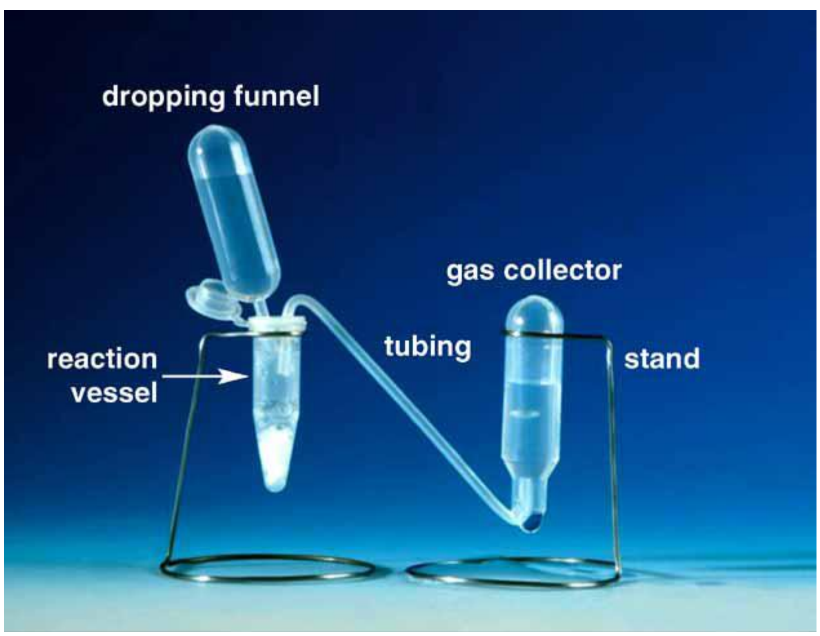

Figure 1.4: Small scale and low-cost gas apparatus by Kvittingen & Verley

burets. In this study the use of microburet in general and analytical chemistry was illustrated through acid-base, oxidation-reduction, precipitation, complexometric and pH titrations. The data obtained by students using the microburets were compared with data obtained using Beral pipettes and standard 50 and 10 mL burettes. Microscale titration performed using less than 2 mL of titrant proved to be as accurate as macroscale techniques. They also emphasized several versatile features of using a microscale burets: cost effectiveness, time savings and accessibility for the physically challenged.

Flint *et al*. (2002) conducted microscale pH titrations using an automatic pipet. This titration used 5 mL analyte and titrated with bases in a 10 mL beaker. After each addition, the solution is stirred and the pH is determined with a pH meter. The students were still taught the fundamental equivalence concept contained in macroscale titrations and the graphical analysis of a titration. They also gained experience with modern laboratory equipment, small analyte and titrant volumes which make replicate analyses cost efficient and they could quickly see the impact of their technique on the precision of an analysis.

Richardson *et al*. (2003) worked on a microscale quantitative analysis of hard water samples using an indirect potassium permanganate redox titration. They focused on an analysis of the data obtained using microscale techniques, as well as a comparison of actual student data from the instructional laboratories in which accuracy and precision of both microscale and traditional macroscale data were compared. The data indicated that the microscale technique yields data of comparable accuracy and precision to the macroscale technique. However, potential users of the microscale approach should be aware that loss of calcium oxalate precipitate during the filtration step could be a potential source of determinate error. This error should be easily mitigated through careful techniques and use of appropriate microscale glassware.

Pelter *et al*. (2000) used a microscale oxidation puzzle in place of the traditional oxidation of cyclohexanone to introduce student to the operation of the FTIR and to the procedure for obtaining an IR spectrum of a liquid sample. The experiment can be used any time during the semester provided that IR interpretation has been covered in lecture. The important lessons of the experiment are the use of IR spectral analysis in product identification and the selectivity of chemical reactions.

Research was also carried out by Blanchard (2003) on quantitative microscale hydrogenation of vegetable oils to calculate the efficiency of the reaction by comparing the actual amount of hydrogen consumed with a theoretical value calculated from the fatty acid composition recorded on the nutrition labeling. The label identifies the number of grams of saturated, monounsaturated and polyunsaturated fats in a serving size of the oil. Calculations can be made of the mass of each type of fatty acid in the sample, the number of moles of each, the number of moles of carbon-carbon double bonds and finally the volume of hydrogen necessary to reduce all the double bonds. In conclusion, a new hydrogenation experiment for the introductory organic chemistry laboratory provides an opportunity to discuss fats and fatty acids, their physical behavior and their nutritional value.

1.4.2 Impact of Microscale Experiments Towards Learning

It is also important to study the impact of microscale experiments towards student learning. Singh *et al*. (1999) reported on the compatibility of microscale chemistry and green chemistry pedagogic programs: their benefits and impact on academia and industry. The benefits of implementing a microscale-green chemistry laboratory program include reduced times, improved safety and major cost savings. Green chemistry and microscale chemistry are complimentary pedagogies, allowing the ideas of source reduction, material substitution and exposure minimization to be brought effectively into the academic laboratory.

Fleming (1995) described how cooperative learning and microscale experiments can be introduced concurrently and how the cooperative learning environment may facilitate the introduction of these course changes. Most students preferred microscale experiments and there is strong student support for using cooperative learning within the course where almost all students prefer to work with others. This group participation could also result from building confidence among students who may otherwise feel intimidated by having to complete an unfamiliar lab on their own.

Cooper *et al.* (1995) considered microscale chemistry not to just make chemistry experiments faster, cheaper and safer but also as a tool that will transform teaching. They designed dozens of new minilabs by organizing their students into cooperative learnings groups. As a result, students and teachers had lots of fun and there was an improvement in students' achievement in the Comprehensive Test of Basic Skills (American Chemical Society) and in the Advanced Placement Chemistry scores.

McGuire *et al.* (1991) studied a representative group of high school students who did both the macro version and the micro versions of several experiments. They reported data on completion time of the experiments and on how microscale affects student attitude. Three experiments that were carried out included continuous variations, titration of NaOH/HCl and NaOH/vinegar and synthesis of $K_3Fe(C_2O_4)_3.6H_2O$. The time savings were significant with the micro version for continuous variations and titration experiments but the time savings was much less marked with the synthesis experiment. The students showed an overall preference for the macro version over the micro version. However, for each individual experiment, the difference is not statistically significant.

Yoo *et al.* (2006) studied the effect of a small-scale chemistry (SSC) lab program on academic achievement, academic self-efficacy and science-related affective domain of high school students. The experimental group received SSC experiment lessons and the comparison group received traditional experiment lessons. Students were grouped into higher and lower level according to their prior academic achievement. Findings showed that small-scale lab program is more effective than traditional large-scale lab program in elevating academic achievement, curiosity, creativity and self-confidence. Many students found the SSC lab program convenient, marvelous and interesting, suitable for individual and group experiments. Through the SSC lab program, passive and shy students became active participants in learning chemistry. Their curiosity, creativity and self-confidence were increased and anxiety toward science was decreased.

Vermaak (1997) evaluated the cost-effective microscale equipment for a hands-on approach to chemistry practical work in secondary schools. The purpose of the study was to determine whether the engagement of pupils in microscale chemistry resulted in a more positive attitude towards science and an increased understanding of certain concepts. It involved more than 600 pupils (grade 11) from 30 schools of different geographical areas. Variables such as gender and cultural differences, different contexts and contrasts and the methodology were investigated. Results indicated that a significant improvement on subject knowledge and understanding were achieved in all experiments.

Medeira (2005) investigated whether practical work using microchemistry kits contributed to students understanding of chemistry content and to find out teachers' and learners' opinions about practical work using microchemistry kits. Samples of 500 grade 9 students were involved in the study. Both experimental and comparison groups were administered a test before and after 8 weeks of intervention with the experimental group. The intervention consists of doing practical work using worksheets developed by RADMASTE Centre, University of Witwatersrand.

This study will focus on the development of microscale chemistry experimentation for secondary schools in Malaysia. The feasibility and effectiveness of using the technique will also be determined. The first part of the study is to develop microscale chemistry experimentation for Form Four and Form Five chemistry syllabuses. The second part of this study is to obtain feedback from teachers and students on the feasibility and effectiveness of using the microscale technique.

1.5 Scope and Objective of the Study

The main purpose of this study is to develop microscale chemistry experimentation according to Integrated Curriculum for Secondary Schools, Malaysian chemistry syllabus and evaluate the feasibility of the experimentation to the Malaysian syllabus, teachers and students. The objectives of the study include:

(i) To develop microscale chemistry experiments for upper secondary chemistry students that correspond to traditional macroscale experiments.

(ii) To compare between microscale and macroscale experiments in terms of accuracy and precision of results obtained, amount of chemicals used, apparatus required, time needed and amount of waste produced.

(iii) To determine effectiveness of an individualized approach through microscale chemistry experiments on students' understanding of chemistry concepts, attitude and motivation.

(iv) To investigate students' and teachers' opinions and problems on using the microscale technique.

Based on the purposes and objectives of this study, the study involves three stages:

1.5.1 Development of Microscale Chemistry Experimentation for Secondary Schools

Fifty microscale chemistry experiments for Form Four syllabus and thirty five microscale chemistry experiments for Form Five syllabus were developed based on the Malaysian chemistry curriculum specification for secondary schools (Curriculum Development Center, 2004 & 2006). Topics in the Form Four syllabus include introduction of chemistry, the structure of the atom, chemical formulae and equations, periodic table of elements, chemical bonds, electrochemistry, acids and bases, salts and manufactured substances in industry. Topics in the Form five syllabus include rate of reaction, carbon compounds, oxidation and reduction, thermochemistry and chemicals for consumers.

Most of the experiments were designed for use with the Microchemistry Kit (RADMASTE, South Africa) which is basically made up of plastic ware and also small volume glassware as suggested for the Microchemistry Equipment Kit (National Microscale Chemistry Center, USA). The basic items included a comboplate (combination 24-well and 96-well plate), syringes, propettes, vials, light emitting diode for confirmation of current flow and also the microburette for acid-base titrations.

Food analysis experiments based on the microscale approach were also developed as an application to introduce analysis of food to students. Among the topics in the chemistry curriculum are chemicals for consumers which involve students discussing the use of food additives such as preservatives, antioxidants, flavouring agents, stabilizers, thickening agents and food dyes (Curriculum Development Centre, 2006). These supplementary experiments will expose students to these methods of analyses in the chemistry laboratory. Four methods of analysis were developed which include determination of sugars, salts, benzoic acid and sulphur dioxide. The chemicals used in these analyses were scaled down by a factor of 10. Comparisons were made between conventional methods of analyses and analyses using a microscale approach in terms of quantity of chemicals used, waste produced, time duration as well as method precision and accuracy.

1.5.2 Teachers' Feedback

A workshop was conducted for teachers to determine their feedback on the microscale chemistry experiments. Penang chemistry teachers were involved in the workshop. All the teachers (66) were exposed to a one hour lecture and hands-on experiments individually: confirmation tests of cations in aqueous solutions, electrolysis of aqueous solutions, determination of end point for a neutralization reaction between an acid and a base, electroplating of metals and reduction of copper(II) oxide. An evaluation questionnaire was administered. Five constructs covered: the worksheet, the microscale kit, evaluation of microscale experiments, overall evaluation and feasibility of microscale experiments.

1.5.3 School Treatment

School treatment involves exposing target group (students in schools) to the microscale chemistry experiments. It is conducted to determine students' feedback on microscale experimentation and the effect of this approach on students' understanding of chemistry concepts, attitude towards chemistry practical work and motivation. A 'quasi-experimental pre test-post test control group' design was used. For this study, 170 students were involved: 83 in the experimental group and 87 in the control group. The experimental group conducted hands-on microscale experiments whereas the control group conducted traditional experiments. Pre and post tests were conducted before and after the treatment for both groups. Instruments involved in this treatment include a chemistry concept test, attitude towards chemistry laboratory questionnaires, motivation in chemistry learning questionnaires and interviews for teacher and students to evaluate feasibility of using this approach.

1.6 Significance of the Study

There is nonetheless good reason to believe that laboratory activities are important in fostering understanding of certain aspects of the nature of science, in promoting intellectual and conceptual development and, in particular in developing positive attitudes towards science. Laboratories activities also seem to be an important ingredient in the development of certain problem-solving skills. So, microscale technique is an important innovation for raising the interest of young students in chemistry laboratory activities.

The success of this study can make a great impact in chemical education in Malaysia. Firstly, the implementation of this technique in the laboratory gives benefits to both students and teachers. They will be more confident to do the experiments and more experiments can be done. New experiments can be created to provide the basis of more contextual learning. Laboratory activities are important in the development of problem solving skills and greater understanding of chemical concepts.

The implementation of this technique would not only be possible at the secondary level but also for form six and matriculation syllabuses, first year chemistry and at the primary school level. Microscale chemistry can reduce costs, disposal of chemical wastes is easier due to the small quantities, safety hazards are often reduced and many experiments can be done quickly. Since such small quantities of chemicals are used, chemistry experiments can even be carried out in rural schools or at home (distance education learners) where there are no traditional laboratories.

Application of microscale chemistry experiments provides the opportunity for discussion of the environmental responsibilities in relation to toxic chemicals, of individuals at work and at home, as well as similar responsibilities of businesses. Environmental awareness can be cultivated in precollege students no matter what field their interests lie in. Accessibility of science to all will break the urban and rural infrastructure division in science and technical education.

The implementation of this technique in the laboratory gives benefits to both new and experienced teachers. They will be more confident to run the experiments because of the use of the plastic apparatus means glassware breakages are minimized and only a small quantity of chemicals is used. So, more experiments can be done and they also can create new experiments that provide the basis of more contextual learning.

1.7 Definition of Terms

(i) Microscale Chemistry Technique

Microscale Chemistry Technique in this study refers to using the microscale chemistry kit and significantly reduced amounts of chemicals in the laboratory during the laboratory session.

(ii) Traditional Technique

Traditional technique in this study refers to using the ordinary glassware and amounts of chemicals in the laboratory during the laboratory session.

(iii) Understanding of chemistry concepts

Chemistry concept in this study refers to each of the student's score in the achievement test. The test is administered to evaluate student understanding of the concepts in all the topics that are carried out during the treatment.

(iv) Attitude

Attitude in this study refers to the student's attitude in learning chemistry include interest in doing practicals in chemistry, enjoyment of performing practicals and handling equipment, practical aspects of laboratory work and how students consider laboratory work as 'a way of learning'.

(v) Motivation

Motivation in this study refers to the student's motivation in learning chemistry include intrinsic goal orientation, extrinsic goal orientation, task value, control beliefs of learning, self-efficacy for learning and performance and test anxiety.

(vi) Experimental Group

Experimental group refers to a group of students who are exposed to the microscale chemistry technique in the laboratory and working individually using the kit during the laboratory session in chemistry.