



Faculty of Resources Science and Technology

**Development of a Practical Kit and a Citizen Scientist Program for
Learning Chemistry**

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**Faculty of Resources Science and Technology
UNIVERSITI MALAYSIA SARAWAK
2023**

Development of a Practical Kit and a Citizen Scientist Program for
Learning Chemistry

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A thesis submitted

In fulfillment of the requirements for the degree of Master of Science

(Chemistry)

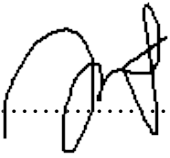
Faculty of Resources Science and Technology

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2023

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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Date : 18th June 2023

ACKNOWLEDGEMENT

First and foremost, praises and thanks to the God, the Almighty, for His showers of blessings throughout my research work to complete the research successfully.

I would like to express my deep and sincere gratitude to my research supervisor, Assoc. Prof. Dr. Sim Siong Fong, for giving me the opportunity to do research and providing invaluable guidance throughout this research. Her dynamism, vision, sincerity and motivation have deeply inspired me. She has taught me the methodology to carry out the research and to present the research works as clearly as possible. It was a great privilege and honour to work and study under her guidance. I am extremely grateful for what she has offered me. I would also like to thank her for her empathy. I am extending my heartfelt thanks to my co-supervisor, Assoc. Prof. Dr. Rafeah binti Wahi, of Faculty of Resources Science and Technology at UNIMAS, for the advice and support given during my period of study.

I am extremely grateful to my parents for their love, prayers, caring and sacrifices for educating and preparing me for my future. I am very much thankful to my wife, Kiew Leh Yieng and my children, Daniel Wong Ming Yi, Elisha Wong Ming En, Jeremy Wong Ming Xu and Lucas Wong Ming Ze, for their love, understanding, prayers and continuing support to complete this research work successfully.

Finally, I would like to thank the management of the Universiti Malaysia Sarawak for making it possible for me to complete my study here in Sarawak. Thank you all.

ABSTRACT

Laboratory practical is an essential component for effective learning of science. Providing laboratory experience can be challenging for some rural schools with limited laboratory facilities. The situation was exacerbated when schools were closed due to the COVID-19 pandemic. This thesis reports a laboratory kit design based on the Standard Curriculum for Secondary Schools in Malaysia (Kurikulum Standard Sekolah Menengah, KSSM). The kit was evaluated by students and experienced teachers from town and rural schools. Pre- and post-test was conducted with the students before and after using the kit. A questionnaire was disseminated to appraise the students' perceptions on practical learning. There was a significant improvement ($p < 0.05$) in the overall score of the post-test (90.32) compared to the pre-test (71.00). Both rural and town schools demonstrated a significant increase in the overall mean scores, from 68.67 and 73.34 in the pre-test to 91.34 and 89.33 in the post-test. There was also improvement in affection for chemistry among students after using the kit. The practical kit can be deployed in schools with laboratory constraints and to be used outside the school settings. It was designed to be affordable compared to traditional lab setting, safe and environmental-friendly due to minimal chemical used, and providing individualized hands-on exposure. Besides, this thesis also reports a citizen science program on household food waste for students to introduce the idea of citizen science to them and to evaluate their learning experience. The project focused on quantification of avoidable solid food wastes in the households using the food waste diary. The results were positive, that is more than 80% of the participants agreed that this program increased their interest in chemistry learning, raised awareness of food waste reduction and waste management, and improved scientific skills such as food waste measurement.

Keywords: Chemistry laboratory kit; COVID-19; Standard Based Curriculum for Secondary School; citizen scientist; food waste

Pembangunan Kit Amali dan Program Saintis Warganegara untuk Pembelajaran Kimia

ABSTRAK

Aktiviti amali adalah komponen penting untuk pembelajaran sains yang berkesan. Untuk menyediakan pengalaman makmal boleh menjadi cabaran kepada sekolah luar bandar yang mempunyai kemudahan makmal yang terhad. Keadaan bertambah serius apabila sekolah ditutup akibat pandemik COVID-19. Tesis ini melaporkan rekabentuk kit amali berasaskan Kurikulum Standard Sekolah Menengah (KSSM) di Malaysia. Kit ini dinilai oleh pelajar dan guru berpengalaman dari sekolah bandar dan luar bandar. Ujian pra dan pasca telah dijalankan bersama murid sebelum dan selepas menggunakan kit. Satu soal selidik telah diedarkan untuk menilai persepsi pelajar terhadap pembelajaran amali. Terdapat peningkatan yang ketara ($p < 0.05$) dalam markah keseluruhan pasca ujian (90.32) berbanding pra ujian (71.00). Kedua-dua sekolah luar bandar dan bandar menunjukkan peningkatan yang ketara dalam skor min keseluruhan daripada 68.67 dan 73.34 dalam pra ujian kepada 91.34 dan 89.33 dalam pasca ujian. Terdapat juga peningkatan dalam minat terhadap kimia dalam kalangan pelajar selepas menggunakan kit tersebut. Kit amali boleh digunakan di sekolah dengan kekangan makmal dan untuk digunakan di luar persekitaran sekolah. Ia direkabentuk dengan harga mampu milik berbanding dengan makmal tradisional, selamat dan mesra alam kerana penggunaan bahan kimia yang minimum, dan memberikan pendedahan individu secara langsung. Selain itu, tesis ini juga melaporkan program sains warganegara tentang sisa makanan untuk pelajar bagi memperkenalkan idea saintis warganegara kepada mereka dan menilai pengalaman pembelajaran mereka. Projek ini memberi tumpuan kepada pengiraan sisa makanan pepejal yang boleh dielakkan dalam isi rumah menggunakan diari sisa makanan. Terdapat keputusan yang positif, iaitu lebih daripada 80% peserta bersetuju bahawa program ini meningkatkan minat mereka

dalam pembelajaran kimia, meningkatkan kesedaran tentang pengurangan pengurusan sisa makanan, dan meningkatkan kemahiran saintifik seperti pengukuran sisa makanan.

Kata kunci: *Kit amali kimia; COVID-19; Kurikulum Berasaskan Standard Sekolah Menengah; saintis warganegara; sisa makanan*

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LIST OF ABBREVIATIONS

ASM	Academy of Science Malaysia
COVID	Coronavirus Disease
DOHE	Department of Higher Education
KBSM	Kurikulum Bersepadu Sekolah Menengah (Integrated National Curriculum for Secondary School)
KBSR	Kurikulum Standard Sekolah Menengah (Standard Secondary Schools Curriculum)
KSSM	Kurikulum Standard Sekolah Menengah (Standard Secondary Schools Curriculum)
OED	Oxford English Dictionary
PPPM	Pelan Pembangunan Pendidikan Malaysia (Malaysia Education Development Plan)
RLs	Remote Labs
RM	Ringgit Malaysia
SMK	Sekolah Menengah Kebangsaan (National Secondary School)
SPM	Sijil Pelajaran Malaysia (Malaysian Certificate of Education)
SPS	Science Process Skills
STEM	Science, Technology, Engineering and Mathematics
UNIMAS	Universiti Malaysia Sarawak
VLs	Virtual Labs

CHAPTER 1

INTRODUCTION

1.1 Study Background

Chemistry is one of the most important branches of science; it is a difficult subject for many students because curricula usually contain many abstract concepts central to further learning in chemistry and other sciences (Taber, 2002). Chemistry develops from theoretical and practice, and the heart of chemistry comes from practise at the laboratory (Hodson 2001). In learning chemistry, it is important that students use an inquiry learning pedagogical approach to obtain their thoughts, opinions, and observations. This student-centred approach strengthens the connection between teaching and research (Spronken-Smith & Walker, 2010). However, there are problems related to chemistry education worldwide in general and in Malaysia in particular. These include, first, the ability to develop practical skills, and second, the ability to apply various chemistry skills to solve problems daily (Fadzil & Saat, 2013).

The first issue, the ability to develop practical skills in students is of concern to educators. The ability to perform hands-on work in the science laboratory is a crucial science process skill and a common goal of the science standards (Schwichow et al., 2016). Hamza (2013) argued that students need hands-on work experiences for future learning and that science experiences can be fruitful in a different setting. Hands-on work gives students the opportunity to investigate phenomena, draw conclusions, and practice scientific skills using equipment, leading to meaningful science learning and the development of critical thinking skills (Shana & Abulibdeh, 2020).

Several studies shown that many students at all levels of education have misconceptions about basic chemistry concepts (Nakhleh, 1992; Garnett et al., 1995; Taber, 2002; Çalik et al., 2007). The main reason is that chemistry knowledge is learned at three levels, namely submicroscopic, macroscopic, and symbolic (Figure 1.1) and the connection between these levels should be explicitly taught (Johnstone, 1991; Gabel, 1992; Harrison & Treagust, 2000; Ebenezer, 2001; Ravialo, 2001; Treagust et al., 2003; Taber, 2003; Chandrasegaran et al., 2007).

Macroscopic level describes the quantity properties of tangible and visible phenomena in learners' everyday experiences of observing changes in the properties of matter, such as changes in colour, formation of precipitates and release of gases in chemical reactions (Chandrasegaran et al., 2009). Luviani et al. (2021) emphasized that the submicroscopic level is also known as a molecular representation that provides explanations at the atoms, molecules, and ions level and Symbolic level involves the use of chemical formulas and equations, drawings, diagrams, and models of particles to symbolize the matter (atoms, molecules and ions). It can provide information at both the macroscopic level (number of mole of the substances) and the submicroscopic level (number of formula units of the substances). The interactions and distinctions between them are also important features of chemistry learning and necessary to understand chemical concepts (Luviani et al., 2021). Thus, if students have difficulty at one of the levels, it will most likely affect their understanding at another level.

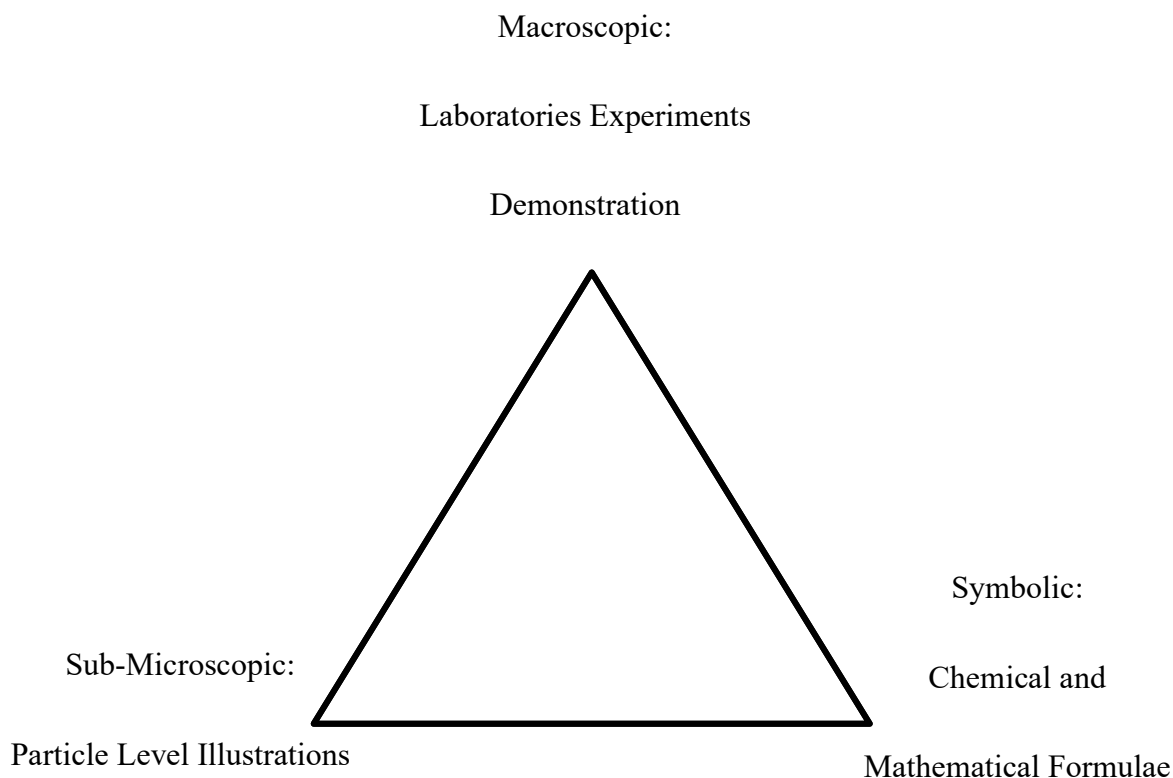


Figure 1.1: Levels of chemistry knowledge

Numerous studies have confirmed that science learning can be enhanced when students conduct hands-on experiments in the laboratory (Hofstein, 2004; Hofstein & Lunetta, 2004; Lunetta et al., 2007). Laboratory activities have been assigned a special role in science education. Therefore, hands-on laboratory work is fundamental and essential to students' understanding and skill development in science education, but it is often missing from actual school curricula around the world (Bradley et al., 1998). Laboratory activities play an important role to reinforce understanding on the concepts making chemistry real for the students. Both physical and cognitive skills can be developed through the laboratory experience, such as manipulating variables, constructing hypotheses, understanding and following procedures, making observations and inferences, taking data readings, analysing data and results (Dietmar, 2021).

Besides the ability of practical skills, it is crucial to develop the ability to apply different chemistry knowledge in daily problem solving. Several studies have shown that secondary school students prefer to actively participate in learning science through hands-on laboratory work (McFarlane, 2013; Hasni & Potvin, 2015; Schwichow et al., 2016). To enhance students' interest in learning science, project-based approach can provide opportunities for students to engage and develop an ability to apply different chemistry concepts in daily problem solving. Previous research revealed that citizen science program has a great potential to foster learning of science (Bonney et al., 2009). Citizen science is scientific research conducted completely or partially by amateur or nonprofessional scientists (Gura & Trisha, 2013). Little research has been done on the effects of citizen science projects on the knowledge and attitudes of participants, but available data suggest that the results are positive (Brossard et al., 2005). There are researches on citizen science, from a long-running and large-scale project to measure precipitation of raining, hail and snow in the United States, related to environmental chemistry (Holzer et al., 2011).

In Malaysia, enrolment of students into science stream fell short of expectations. The government has targeted 60% of student entry into science stream and 40% for the art stream (Chew et al., 2014). This challenge to improve science literacy among Malaysian students is a heated conversation in the education field. According to studies, the problem of low enrolment in science subjects at the secondary school is worrying (Smith, 2011; Fadzil & Saat, 2014; Kennedy et al., 2014). Table 1.1 shows the enrolment of students into science stream from the year 2018 to 2020 based on the record of the Ministry of Education (Laporan Tahunan Pelan Pembangunan Pendidikan Malaysia, 2020). The percentage of students in Science, Technology, Engineering and Mathematics (STEM) were 47.18 % for the year

2020, 43.47% for the year 2019 and 44.36% for the year 2018 (Laporan Tahunan Pelan Pembangunan Pendidikan Malaysia, 2020).

Table 1.1: The percentage of enrolment of students in science stream

Year	Percentage (%)
2018	44.36
2019	43.47
2020	47.18

The trends reported in Malaysia have also been observed in other countries, namely France (Charbannier & Vayssettes, 2009), England and Wales (Smith, 2011), Australia (Kennedy et al., 2014) and Western European countries (Sjøberg & Schreiner, 2005; Organisation for Economic Cooperation and Development, 2007; Van Griethuijsen et al., 2015). This suggests that the decline in enrolment of students in science education may transcend national and cultural boundaries. To make matters worse, student interest in science has gradually declined over the years (Osborne et al., 2003). This has led policymakers to worry about their country's economy, where science and technology play an essential role in their people (Gago et al., 2004). Previous research showed that the lack of practical work may affect the students' interest and reduce their enrolment in science classes (Tolessa & Seid, 2016).

The Ministry of Education of Malaysia had review on the education system in Malaysia in 2011. The outcome was the implementation of Standard Secondary School Curriculum (Kurikulum Standard Sekolah Menengah, KSSM) starting in 2017 to replace the Integrated Secondary School Curriculum (Kurikulum Bersepadu Sekolah Menengah,

KBSM) which began in 1989. This step aimed to meet new policies under Malaysia Education Development Plan (Pelan Pembangunan Pendidikan Malaysia, PPPM) 2013-2025 for curriculum quality to be comparable to the international standards (Dokumen Standard Kurikulum dan Pentaksiran, 2018).

The KSSM chemistry curriculum aims to develop scientifically literate students through learning experiences, understanding chemistry-related concepts, skill development, and appreciation of the impact of scientific and technological developments in society (Curriculum Development Center, 2018). Students will be able to communicate, make decisions based on scientific knowledge, and be able to continue their education and careers in STEM (Science, Technology, Engineering, and Mathematics). The chemistry curriculum at KSSM emphasizes inquiry and problem solving. Scientific process skills and thinking skills are built in the process of inquiry and problem solving. The scientific process skills (SPS) are needed to find solutions to a problem or make decisions in a systematic way (Curriculum Development Center, 2018). The mental process promotes critical, creative, analytical, and systematic thinking. Mastery of SPS combined with a positive attitude and sound knowledge ensures effective thinking in students. Manipulative skills are psychomotor skills that enable students to perform hands-on work in science. They include the development of hand-eye coordination (Curriculum Development Center, 2018). Examples of these manipulative skills include the ability to correctly and safely handle scientific equipment, chemical substances, and specimens.

Nevertheless, there are some challenges in implementing practical chemistry sessions in Malaysia, especially with limited facilities for practical sessions in rural areas or home-based students or students learning remotely due to quarantine/pandemic Covid-19.

Campbell (2001), Fadzil and Saat (2013) have found that science teaching and learning have focused too much on the retention of knowledge, with students doing too much writing and too little hands-on work. Thus, students may have trouble in handling materials and apparatus in the laboratory. This would end up producing or graduating students who lack of the ability to develop practical skills (Campbell, 2001; Fadzil & Saat, 2013). In Malaysia, most schools are fully equipped with laboratories, however the facilities are insufficient to support individual work. Generally, schools can cater to group work in the size of 4-5 students (Sharifah & Lewin, 1993). In fact, students should work through the hands-on activities individually to promote and develop various process-related skills, such as making hypothesis and observation, interpreting data, making prediction and communication, and drawing conclusions (Organisation for Economic Co-operation and Development, 2007). According to Tesfamariam, Lykknes, and Kvittingen (2015), the obstacles to conduct hands-on activities are mainly due to large class sizes, budget and time constraints, and inadequate teacher preparation. As a result, hands-on activities are often dropped from the curriculum in most developing countries.

Some institutions have innovated practical experience through virtual or remote labs (Zakaria et al., 2012). These labs allow learning to occur regardless of location or time; they transfer instruction from the impenetrable walls of a classroom to any location where a computer is available and allow applications to be made more dynamic through simulations (Yang & Heh, 2007). However, some skills and abilities traditionally acquired in hands-on laboratories, such as using laboratory equipment and tools, measuring, and adapting real laboratory experiences to daily life, cannot be developed virtually. Besides, there is lack of interaction between peers and teachers in virtual learning (Ma & Nickerson, 2006).

Some institutions use microscale chemistry in both developed and developing countries to provide hands-on experiences in schools. Research by Hanson et al (2011) has shown that small-scale devices can provide the same function as large macro-glass devices for standard laboratories. However, there are limitations in microscale chemistry techniques; it can be challenging to handle the miniature apparatus – fitting, observing the results and cleaning. Also, microscale apparatus can be quite costly to maintain for schools (Tsefamariam et al., 2014).

Besides, there are challenges on the second issue, which is the ability to apply different concepts for problem solving in chemistry. This is confirmed by Lunetta et al (2007) stated that educators always face challenges in nurturing interest in learning chemistry among school children. Real life application is necessary for the chemistry knowledge and the scientific skills remain only theoretical science but not practical activities. Students need to recognize the chemical nature and interactions of matters in everyday substances and do not understand the role chemistry knowledge plays in solving everyday problems (Cardellini, 2012). They need to see the practical benefits of their efforts and the usefulness of the chemical knowledge they have acquired.

According to research by Cardellini (2012), apart from nurturing interest in chemistry, it is challenging to ensure that students see the importance of chemistry instruction by applying chemistry concepts to solve problems from daily life, such as food waste. Learning about the nature of chemistry, poses the problem of how to facilitate actual hands-on investigations in which chemical ideas play a central role and skills are used (Marchak et al., 2021). Citizen Science with a focus on chemistry offers a limited alternative, but one that has yet to be fully explored. Therefore, the connection between chemical theory

and its real-world applications must be demonstrated to foster student interest in the subject (Lukyanenko et al., 2020).

Previous research by Dickinson and Bonney (2012) has shown that the major challenges to be overcome if the citizen scientist approach to lifelong chemical education is to be used more widely are three: increasing the willingness of professional chemists to play a leading role in projects, convincing these chemists to work in multidisciplinary teams with other scientists, since “Environmental chemistry” is expected to be a primary target, designing projects that appeal to youngsters and can be easily incorporated into their current lifestyles (Dickinson & Bonney, 2012).

1.2 Problem Statement

This research is aimed at developing a practical kit with flexibility and affordability; and designing a citizen scientist program on food waste. According to Mafumiko (2008), there was non-availability of the necessary equipment for chemistry activities, the cost of expensive, delicate and complicated equipment puts the benefits of science out of the reach of students especially those in less endowed communities in rural areas. Students may only observe demonstrations of such activities, as they are performed by teachers, or through video animations (Mafumiko, 2008). There was micro-scale chemistry equipment has been used to replace conventional macro equipment, but they were not suitable for Malaysian syllabus and curriculum. For examples, micro chemistry equipment was introduced in underprivileged basic schools in South Africa by Bradley (2000), Tanzania by Mafumiko (2008) and Mozambique by Kombo (2006). In this study, the practical kit was developed for KSSM syllabus to ensure the ability of practical skills among students at an individual

level. It is flexible and easy to carry, whether used in schools with laboratory constraints or outside the school settings.

To nurture the ability of applying chemistry knowledge in daily life, citizen scientist program on food waste was introduced in this research. This is to expose the students to learn through citizen science where this strategy can be potentially integrated into chemistry curriculum in order to boost the interest of students in learning chemistry (Jenkins, 2011). .

1.3 Objectives

In order to improve the teaching and learning of secondary students in chemistry, this study attempted to improve the practical experience and investigate the potential active learning programme for these students. The specific objectives of the study include:

- (i) To develop a chemistry portable practical kit that contains experiments for upper secondary chemistry students that serve the KSSM.
- (ii) To develop an inquiry learning program on the food waste topic under KSSM chemistry syllabus based on the citizen scientist approach .

1.4 Significance of the Study

In the context of education for all, we must take up the challenge of providing hands-on experience in chemistry (Bradley, 1999). The success of this research study can have a significant impact on chemistry education in Malaysia. First, the practical set developed can reduce the cost and minimise the chemical waste disposal. Chemistry experiments can even be conducted in rural schools or at home without having traditional laboratory setting (Mashita, 2009). Secondly, students can read and understand the procedure in the user's

manual and are able to follow the instructions given to conduct experiments in the practical kit.

1.5 Scope of the Study

This research is aimed to develop a practical kit design a citizen scientist program on food waste.

Thirty students from rural and town schools around Kuching, Sarawak, Malaysia were randomly selected for the practical kit. The scope of the study for the citizen scientist programme is limited to thirty students in Kuching, Sarawak, Malaysia. According to Bartlett et al., this is the minimum number of respondents to conduct a t-test statistical analysis of a study. The number of respondents is rather limited due to Covid-19 pandemic, resources and financial constraint (Bartlett et al., 2001). These are form five students between the ages of 16 and 18 who will be contacted through their chemistry teacher. This recruitment phase will last a maximum of 2 months. Each student invited to the study will be asked to complete a cognitive test and an attitude questionnaire before and after using the kit, to assess any changes in their knowledge and attitude towards chemistry learning.

1.6 Chapter Summary

The thesis is divided into five chapters. Chapter 1 begins with an introduction to the background of the study. It then describes the problem of this study, the specific research objectives, and finally the significance of the study.

Chapter 2 reviews of the literature that relate the introduction with past studies and findings.

Chapter 3 discusses the study about development of a portable practical kit for laboratory learning of chemistry based on KSSM. This chapter begins with introduction to

discuss the specific idea of a practical kit for KSSM. It then describes the research methodology, results and discussion of the study.

Chapter 4 discusses the development of a citizen scientist program for KSSM. It outlines with introduction about citizen scientist concepts and definition research methodology to quantifying food waste as citizen scientist program. This chapter also present the result and discussion of the study.

Chapter 5 summarises the thesis by outlining the research findings and making recommendations for further research, in order to improve chemistry education in KSSM.

CHAPTER 2

LITERATURE REVIEW

2.1 Practical Work

2.1.1 Definition

Practical work in this study refers to students working individually or in small groups in science learning activities to manipulate the materials or object and observing on what they are investigating (Fadzil & Saat, 2013). Abrahams and Millar (2008) and Abrahams et al. (2013) define practical work as any teaching and learning in which real objects are manipulated and observed. Observation and manipulation of objects and materials can take place in school laboratory or in an out-of-school laboratory setting such as at home. Learning processes involve the collection and interpretation of data.

Practical work engages students in investigation, communication, inquiry and analysis activities related to scientific skills (Shana & Abulibdeh, 2020). Appropriate hands-on laboratory activities can effectively promote the development of reasoning, inquiry, and problem-solving skills in students. These activities can also promote positive mindset and provide opportunities for students to improve their collaboration and communication competency (Hofstein & Lunetta, 1982).

2.1.2 Laboratory Practical Work in Chemistry Education

Practical work is essential in chemistry education (Nakhleh et al., 2003) and has long played a special and fundamental role in science curricula as a means of understanding the world of nature. Cooper and Stowe (2018) mentioned that the goal of chemistry education is to increase students' knowledge of the natural world and to help them understand the

information and models that scientists use to describe their presence. Teaching and learning science involve presenting to learners specific phenomena or placing them in situations where they can observe with their own eyes (Cooper & Stowe, 2018).

A study by McFarlane (2013) emphasizes that to increase student interest in learning science subjects, it is necessary to make hands-on instruction more active and provide opportunities for them to engage with science. This belief needs to transform by adopting student-centered approaches to science learning. Therefore, hands-on work is one of the most distinctive features of science that can spark students' interest in learning the subject (Allen, 2012; Sorgo & Spornjak, 2012).

In countries with a long culture of laboratory instruction in science at the school level, hands-on work is considered by many teachers to be an important aspect of their daily teaching. Learners are expected to understand and remember things that have been done rather than things that have only been told (Abraham & Millar, 2008). Many educators and others interested in science education consider it the key to sparking and sustaining students' interest in science and encouraging them to pursue the subject in future. Research in hands-on work has developed tremendously over the years and is increasingly given the priority (Hofstein & Mamlok, 2007).

2.1.3 Challenges in Conducting Laboratory Practical Work in Malaysia

Students have to play an active role in the teaching and learning process to be able to develop understanding and to construct meaning. At the same time, their teachers act as facilitators to provide necessary opportunities for learners (Jenkins, 2000). Despite the emphasis on the advantages of individual lab work, the research found that teachers commonly favour practical activities in groups and this limits the active participation among

students in Malaysia. Some members tended to play passive roles and even observed passively (Sharifah & Lewin, 1993).

Recent studies have shown that practical work is still needed to be improved in many science laboratories in Malaysia (Fuccia et al., 2012; Abrahams et al., 2013; Fadzil & Saat, 2013). Science laboratories are the best place to learn scientific skills, such as manipulative skills, which are learned as part of formal science education (Fadzil & Saat, 2013). Due to the lack of hands-on work in science classrooms, students may need help with using tools and equipment in the laboratory (Abrahams et al., 2013). Consequently, these students lack the requisite requirement for programmes like medicine, engineering and any other science related disciplines (Omiko, 2015). The literature has a consensus that students have difficulty using and handling scientific equipment knowledgeably (Wickman & Ostman, 2002; Grant, 2011; Fadzil & Saat, 2013; Hamza, 2013; Tesfamariam et al., 2015).

In addition, studies have shown that science laboratory activities in school are also critical in preparing students for higher education (Delargey, 2001; Buffler et al., 2001). It is assumed that students' acquisition of practical skills at the higher level depends on their progress at the lower level. The studies clearly show that inadequate opportunities to conduct experiments in school have greatly affected students' transition to higher levels of education due to lack of skills and experience (Wickman & Ostman, 2002; Grant, 2011; Fadzil & Saat, 2013; Hamza, 2013; Tesfamariam et al., 2015).

Grant (2011) also found that the lack of practical skills at the university level is primarily due to little exposure to hands-on work in high school. Therefore, higher education institutions need to adapt laboratory-based instruction to emphasise developing of practical

skills in first-year internships. Wickman and Ostman (2002) demonstrated that university students learn science by sequentially drawing on previous experiences in school.

2.2 Current Strategies and Approaches for Laboratory Practical Work

2.2.1 Virtual Labs and Remote Labs

Virtual labs (VL) replace hands-on learning with a computer simulation that students can interact with to gather information. Students enter values and collect output data from an online simulation of a real-world problem (Shimba et al., 2017). Remote Labs (RLs) allow students to operate equipment on campus, but through a computer interface. This can be done by remote control, but also by sending instructions to an on-campus staff member who carries out the student's instructions (Miguel et al., 2015). Thus, remote hands-on can be synchronous remote participation, when instructions are transmitted in real time, or asynchronous participation by proxy, when instructions are sent but later carried out by a staff member (Honig et al., 2022).

Due to the rising cost of chemicals and equipment, some facilities have resorted to virtual labs (VLs) or remote labs (RLs), while others have reduced the number of their lab activities to cut costs (Chan et al., 2021). The advantages of VLs or RLs, which provide tools for location- and time-independent education, move instruction from the closed walls of a classroom to any location with a computer and allow for more dynamic applications with simulations (Yang & Heh, 2007). When experimenting in a virtual environment, abstract concepts of chemistry education become concrete, daily life and instruction are integrated, and students can progress at their own pace according to their individual learning needs (Stieff & Wilensky, 2003). These labs can be used as a supportive tool in real labs or as an alternative lab when a physical lab is not available or the conditions of the physical lab are

inadequate. VLS are accessible to people with disabilities and can be viewed or even recorded by many people. VLS can be a better alternative to hands-on laboratories for hazardous experiments (Heradio et al., 2016).

The major drawback is that some skills and abilities that can be acquired in hands-on laboratories, such as using laboratory equipment and tools, taking measurements and adapting real laboratory experiences to daily life, cannot be taught through VLS and RLS (Hamed & Aljanazrah, 2020). Using these labs and reducing lab activities will limit students' efforts to improve their research and lab skills in preparation for work. Developing manipulative skills is an important goal of hands-on work (Abrahams et al., 2013). According to Kempa (1986), manipulative skills are best defined as psychomotor skills relate to individual cognitive functions with corresponding physical movements. In science, manipulative skills focus on using and handling of scientific equipment and chemical substances during scientific investigations in the laboratory (Fadzil & Saat, 2014). In addition, students are introduced to proper techniques for the safe use, cleaning, and storage of scientific equipment. If students are unable to acquire scientific manipulation skills, it can seriously affect their acquisition of other desirable skills in the laboratory. For example, if they have difficulty operating a piece of equipment, it may prevent them from making important observations and collecting relevant data (Anderson, 1970; Johnstone & Al-Shuaili, 2001; Fadzil & Saat, 2014). In addition, students who are proficient in scientific manipulatives have a better opportunity to focus on developing scientific process skills, which include skills such as observing, classifying, measuring and using numbers, inferring, predicting, communicating, using space-time relationships, interpreting, operationally defining, controlling variables, hypothesizing, and experimenting (Johnstone & Al-Shuaili, 2001).

2.2.2 Multimedia Presentation

Mayer (2001) stated that the purpose of multimedia is to provide multiple channels of communication to address learner differences and present instructional content through optimal modalities, including text, narratives, graphics, illustrations, photographs, diagrams, animations, videos, music, sound effects, virtual reality, and interactive programs. A set of multimedia design principles, including multimedia, contiguity, segmentation, coherence, personalization, and individual differences, and learners were able to achieve better learning effectiveness (Mayer et al., 2003; Mayer et al., 2005; Inglese et al., 2007; Clark & Mayer, 2008). This is an effective teaching tool in crowded classrooms and allows for the presentation of long experiments in a limited time frame. It is useful for students as it facilitates understanding and for teachers as a guide for teaching (Edelson et al., 1999; Kumpulainen et al., 2003). However, one of the disadvantages was that students were uncomfortable with having to watch the video for a long time; the second disadvantage was that students did not have time to examine the experimental materials and try the experiments themselves (Sever et al., 2013).

2.2.3 Microscale Chemistry

Microscale chemistry refers to an approach or technique for conducting experiments on a smaller scale using small amounts of chemicals and often (but not always) with simple equipment (Rayner-Canhan, 1994; Skinner, 1997). Microscale chemistry involves reducing chemical reagents to an absolute minimum, i.e., 25-100 milligrammes of solids and 50-200 microliters of liquids, and switching from glassware to modern polymer or plastic materials (Bhanumati, 1997). Research showed that small-scale devices can serve the same purpose as large macro-glass devices for standard laboratories (Bradley, 1999). Some institutions in

developed and developing countries are now using microscale chemistry equipment to address the lack of hands-on activities in schools (Hanson, 2011).

However, there are limitations in the practice of microscale chemistry techniques. Study by Mashita et al. (2009) stated that experiments that require heating and concentrated acids (e.g., nitric acid) are not readily feasible due to the plastic nature of the equipment used in microscale chemistry. Besides, students may need help to handle the actual size apparatus when they need to use it in the real practical test in the classroom. They found the apparatus is too small (Mashita et al., 2009). Research also found that some students often could not see if precipitates were formed. Identification of the colours of such precipitates was often a problem for them (Hanson, 2014). Teachers need help to identify some devices in the kit, problems assembling some devices, problems cleaning some plastic devices, problems with some glass devices breaking, and problems determining accurate readings. Some reactions in microscale experiments were too reactive to make the students fail to make accurate observations (Tesfamariam et al., 2014). Microscale chemistry may save cost in terms of usage of chemicals, but the microscale equipment and glassware are actually very costly.

2.3 Definition of Citizen Science

The first recorded use of the term citizen science appeared in an issue of the MIT Technology Review from January 1989, according to the researchers of the Oxford English Dictionary (OED). The ‘Lab for the Environment’ article discusses three examples: community-based labs researching environmental hazards, Greenpeace’s lab work, and Audubon's recruitment of volunteers in a ‘citizen science’ program (Haklay et al., 2021).

Citizen science is sometimes described as public participation in scientific research, participatory monitoring, and participatory action research, the results of which are often

advances in scientific research by improving the capacity of the scientific community and increasing the public's understanding of science (Hand, 2010; Doyle et al., 2019; Steven et al., 2019).

2.3.1 Citizen Science Project in Chemistry Education

The citizen science project has great potential in the chemistry instruction and learning. There is evidence that the best way to learn about “nature of science” is through direct instruction and reflection on the processes of learners’ involvement in scientific inquiries (Abd-El-Khalick, 2005). It is suitable for anybody, including school students or members of the general public, in the context of life-long learning. Citizen science involves volunteers carrying out scientific investigations, often in collaboration with professional scientists (Bell et al., 2005). The idea has gained considerable momentum, such that a central database, associated with a Citizen Science Association, exists for existing activities in the United States. Environmental monitoring, whether of the soil, water, or air, provides the theme of the majority of projects, which suggests that chemistry related projects (Overdevest et al., 2004).

2.3.2 Pedagogical Approach related to Practical Work and Citizen Science Project

There are three approaches towards inquiry-based instructions. First, the confirmation test, in which the teacher has taught a specific topic and then develops a procedure that takes students through an activity whose results are already known (Toma, 2022). This method allows teachers to reinforce concepts taught and guide students to follow procedures, collect and record data correctly, and improve their understanding. Second, Toma (2022) stated that a structured inquiry is used in which students conduct an investigative process on a question formulated by the teacher within a given framework. The

necessary materials are also provided by the teacher. Teachers know the results but do not reveal them. Students must find out the results themselves by working out the hands-on activities. Third, guided inquiry. Teachers provide the materials needed to solve the problem, and students must construct their own steps for the action (Almuntasheri et al., 2016). This method is suitable for high school students who are given a framework but left room for further experimentation.

2.4 Methods of Teaching and Learning of Chemistry

According to Edgar Dale's cone of experience, shown in Figure 2.1, people learn, retain, and remember 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say and write, and 90% of what they say while doing a thing (Letrud & Kare, 2012). Based on Dale's cone of experience, direct and purposeful learning experiences, such as hands-on experiences, are the most effective method. Dale's cone of experience suggests that when choosing a teaching method, it is vital to involve students in the process so that they retain the information optimally (Davis & Summers, 2015).

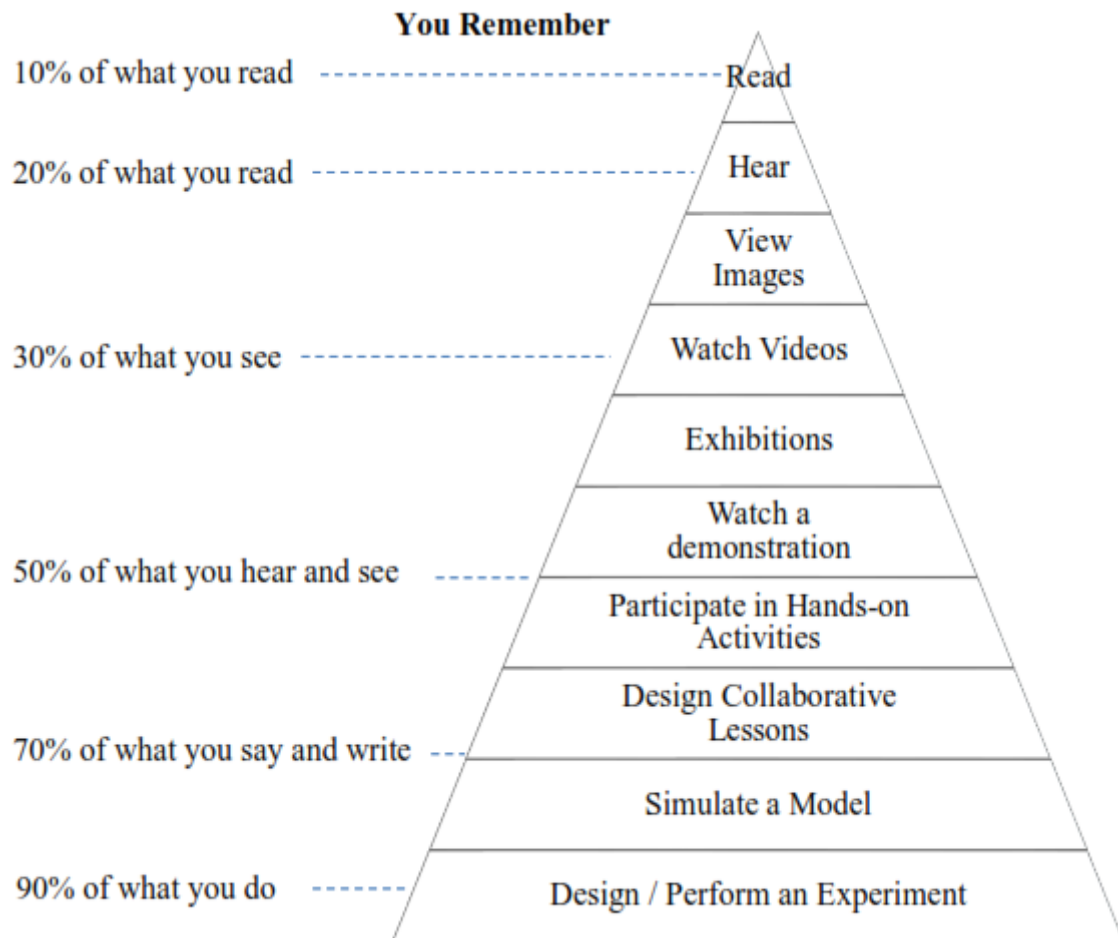


Figure 2.1: Edgar Dale's Cone of Experience

According to the proposed facts by Wrenn and Wrenn (2009), hands-on work activities and classroom projects will help students connect to knowledge learned in the classroom. These activities should reinforce instructional concepts and encourage students to engage in the teaching and learning process. Science subjects should be explicitly explained to students so they can fully benefit from them. Otherwise, students would view hands-on work as merely a diversion from the routine activities of speaking, listening, and writing (Shana & Abulibdeh, 2020). Therefore, practical learning is the key to developing students' knowledge and skills by combining practise and theory. Introducing practical work is useful for teachers in schools because it helps them teach various topics in the science

curriculum by engaging students in the learning process (Abraham & Millar, 2008). Many schools could also improve their science curriculum by providing practical work along with teaching theoretical knowledge using traditional teaching methods.

2.5 Teaching and Learning of Chemistry during COVID-19

The pandemic COVID -19 cost many lives and changed the global education system. This has led to a rapid transition from face-to-face classroom meetings to online education via video conferencing platforms, such as Zoom or Google Meet (Tigaa & Sonawane, 2020). A study by Lapitan et al. mentioned that many chemistry educators used the following pedagogical approaches: (1) synchronous (2) asynchronous learning and (3) blended learning strategy. In synchronous online teaching, lecturers deliver their lectures in real time and students meet with online software via video conferencing during scheduled lecture times. Students can attend the lectures and ask questions verbally or via live lectures or text chat. In asynchronous lectures, the lecturer records the lecture videos and uploads them to the YouTube or learning management system so that students can access them at their most convenient time. The blended online learning strategy is practically the most appropriate method as it combines the advantages of synchronous and asynchronous strategies. The main motivation in the blended strategy is to increase the student's participation in their own learning process rather than quietly participating in a synchronous discussion (Lapitan et al., 2020). However, during the transition to online education, both students and teachers faced enormous challenges, especially in rural areas. Access to reliable internet and electricity infrastructure has been found to be critical to engage students and improve access to educational resources to motivate students and improve learning outcomes (Tigaa & Sonawane, 2020).

CHAPTER 3

DEVELOPMENT AND ASSESSMENT OF A CURRICULUM-BASED PRACTICAL KIT FOR LEARNING OF CHEMISTRY

3.1 Introduction

In learning chemistry, educators must consider the ability to develop practical skills in students. This is conducted through laboratory practicals, which is an essential component in the learning science. Woolnough and Alsop (1985) infers that laboratory activities are exercises aid to develop practical skills in students giving them the ‘feel’ for phenomena, and to be actively and immensely involved as a ‘problem-solving scientist’.

The curriculum for science in Malaysia adopted the British educational framework after its independence in 1957 (Sumintono, 2015). The curriculum gradually evolved incorporating the culture and religion of the multiracial society in Malaysia, leading to the formation of the KBSR and KBSM. This curriculum was first introduced in 1980s, emphasizing on reading, writing and arithmetic skills in balance with spiritual, emotion and physical development, inculcating life-long learning (Lee, 1992). This curricular structure was then revised and replaced with KSSR (Standard Based Curriculum for Primary School) and KSSM (Standard Based Curriculum for Secondary School), shifting towards student-centered learning with a focus on the 21st century skills such as communication, critical thinking, problem solving and innovation (Malaysia Education Blueprint 2013 - 2025). One of the changes in the science curriculum upon reformation from KBSM to KSSM is the re-introduction of practical assessment in the SPM for upper secondary students. The practical assessment was fully implemented in 2021, replacing the written test; students are expected to conduct experiments individually. This is to ensure students demonstrate mastery of

science process and manipulative skills which include handling of apparatus, implementing the experiment, recording the observation, analyse and evaluate the data.

Implementing the practical activities is challenging for some schools, especially those in rural areas. Some schools do not have a laboratory, or the laboratories are too old with shortage of chemicals and consumables (ASM Advisory Report 2011). This situation is exacerbated over the COVID (Coronavirus Disease) pandemic when the practical lessons were affected. Classes were forced online, which poses a huge challenge for effective practical learning. Some laboratory lessons were delivered via video demonstration. However, this approach does not warrant a similar experience with the hands-on exposure (Bradley, 1999). When the practical assessment was implemented in 2021, students and parents continuously expressed their concerns over students' learning efficiency and readiness for practical assessment. A student articulated her concern saying, *"I feel let down at this moment. This is an important exam for me and, as a science student, I am sitting for nine subjects. However, the paper 3 for all my science subjects cover lab work and we hardly did them during online classes"* (theVibes.com, 2021).

A breakthrough is motivated to overcome the challenge in maintaining practical classes when schools are closed or laboratory facilities are unavailable. In the traditional setting, laboratory classes are carried out within the school timetable, with teachers facilitating the lessons. The conventional laboratory lessons for chemistry inherits two major limitations: inflexible and high cost of maintenance. A readily available solution is the science kit which is often sold as a toy to impart learning. Most of the kits are designed to provide more entertaining experience in learning science. These kits aim to stimulate interest, enhance learners' understanding and create positive habits of mind for science

(Hodson, 1993; Hofstein & Lunetta, 2004). The learning process is rather unstructured, informal and ungoverned by a syllabus. The microscale apparatus can be an alternative option for experimental learning; however, they are expensive and are usually designed to teach very specific topics. The cost incurred to maintain a microscale set, restricts individual hands-on exposure. Hence in this study, a practical kit was developed based on the syllabus of KSSM for chemistry, offering advantages of flexibility where it can be deployed in schools with laboratory constraints or to be used outside the school settings. The kit is affordable, safe and environmental-friendly providing personalized hands-on exposure. The effectiveness of the kit for learning of chemistry was evaluated via cognitive assessment and questionnaires.

3.2 Materials and Methods

3.2.1 Development of Kit

3.2.1.1 Scope of Learning

The kit was designed based on the chemistry syllabus for Form 4 and Form 5, equivalent to Year 10 and Year 11 for Cambridge curriculum. Table 3.1 summarizes the syllabus for the two levels, and a total of twelve (12) experiments were identified and incorporated in the kit. The user's manual (Appendix A) contained the background, objective, experiment procedure, records of observations/results and post-lab activity for each experiment. The manual was completed with access to the Materials Safety Data Sheet that had uploaded to Google Drive (<https://docs.google.com/document/d/1Ubt3azdaH3OlhvWx3oTvTfs2bK5MM1aSSaGizJXNg40/edit?usp=sharing>) and the function of each apparatus was described (Appendix B). The user's manual was prepared in bilingual (English and Malay language).

Table 3.1: Syllabus of chemistry and experiments for Form 4 and Form 5

Form	Theme	Scopes of learning	Experiments in the kit
4	Importance of Chemistry	• Introduction to chemistry	
	Basic Chemistry	• Matter and atomic structure • Mole, chemical formula and chemical equations • Periodic table • Chemical bonding	
	Interactions Between Matters	• Acid, base and salts • Chemical reactions	1. To prepare a standard solution 2. Dilution 3. Solubility of salt in water 4. Precipitation (Double decomposition reaction) 5. Preparation of insoluble salts 6. The role of water in showing acidic property 7. The role of water in showing alkaline property
	Industrial Chemistry	• Manufacturing industry	
5	Chemistry Process	• Redox reactions	8. Displacement reaction
	Organic Chemistry	• Carbon compounds	
	Heat	• Thermochemistry	9. Exothermic and endothermic reactions 10. Heat of displacement 11. Heat of precipitation 12. Heat of neutralization between strong alkali and weak acid
	Technology in Chemistry	• Polymer • Consumer chemistry and industry	

3.2.1.2 Design and Optimisation of Kit

The experiment procedures were optimized to ensure minimal quantity of chemicals were used to observe the experimental changes promising reasonable cost, minimum hazard to users and no wastage. The optimization takes into account of the chemicals used, the amount made available to the users, the suitable apparatus size and type, safety as well as disposal of the chemicals. The chemicals and apparatus are provided in a kit of dimensions 32 cm (Length) $\times$ 23 cm (Width) $\times$ 16 cm (Height) as shown in Figure 3.1. The chemicals are stored in individual screw cap vials and the experiment manual is included. Personal protective equipment including gloves and safety goggles are also provided. A mercury free thermometer is supplied to ensure users are not exposed to any hazardous risk. All chemicals and apparatus provided in the kit are summarized in Table 3.2.



Figure 3.1: Photo of the laboratory practical kit

Table 3.2: List of chemicals and apparatus provided in the kit

No.	Chemicals/Apparatus	Quantity provided
1	Ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$	1.5 g
2	Barium chloride, BaCl_2	0.5 g
3	Barium sulphate, BaSO_4	0.5 g
4	Calcium carbonate, CaCO_3	0.5 g
5	Copper (II) sulphate, CuSO_4	5.0 g
6	Lead (II) chloride, PbCl_2	0.5 g
7	Lead (II) nitrate, $\text{Pb}(\text{NO}_3)_2$	3.3 g
8	Oxalic Acid, $\text{C}_2\text{H}_2\text{O}_4$	5.5 g
9	Potassium iodide, KI	2.7 g
10	Sodium carbonate, Na_2CO_3	2.6 g
11	Sodium hydroxide, NaOH	5.0 g
12	Zinc metal, Zn	2 pcs
13	Beaker (50 mL)	2 units
14	Brush	1 unit
15	Conical flask (50 mL)	1 unit
16	Dropper	2 units
17	Filter funnel (40 mm)	1 unit
18	Filter paper (90 mm)	10 units
19	Glass rod	1 unit
20	Hand gloves	2 pairs
21	Litmus paper (red)	1 unit
22	Litmus paper (blue)	1 unit
23	Measuring cylinder (25 mL)	1 unit
24	Note book	1 unit
25	Pipette	1 unit
26	Pipette pump	1 unit
27	Pocket weighing scale (200 g /0.1 g)	1 unit
19	Glass rod	1 unit
20	Hand gloves	2 pairs
21	Litmus paper (red)	1 unit
22	Litmus paper (blue)	1 unit
23	Measuring cylinder (25 mL)	1 unit
24	Note book	1 unit
25	Pipette	1 unit
26	Pipette pump	1 unit
27	Pocket weighing scale (200 g /0.1 g)	1 unit
28	Polystyrene cup with lid	2 units
29	Reagent bottle (50 mL)	1 unit
30	Spatula	1 unit
31	Thermometer	1 unit
32	Volumetric Flask (25 mL)	1 unit
33	Volumetric Flask (50 mL)	1 unit
34	Washing bottle (250 mL)	1 unit
35	Weighing boat (Rhombus) 55×35 mm	2 units
36	Safety goggles	1 unit

3.2.2 Evaluation of the Kit for Learning of Chemistry

The kit was subjected to three-stage of evaluation. The kit was first introduced to two selected students from Lodge International School and SMK Jalan Arang to assess the adequacy of the kit (whether the chemicals/apparatus are appropriate and sufficient) and the manual clarity. The students were requested to carry out the experiments with the kit and to provide feedback and a reflection report. The kit was improved based on the feedback gathered from the preliminary assessment.

The kit was then evaluated by ten chemistry teachers (more than ten years of teaching experience) from nine schools in Kuching. The teachers are from SMK Kuching High (1), SMK Bandar Kuching No.1 (1), SMK Seri Setia (1), SMK Jalan Arang (1), SMK Padungan (2), SMK Siburan (1), SMK Paku (1), SMK Matang Jaya (1), SM Sains Kuching (1). Their feedback and suggestions were collected for improvement of the kit.

The final stage involves deployment of the kit to schools to support teaching and learning of chemistry. At this stage, the assessment involved a cognitive test and an attitude survey, before and after using the kit. A total of 30 Form 5 students were randomly selected from 3 town schools and 1 rural school. Due to the pandemic COVID -19 and limited budget, a total of thirty Form five students from three town schools and one rural school were randomly selected. The total number of respondents was the minimum requirement for conducting a statistical analysis of the study. The schools that were willing to participate in the study included SMK Jalan Arang (town, thirteen students), SMK Pending (town, one student), SMK Stampin (town, one student) and SMK Paku (rural, fifteen students). Note that a rural school is defined as a school located in areas with total population less than 10,000 according to the Ministry of Education. Figure 3.2 shows the schools where teachers

and students were involved in assessment of the laboratory kit. “SMK” refers to the national secondary school in Malay language (Sekolah Menengah Kebangsaan).



Figure 3.2: Locations of schools involved in assessment of the practical kit

3.2.3 Instructional Design and Statistical Analysis

The cognitive test was administered to evaluate the students’ level of understanding and the questionnaires appraised the students’ perceptions on practical learning. The kits were delivered to the students, and they were given two months to complete the experiments at home. This study was conducted during the COVID pandemic when schools were online. The learning was guided via Google Meeting and demonstration videos were uploaded in YouTube (<https://youtube.com/playlist?list=PLj4JnmNj-rhPLO7uMrQ8FUnwHQ8yWfm0U>). Upon completion of the experiments, the cognitive test (Appendix C) and attitude survey (Appendix D) were repeated; additional 16 items were added to the post-attitude survey and respondents were invited to offer their opinions,

comments and suggestions on the laboratory kit (Appendix E). The cognitive test and attitude survey were carried out via Google Form. The cognitive test covers 4 components each with 5 questions: (1) handling of materials and apparatus, (2) theoretical fundamental, (3) practical knowledge and (4) laboratory safety rules. The overall scores attained by each respondent was tabulated for statistical analysis. The attitude survey was designed based on Vermaak (1997) with a total of 28 items to gauge the students' interest in performing practical, satisfaction in practical experience, opinions and values on the importance of practical in learning of chemistry. The responses are a 5-point Likert scale of 5: Strongly Agree, 4: Agree, 3: Neutral, 2: Disagree and 1: Strongly Disagree. The data obtained was analyzed using T-test to determine whether there is any significance difference in the followings before and after using the kit ($\alpha = 0.05$):

- i. the knowledge level of students;
- ii. the attitude of students towards learning of chemistry;
- iii. the knowledge level of students in rural and town schools;
- iv. the attitude of students in rural and town schools.

3.3 Results and Discussion

3.3.1 Preliminary Assessment of the Kit

The practical kit received positive responses from two selected students during the preliminary assessment. The students were excited for being exposed to the laboratory practical, handling the glassware and making their learning in the classroom relevant. Some reflections and testimonials provided are as in Appendix F.

3.3.2 Assessment of the Kit by Experienced Teachers

The experienced teachers were given a feedback form after using the practical kit. Their responses on the practical kit were very positive. All the respondents agreed that the manual is easy to read, and the procedure is easy to follow. The apparatus's list and description help the students to recognize common glassware used in the laboratory. The background knowledge provided in each experiment remind the students on the related fundamental. The materials and apparatus in the kit are adequate and easy to find. The post-lab questions can be used to evaluate the students' learning after the experiment.

3.3.3 Effectiveness of the Kit for Learning of Chemistry

The mean scores of pre- and post-test are summarized in Table 3.3. There is a significant improvement in the overall score after using the practical kit. The improvements were recorded in all components including handling of materials, practical knowledge and the safety awareness, except theoretical fundamental. Studies evidenced that students' achievement is profoundly governed by the science process skills which allows students directly conduct experiments, interpret data and solve problems (Baser & Durmus, 2010; Irwanto et al., 2018).

Table 3.3: Mean scores and standard deviation of pre- and post-test ($N=30$)

Component of assessment	Mean (Standard Deviation)	
	Pre-	Post-
Handling materials and apparatus	15.17 (4.25)	23.33* (3.03)
Theoretical fundamental	21.17 (4.49)	22.83 (3.13)
Practical knowledge	14.83 (6.09)	21.33* (4.14)
Laboratory safety rules	19.83 (5.00)	22.83* (3.39)
Overall score	71.17 (11.27)	90.32* (9.00)

* $p < 0.05$

The performance of the pre- and post-test was examined based on types of schools (town against rural schools). The mean scores according to school types are shown in Table 3.4. Both rural and town schools demonstrate a marked increase in the overall mean scores in the post-test with improvements in the handling of materials and safety understanding ($p < 0.05$). Likewise, no statistical difference ($p > 0.05$) is found in the theoretical knowledge of students from both school types, before and after using the kit. In practical knowledge, students from rural school attain a lower score (mean score = 13.00) compared to those from the urban schools (mean score = 16.67). After using the practical kit, the mean score in practical knowledge achieved by students from both school types showed a significant improvement, with a comparable mean score of 23.33. The National Science Education Standards in the United States and other contemporary science education literature

ascertained that practical is a vital medium to introduce students to central conceptual, procedural knowledge and skills in science (Bybee, 2000).

Table 3.4: Comparison of mean scores and standard deviation of pre- and post-test

Component of assessment	Mean (Standard Deviation)			
	Rural		Town	
	Pre-	Post-	Pre-	Post-
Handling materials and apparatus	15.67 (4.58)	24.67* (1.29)	14.67 (3.99)	22.00* (3.68)
Theoretical fundamental	21.00 (5.07)	22.67 (3.72)	21.33 (3.99)	23.00 (2.54)
Practical knowledge	13.00 (5.92)	21.33* (4.81)	16.67 (5.88)	21.33 (3.52)
Laboratory safety rules	19.00 (5.07)	22.67* (3.20)	20.67 (4.95)	23.00 (3.68)
Overall score	68.67 (8.34)	91.34* (10.26)	73.34 (13.43)	89.33* (7.76)

* $p < 0.05$

The students' attitude towards learning of chemistry, before and after using the kit, was examined. The mean score of attitude according to factors are tabulated in Table 3.5. The results indicate that the practical kit has boosted the students' interest in learning chemistry. This positive experience of laboratory work in promoting learning of chemistry is corroborated in numerous studies (Thompson & Soyibo, 2002; Hofstein, 2004; Lunetta et al., 2007). Tesfamariam, Lykknes and Kvittingenv (2014) supports that a small-scale kit allows the students to perform experiments individually thus enhancing active learning rendering chemistry class more interesting and enjoyable. Given the opportunities to handle the equipment and materials, students can construct knowledge of phenomena and make the

scientific concept relatable (Tobin, 1990). Laboratory activities play a central role in the science curriculum; educators have consistently supported the benefits accrue from engaging students in the laboratory activities. The practical experience also fosters the development of skills in cooperation and communication (Hofstein, 2004).

Table 3.5: Mean score and standard deviation of attitude towards practical work ($N=30$)

Factors assessed	Items	Mean (Standard Deviation)	
		Pre-	Post-
Students' interest in doing practical work in chemistry	• Performing experiments in chemistry increases my interest in the subject.	3.27 (0.58)	4.53* (0.63)
	• Learning chemistry without practical is uninteresting.	3.70 (0.60)	4.50* (0.68)
	• Chemistry practical work is very tiring.	3.37 (0.85)	2.13* (1.11)
	• The more time I spend on chemistry practical work the greater my interest.	3.70 (0.75)	4.23* (0.82)
Students' satisfaction in performing laboratory practical	• Practical work in chemistry is boring and routine.	3.03 (0.32)	1.53* (0.77)
	• I enjoy seeing things for myself during practical.	3.50 (0.51)	4.63* (0.49)
	• I enjoy handling equipment and chemicals.	3.63 (0.56)	4.33* (0.71)
	• Performing chemistry experiments is too complicated for me.	3.47 (0.57)	2.00* (0.87)
	• I am looking forward to the next chemistry experiment.	3.97 (0.56)	4.43* (0.68)
	• I prefer lessons given by the teacher because practical work is disorganized.	3.37 (0.61)	2.23* (0.77)
	• I do not like chemistry experiments because the observations are never exact.	3.23 (0.57)	1.83* (0.75)
	• With the help of practical work, chemistry comes alive.	3.37 (0.56)	4.43* (0.68)
Opinions about laboratory practical	• Performing experiments in chemistry is a waste of money	3.37 (0.56)	1.46* (0.73)
	• More time should be devoted to chemistry practical works	2.73 (0.69)	3.97* (0.76)
	• If I do many experiments myself, I will do better in the exams	3.20 (0.71)	4.33* (0.80)
	• Periods for practical are a waste of times	3.73 (0.45)	1.40* (0.50)
	• Viewing videos which show experiments being performed is better than doing the experiment myself.	3.13 (0.82)	2.20 (1.03)
	• Practical work remains important even after the novelty wears off	3.27 (0.87)	3.70 (0.79)
	• It is sufficient for one pupil to perform the experiment and the rest to get the results from him.	3.23 (0.86)	2.13* (1.11)
	• There is no sense of redoing experiments that scientists have done in the past.	3.50 (0.86)	1.86* (0.97)
Attitude towards laboratory practical	• I prefer doing experiments myself to watching the teacher demonstrate them.	2.63 (0.81)	3.70* (1.09)
	• I learn more when I do the experiment myself.	3.07 (0.52)	4.50* (0.73)
	• I prefer reading my chemistry book to doing experiments.	3.33 (0.64)	2.63* (1.10)
	• Chemistry can be learnt and understood without practical.	3.30 (0.65)	2.20* (0.71)
	• I understand basic concepts better when I perform the experiment myself.	3.60 (0.72)	4.53* (0.57)
	• Performing experiments help me understand the theory better.	3.93 (0.78)	4.63* (0.61)
Perception about the importance of practical	• Chemistry practical work too relevant with my daily life.	2.90 (0.71)	3.67 (0.99)
	• Doing chemistry practical work can apply chemistry knowledge in solving problems.	3.70 (0.65)	4.60* (0.56)

* $p < 0.05$

The perceptions of students from rural and town schools towards laboratory practical, before and after using the kit, are summarized in Table 3.6. There is an improvement in affection for chemistry among students from both school types, where a more significant increment is recorded in the rural school. The level of satisfaction has also increased when performing practical using the kit. Students find practical work relatively useful and enjoyable compared to other teaching and learning activities (Cerini et al., 2003).

Table 3.6: The mean score of attitude towards laboratory practical before and after using the kit for students from rural and town schools

Factors assessed	Mean (Standard Deviation)			
	Rural		Town	
	Pre	Post	Pre	Post
• Students' interest in doing practical work in chemistry: Performing experiments in chemistry increases my interest in the subject	3.20 (0.56)	4.53* (0.64)	3.33 (0.62)	4.53* (0.64)
• Students' satisfaction in performing laboratory practical: With the help of practical, chemistry comes alive	3.33 (0.49)	4.40* (0.74)	3.40 (0.63)	4.47* (0.64)
• Opinions about laboratory practical: More time should be devoted to chemistry practical work	2.60 (0.74)	3.93* (0.80)	2.87 (0.64)	4.00* (0.76)
• Attitude towards laboratory practical: I understand the basic concepts better when I perform the experiment myself.	3.53 (0.64)	4.47* (0.52)	3.67 (0.82)	4.60* (0.63)
• Perception about the importance of practical: Doing chemistry practical work can apply chemistry knowledge in solving problems	3.73 (0.70)	4.60* (0.51)	3.67 (0.62)	4.60* (0.63)

* $p < 0.05$

The opinions of students on the usefulness of the kit are shown in Table 3.7. For items 1, 2, 6, and 13, 100% of students agree that the practical kit has helped to improve their skills in handling chemicals and apparatus in the practical exam. It is agreed that the kit provides more opportunities for hands-on and has improved their understanding of the fundamentals. Kelkar & Dhavale (2000) had reported that undergraduate students performed experiments and their skills in handling the equipment were markedly improved after adoption of small-scale kit in their laboratory. For items 4, 5, 9, 10, 11, 12, 14, 15 and 16, above 75% of the students acknowledge an increase in their interest in chemistry and appreciate the experience of working like a chemist. They are willing to do more experiments and indicate that they can be completed quickly without problems capturing the observations. This result is supported by study of Gendjova (2006), concluded that home experiments are able to develop their interest in science subject.

Table 3.7: Students' opinion about the practical kit

Students' Perception	Percentage of students (%)		
	Agree / Strongly agree	Neutral	Disagree / Strongly disagree
1. I like to use the practical kit.	100.00	0.00	0.00
2. The practical kit helps me to improve my skills in handling chemicals and apparatus in practical exam.	100.00	0.00	0.00
3. It is difficult to handle the materials and apparatus in the kit.	3.33	20.00	76.67
4. The practical kit boosts my interest in learning chemistry.	90.00	10.00	0.00
5. I hope my teacher can use the practical kit in my school.	80.00	20.00	0.00
6. Doing the experiment in the kit makes me understand chemistry concepts better.	100.00	0.00	0.00
7. The result of experiments cannot be observed easily.	10.00	30.00	60.00
8. I was afraid to try out the experiments using the kit.	6.67	16.67	76.66
9. The experiments in the kit can be completed quickly.	76.67	20.00	3.33
10. It is fun to do the experiments using the kit.	93.33	6.67	0.00
11. I am willing to do more experiments.	90.00	10.00	0.00
12. I am more aware about the safety of chemicals after using the kit.	76.66	16.67	6.67
13. The practical kit gives me more opportunity to use the chemicals and apparatus than before.	100.00	0.00	0.00
14. The practical kit makes me feel that I am working like a chemist.	86.67	13.33	0.00
15. I think the practical exam is easier when my teacher use the practical kit in school.	80.00	20.00	0.00
16. I will buy this practical kit if it is available in the market.	80.00	16.67	3.33

Students also express their learning experience in chemistry after using the kit. Students' attitudes toward chemistry are positive and they have developed science process skills. The learning process is shifted to become "student-centered" rather than "teacher-centered". Some of their comments, testimonials and feedback are extracted and provided in Appendix G.

The kit is designed for inquiry-based learning similar to the traditional lab, emphasizing on psychomotor experience involving physical investigation. Research shows that hands-on experiences in science laboratory play a central role in scientific education (Tobin, 1990; Hofstein & Lunetta, 2004; Ma & Nickerson, 2006; Singer et al., 2006; Hofstein & Mamlok-Naaman, 2007; Lunetta et al., 2007; Satterthwait, 2010;). It contributes to better assimilation of knowledge and help students to acquire critical reasoning skills (Gros, 2012; Lamba, 2015).

Scott (2009) revealed that students who completed science courses using non-traditional lab (virtual and remote) demonstrated significantly lower mean course grades and a lower passing rate than those with traditional labs (hands-on). Sicker et al. (2005) likewise suggests that students with traditional lab experience has out-performed those exposed to virtual laboratories. Although in this study, we observed positive outcomes from the hands-on practical, there are studies demonstrating comparable or more outstanding achievements in non-traditional delivery over the traditional lab (Tzafestas et al., 2006; Farrokhnia & Esmailpour, 2010; Frederick, 2013; Hawkins & Phelps, 2013; Brinson, 2015). Chan et al. (2021) advocates those virtual chemical laboratories can be as effective or even better than the conventional hands-on laboratory. Despite that, Colorado DOHE (2012) compared students who completed biology, chemistry and physics with non-traditional and traditional

laboratory learning concluding that the latter group achieved significantly better grades in biology and chemistry; no statistical difference is identified in physics. The discrepancies in observation may depend on the outcome indicators and the evaluation instruments. Various technologically-mediated approaches are made available to substitute or to be blended with the traditional laboratory learning. However, the laboratory skills and experience with the specific equipment and supplies are not transferrable via online delivery. Hence, Chan et al. (2021) further concluded that better learning outcomes are a result of combination of virtual and hands-on laboratory learning.

3.4 Conclusion

The practical kit developed based on the National Curriculum of Chemistry for Secondary School has offered a positive learning experience, increasing the motivation of students from rural and town schools. When schools are closed over the COVID-19 pandemic, it is an alternative to expose students to laboratory learning. The kit is designed to provide structured learning with flexibility in learning spaces and paces. It can be a take-home laboratory kit or be used in the classroom setting. The kit is affordable compared to conventional lab setting, cost saving, and environmentally friendly due to minimal amount of chemicals used to conduct the experiments in the kit.

CHAPTER 4

DEVELOPMENT OF A CITIZEN SCIENTIST PROGRAM FOR KSSM

4.1 Introduction

Besides the ability in practical skills, it is crucial to nurture students with the ability to apply different chemistry knowledge for daily problem solving. This can be achieved through activity-based hands-on approach, which can provide students with chances to enhance their interest and engage in science. Citizen scientist program is a method designed for this purpose.

Citizen Science refers to public participation in scientific research activities in which citizens are actively involved either intellectually with their knowledge or physically with their capabilities and sources (Sanz et al., 2014). Through citizen science, new knowledge and understanding are constructed. Anyone who voluntarily participates in observation, collecting, analysis and interpretation of data, and reporting the results is called a citizen scientist. Citizen scientist can be engaged in a wide range of research areas including science, astronomy, medicine, climate change, conservation, ecological restoration, environmental monitoring, and many more (Lewendowaski et al., 2017).

Research suggests that citizen science can foster connections between people and nature where they live (Cosquer et al., 2012; Toomey & Domroese, 2013; Schuttler et al., 2018). Engaging the public in observing and collecting data from nature-based studies has been shown to increase participant awareness, leading to attitudinal and behavioural changes toward conservation (Cosquer et al., 2012; Toomey and Domroese, 2013; Johnson et al., 2014; Forrester et al., 2016; Schuttler et al., 2018). Science education in schools can only be

successful if students experience the process of learning. These processes of exploration and discovery are delightful, engaging, and incredibly fun. Whether they make science their profession or pursue it as a hobby, citizen science offers everyone the opportunity to learn about the world while contributing to the greater good. Teachers, as facilitators of citizen science in formal learning environments, can play a critical role in successfully integrating such projects into their classrooms and schools (Weinstein, 2012). This study aims to expose the students to learning through citizen science where this strategy can be potentially introduced in the syllabus of KSSM to improve the learning efficiency. Specifically, the objectives of this study are:

1. to design and implement a citizen science project of household food waste survey for students of Form 5;
2. to evaluate the learning experience of the citizen scientists.

4.2 Methodology

In this study, a citizen scientist project was developed to focus on the amount and composition of food waste in households. Food waste in the supply chain is a popular topic in the public media and literature (Stuart, 2009; Bloom, 2010). Reports indicate that households are the main source of food waste, especially in developed countries, where the highest percentage of food waste comes from the post-consumer stage (Parfitt et al., 2010; Brautigam et al., 2014; Gooch & Felfel, 2014). Household food waste falls into two broad categories: avoidable and unavoidable. Preventable food waste includes leftover plates, over-prepared food, and food that has spoiled or reached its best-before date. Unavoidable food is parts of vegetables and animals that are not used for consumption, such as peels and bones.

There are several methods to collect the data on food waste, namely questionnaires (Silvennoinen et al., 2012, 2013) and food waste diaries (Silvennoinen et al., 2012). Questionnaires is used to determine the food waste indirectly; it is unsuitable for estimation of the quantity of food. Meanwhile, food waste diary is another method used to obtain the waste composition and quantity. Food waste diary studies are not tied to a geographic area, allowing more respondents to participate. In addition, to improve data collection and processing, households could enter the required data directly online instead of making entries in a paper-based diary.

A project was designed and implemented with a group of Form 5 students to introduce the idea of citizen science to them and to evaluate their learning experience. An invitation was sent to 10 schools for participation in this project. A total of 30 students from 6 schools showed interest to take part in this study. The schools involved include SMK Jalan Arang (12 students), SMK Pending (1 student), SMK Stampin (1 student) and SMK Batu Kawa (8 students), SMK Batu Lintang (2 students) and SMK Kuching High (6 students). The project focused on quantifying avoidable solid food waste in households using the food waste diary. This includes all food and raw materials that could have been consumed if stored or prepared differently. Waste such as vegetable scraps, peels, bones, and coffee grounds were not included in this study.

A template of food waste diary was prepared; Figure 4.1 shows template of the diary. The diary expects the participants to identify the categories of food wastes produced over breakfast, lunch and dinner, and their quantities. The participants are also asked to record reasons to each of the disposal i.e., spoiled, best before or use by date has expired, leftover and etc.

Table 4.1: Template of the food diary

DAY 1	Breakfast / Lunch / Dinner			
	Categories of wasted food	Tick	Weight (gram)	Reasons for disposing food
	Vegetables and potatoes,			
	Home cooked food,			
	Milk products,			
	Fruits and berries,			
	Bakery and grain products,			
	Meat, fish, egg,			
	Convenience and take away food,			
	Rice and pasta,			
	Other			
	TOTAL			

The participants took part in this project were briefed about the concept of citizen science and were invited to complete the food waste diary for a period of 5 days. The participants were requested to weigh and report their avoidable food wastes. After the measurement, the food can be disposed. The participants' socio-demographic information including family education level, employment background and range of household income were obtained through template of food diary. Upon completion of the food diaries, the students' perception survey (Appendix H) towards citizen scientist project was conducted. The respondents were invited to offer their comments on the project. The survey was carried out via Google Form.

The purpose of this citizen science project was conveyed to the participants:

- i. To find out about the food waste produced in the households
- ii. To identify the causes for the food wastage?

4.3 Results and Discussion

The results reverted by the participants on the household food waste was analysed. A total of 16 participants are from the family with income below RM 4,850/month (Category B40) whilst the remaining are between RM4,851 – RM10,970/month (Category M40).

Overall a period of 5 days, a total of 40.63 kg of avoidable food waste was produced by 30 households in which each household generates 270 g of waste per day. The food wastes produced according to types are tabulated in a table in Appendix I.

The total amount of food discarded from the category of M40 was 29.74 kg over 5 days with an average of 371 g of food waste per household/day. Meanwhile, for B40 category (146 households) was 10.89 kg in total, on an average of 155 g food waste per household/day. In this study, household income has a significant impact on the amount of food waste produced when comparing all responses. Respondents who appreciated low food prices produced less food waste, even when they purchased discounted products. The same result was reported for household price consciousness (Williams et al., 2012). When looking at the amount of food waste across household types, we also found that low-income families (category B40) produced less food waste. Similar results have been reported previously, where income is positively correlated with the amount of food waste (Van Garde & Woodburn, 1987; Schneider & Obersteiner, 2007; Williams et al., 2012).

The results were extrapolated to determine the amount of food waste generated over the course of a year. The average annual avoidable food waste ranged from 0 to 430.98 kg per household. A total of 19 respondent households (63 percent) produced less than one kilogram of food waste during the study period, and two respondents reported producing no food waste at all during the five-day study, making a completely waste-free food economy seem plausible. This result is similar to that of some respondents who produced no waste in an Austrian study (Selzer et al., 2009). The data also showed that food waste production had increased on weekends compared to other days. This is similar to the study by Emery et al. (2003), which concluded that holidays increase waste generation because more food is purchased and prepared at home on weekends.

Most discarded food waste was fresh and perishable, or leftovers from cooking and dining. Discarded food was vary: the largest individual waste production was recorded in the discarded foodstuffs were home cooked food 26.39 %, followed by meat, fish and eggs at 19.66%, rice and pasta 17.06%, vegetables and potatoes 10.33%, convenience food and take away food, 9.45%. Others non-perishable foodstuffs include snacks and tinned goods at 8.31% fruits and berries 3.90%, bakery and grain products 3.50% and milk products 1.40%.

Overall students' perception towards citizen science program on food waste report are presented in Table 4.2. Citizen scientist is new to most students, 63.33% of the students have not heard about it before. Despite that, the students found the citizen scientist project beneficial where they could relate it to the daily life. A Study by Phillips et al. (2018) reported that respondents were more interest or engagement in science and improve research skills from citizen science project. A total of 80% of the students think that this food waste report has increased their interest in learning chemistry and hoping their teacher can promote citizen scientist program in school. The study had shown that citizen science projects can facilitate the collaboration needed for collective action and contribute to the motivation that drives individuals to act together (Jordan et al., 2019). In addition, 93.3% of students agreed that they developed a greater awareness of how to manage waste in relation to the environment and create awareness of food waste reduction after completing the project. This is supported by Cigliano et al. (2015), who concluded that participation in a citizen science project can result in behaviour change among participants. Another study also reported that almost all participants had a better understanding of their personal environmental impact (Earthwatch, 2017).

Through the citizen scientist project, 96.67% of the students can understand the waste management concepts better and 100% of them had learnt the correct method to measure food waste. This is supported by a study that found citizen science projects can produce scientific knowledge and have an impact on environmental issues such as water quality, air quality, and health (Phillips et al., 2018). They also agreed that the duration for food waste reporting should be longer to obtain more accurate food waste data. This is supported by the study that participants need to invest time in the project over a longer period of time to obtain high quality data (Noordwijk et al., 2021).

Table 4.2: Overall students' perception towards citizen scientist program

Item	Students' perception	Percentage (%)			Mean
		Agree / Strongly agree	Neutral	Disagree / Strongly disagree	
1	I have never heard about Citizen Scientist Program before.	63.33	23.33	13.33	3.43
2	Citizen scientist program help me to relate what I learnt in textbook with my daily life.	83.33	23.33	3.33	3.93
3	I hope my teacher can promote citizen scientist program in my school.	80.00	20.00	0.00	4.07
4	I think the self-reporting approach on food waste volume and composition is a good method to create awareness to reduce the food waste.	93.33	9.67	0.00	4.37
5	I learn the correct method to measure food waste in my house.	100.00	0.00	0.00	4.26
6	Food waste report makes me understand the waste management concepts better.	96.67	3.33	0.00	4.47
7	I am more aware about waste management toward environment after using food waste report.	93.33	6.67	0.00	4.40
8	I think this food waste report make me more interest in learning chemistry.	80.00	13.33	6.67	4.00
9	I think the duration for the food waste report should be longer to get more accurate data on food waste.	66.67	33.33	0.00	3.90

Students also express their learning experience after the citizen scientist program. Some of the comments are extracted and stated in Appendix K. Students' attitudes toward the program are positive and they have developed science process skills, such as the correct method to measure food waste.

The citizen science projects can bring about scientific progress to support learning in education. Citizen Science can be integrated into education in both formal and informal learning environments. Formal learning generally takes place in schools, colleges, or universities with clear learning objectives, while informal education can take place outside the classroom or after school, often in public settings such as museums, zoos, or aquariums (Eshach, 2007; National Research Council, 2009). Integrating citizen science into formal education offers a unique opportunity to reach all segments of society, fulfilling the promise of its transformative potential for all, beyond the typical target audience of the well-educated, affluent (Ruiz-Mallén et al., 2016). Schools are perceived as potential multipliers: Teachers play a key role as intermediary experts (Weinstein, 2012) - acting as participants, facilitators, and motivators in Citizen Science projects. Teachers' and students' participation in citizen science projects allow for real-life learning (Jenkins, 1999). The citizen science projects can improve formal and informal learning of science, technology, engineering, and mathematics (STEM) (Vohland et al., 2021). This is also emphasized in the chemistry curriculum under KSSM aims to produce active learners. Citizen science can expand and embedded in education system to make transformation and could lead to changes at the individual, community, and global levels.

4.4 Conclusion

The citizen scientist program is a growing method that plays a vital role in science education. Involving the public in the scientific process has several advantages. It is a source

of a large amount of data that could not be collected by a single research team. In addition, citizen involvement increases scientific literacy, lifelong learning, and bridges the gap between the professional scientific community and the public. From this program, students were able to relate the chemistry knowledge with daily life and more aware to reduce the food waste at home.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study developed a curriculum-based laboratory practical kit for learning of chemistry in SPM level in order to enhance the ability of students in practical skills. The kit offers an experience of handling apparatus and performing experiments that is typically performed in a chemistry class. The kit overcome the challenge of laboratory availability allowing flexibility in learning through practice. The findings show that the practical kit has resulted in positive learning experience for teachers and students. The teachers agreed that the kit is designed with simple procedure and the apparatus are organised in a friendly manner, easy for users to recognise. Overall, the teachers concurred that the kit can help the students to master the basic concept of chemistry.

The study also found that the practical kit has improved students' understanding of chemistry knowledge after they using it through the cognitive test conducted. The chemistry knowledge focused in handling materials and apparatus, theoretical knowledge, practical knowledge and general laboratory safety rules. Significant improvements were demonstrated in all aforementioned aspects except theoretical knowledge. This is due to the kit developed was aimed to improve the manipulative skills in chemistry learning. Although no significant difference is deduced in the theoretical knowledge component, the mean score of the post-test was higher than the pre-test.

Students' attitude is important aspect for the success of the learning process. The study showed that both rural and town students agreed that practical kit developed had increased their interest in chemistry learning. Besides, the kit had positive effects toward

pure attitudinal factor where students demonstrated enjoyment whilst performing practical, handling equipment and chemicals. This had increased the students' interest in lab work, and preferred doing the experiments rather than observing the teacher's demonstration and reading the textbook. Students agreed that they can understand basic concepts and theory better with the hands-on experience offered through the practical kit. There were positive outcomes towards the practical kit. Both rural and town students like to use the kit because it helped to improve their skills in handling the materials and apparatus for the practical exam. They fully agreed that the practical kit gave them the opportunity to use the chemicals and apparatus. They agreed that the practical kit made them feel working like a chemist. They had fun and willing to do more experiments.

Besides, this study also experimented the possibility of incorporating a citizen scientist project for learning of chemistry in KSSM syllabus in order to nurture students with the ability to apply different chemistry knowledge in daily problem solving. Students' engagement can increase their scientific literacy providing lifelong learning experience. When students are trained as citizen scientists, they become familiar with scientific methods. Some of them may consider becoming a scientist as a possible future career, which critically impact students' career choices. The findings of the citizen science project on food waste showed that the project was beneficial to students where they could relate it to their daily life. Majority of the students involved in this study agreed that the project has increased their interest in learning chemistry and hoped their teacher could promote citizen scientist program in schools. The students were more aware about waste management and created awareness among the students to reduce food waste. The students can understand the concept of waste management and the correct method to measure food waste. They also agreed that the duration of the project can be lengthened to get more accurate data on food waste. The

results of this study signify that citizen scientist approach can be integrated into the chemistry curriculum to enrich the students' learning experience.

5.2 Recommendations

Although the results of this study are positive, there are limitations. No systematic data were collected on the effectiveness of 'traditional' laboratory practical versus the laboratory kit. In addition, the number of experiments that are accommodated in the laboratory kit is somewhat limited – experiments involving hazardous chemicals and processes i.e., heating is not possible. A larger group of students from different contexts and background for example good, moderate and weak achieving students can be compared. This information will help teachers to evaluate the learning efficiency based on students' performance.

For the citizen scientist project, the main limitation of this study is that the number of participants is rather small. Future work should consider the framework involving a larger population. The project can be implemented through collaboration between schools and universities, for example, a project based on waste separation - how many kg of waste and how they can be converted into the representation of chemical quantity, such as the mass of an element, percentage of an element or compound wasted. Monitoring food waste can be an interesting topic because it can be linked to the consumption of pesticides and fertilizers in agriculture. Food waste means, on the one hand, the waste of nutrients (carbohydrates, fats, proteins). On the other hand, the soil suffers from a lack of nutrients. Chemical aspects can be found in environmental measurements (the pH of precipitation) or environmental issues - climate change, carbon dioxide production, acid deposition.

The concept of citizen science can be used in educational research. The data collected on chemistry/science education can serve as the basis for a strategy for formal educational improvement that includes revising school curricula and the national curriculum.

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APPENDICES

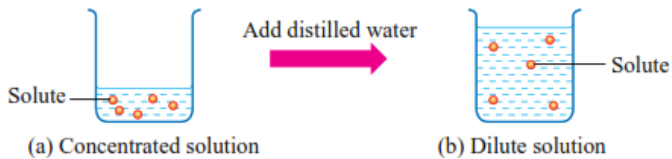
Appendix A

User's Manual

Activity/ Aktiviti	1
Title / Tajuk	To prepare a standard solution / <i>Untuk menyediakan larutan piawai</i>
Objective / Objektif	- To prepare a standard solution - To solve numerical problems involving preparation of standard solutions <i>Untuk menyediakan larutan piawai</i> <i>Untuk menyelesaikan masalah pengiraan berkaitan dengan penyediaan larutan piawai</i>
Background Knowledge Pengetahuan Latar Belakang	A standard solution is a solution with known concentration. It is used to determine the concentrations of other substances, such as solutions in titration. In the preparation of standard solutions, mass of solute and volume of distilled water are two variables to be measured accurately. Formula involved: (i) Number of mol of solution, $n = MV/1000$ [M=concentration, V=volume] (ii) Mass of solid = Number of moles $\times$ molar mass of the solid <i>Larutan piawai adalah larutan yang kepekataannya diketahui dengan tepat. Ia digunakan untuk menentukan kepekatan bahan lain, seperti larutan dalam pentitratan. Dalam penyediaan larutan piawai, jisim zat terlarut dan isipadu air suling adalah dua pemboleh ubah yang akan diukur dengan tepat.</i> Formula terlibat: (i) Nombor mol larutan, $n = MV/1000$ [M=kepekatan, V=isipadu] (ii) Jisim pepejal = nombor mol $\times$ jisim molar bagi pepejal
Aim Tujuan	To prepare a standard solution of 1.0 mol dm^{-3} of sodium carbonate solution in a 25 cm^3 volumetric flask from sodium carbonate powder, Na_2CO_3 <i>Menyediakan 25 cm^3 larutan piawai natrium karbonat 1.0 mol dm^{-3} dalam kelalang volumetrik dengan menggunakan serbuk natrium karbonat, Na_2CO_3.</i>
Before start Sebelum mula	Get a bottle of 500 cm^3 of drinking water (distilled water) from a shop <i>Mendapat sebotol air minuman (air suling) berisipada 500 cm^3 dari kedai</i>
Chemicals Bahan kimia	Na_2CO_3 powder and distilled water <i>Serbuk Na_2CO_3 dan air suling</i>
Apparatus Alat radas	Weighing scale, weighing boat, 50 cm^3 beaker, 25 cm^3 volumetric flask, filter funnel, dropper, washing bottle, spatula, glass rod. <i>Penimbang berat, botol penimbang, bikar 50 cm^3, kelalang volumetrik 25 cm^3, corong turas, penitis, botol pencuci, spatula, rod kaca.</i>
Procedure Prosedur	- Calculate the mass of Na_2CO_3 required to prepare 1.0 mol dm^{-3} aqueous Na_2CO_3 in a 25 cm^3 volumetric flask. Use the empty space below for calculation. Number of mol of solution, $n = MV/1000$ [M=concentration, V=volume] Mass of Na_2CO_3 required, $x = \text{Number of moles} \times \text{molar mass of } \text{Na}_2\text{CO}_3$ [Molar mass of $\text{Na}_2\text{CO}_3 = 106 \text{ g/mol}$] - Weigh $x \text{ g}$ solid Na_2CO_3 accurately in a weighing boat using a weighing scale. - Transfer the solid Na_2CO_3 to a beaker. - Using a washing bottle, add 20 cm^3 distilled water into the beaker and stir to dissolve all Na_2CO_3. - Using a filter funnel and a glass rod, transfer the dissolved Na_2CO_3 to a 25 cm^3 volumetric flask. - Rinse the beaker with distilled water in washing bottle and transfer the contents into the volumetric flask. (Precaution: make sure the water does not exceed 25 cm^3)

	- Using a washing bottle, add distilled water slowly until the water level is near the mark of the volumetric flask. - Use a dropper to add water, drop by drop, to bring the volume to the 25 cm³ of graduation mark. - Close the volumetric flask with a stopper. - Shake the volumetric flask by inverting it several times to get the homogenous solution. The standard solution prepared is the 1.0 mol dm⁻³ Na₂CO₃ solution. - Keep the solution for Activity 2. <i>Kirakan jisim bagi Na₂CO₃ untuk menyediakan larutan natrium karbonat 1.0 mol dm⁻³ dalam kelalang volumetrik 25 cm³. Gunakan ruangan kosong di bawah untuk pengiraan. Nombor mol larutan, $n = MV/1000$ [M=kepekatan, V=isipadu] Jisim Na₂CO₃ = nombor mol × jisim molar bagi Na₂CO₃ [Jisim molar of NaOH= 106 g/mol]</i> <i>Timbang x g Na₂CO₃ dengan tepat dalam botol penimbang dengan menggunakan penimbang berat.</i> <i>Pindahkan pepejal Na₂CO₃ ke dalam bikar.</i> <i>Tambahkan 20 cm³ air minuman ke dalam bikar dengan menggunakan botol pencuci dan kacau untuk larutkan semua pepejal Na₂CO₃.</i> <i>Pindahkan Na₂CO₃ terlarut ke dalam kelalang volumetrik 25 cm³ dengan menggunakan corong turas dan rod kaca.</i> <i>Bilaskan bikar dengan air suling dan pindahkan kandungan tersebut ke dalam kelalang volumetrik. (Langkah berjaga-jaga: pastikan paras air tidak melepasi 25 cm³)</i> <i>Tambahkan air suling secara perlahan-lahan dengan menggunakan botol penimbang sehingga hampir dengan aras senggatan 25 cm³.</i> <i>Tambahkan air suling, titis demi titis dengan menggunakan penitis untuk menjadikan isipadu tepat dengan aras senggatan 25 cm³.</i> <i>Tutup kelalang volumetrik dengan menggunakan penutup.</i> <i>Goncangkan kelalang volumetrik dengan telangkupkan beberapa kali sehingga larutan bercampur dengan sekata. Larutan piawai yang disediakan adalah 1.0 mol dm⁻³ larutan Na₂CO₃.</i> <i>Simpan larutan untuk digunakan dalam Aktiviti 2.</i>
Discussion Perbincangan	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> - Why must the beaker be rinsed with distilled water(step 6)? <i>Mengapakah bikar mesti dibilaskan dengan air suling(langkah 6)?</i> - Why must all contents in step 6 be transferred into the volumetric flask? <i>Mengapakah semua kandungan dalam langkah 6 dipindahkan ke dalam kelalang volumetrik?</i>

Activity/ Aktiviti	2
Title / Tajuk	Dilution / Pencairan
Objective / Objektif	- To prepare a standard solution through dilution of an aqueous solution - To solve numerical problems involving dilution <i>Untuk menyediakan larutan piawai melalui pencairan larutan</i> <i>Untuk menyelesaikan masalah pengiraan yang melibatkan pencairan</i>
Background Knowledge Pengetahuan Latar Belakang	A standard solution at a lower concentration can be prepared from a more concentrated standard solution known as the stock solution. This involves dilution of the stock solution. During dilution, water that is added to the stock solution will alter the concentration of the solution but it would not alter the amount of solute (number of moles) in the solution. <i>Larutan piawai pada kepekatan yang lebih rendah dapat disediakan dari larutan piawai yang lebih pekat yang dikenali sebagai larutan stok. Ini melibatkan pencairan larutan stok. Semasa pencairan, air yang ditambahkan ke dalam larutan stok akan mengubah kepekatan larutan tetapi tidak akan mengubah jumlah zat terlarut (bilangan mol) dalam larutan.</i>

	 (a) Concentrated solution (b) Dilute solution Formula use in dilution method / Formula yang digunakan: $M_1V_1 = M_2V_2$ where M_1 = Initial molarity / kemolaran larutan asal M_2 = Final molarity / kemolaran larutan akhir V_1 = Initial volume / isipadu larutan asal V_2 = Final volume / isipadu larutan akhir
Aim Tujuan	To prepare a standard sodium carbonate solution of 50 cm ³ of 0.1 mol dm ⁻³ from 1.0 mol dm ⁻³ sodium carbonate solution. Untuk menyediakan larutan piawai natrium karbonat 50 cm ³ 0.1 mol dm ⁻³ dari larutan natrium karbonat 1.0 mol dm ⁻³ .
Before start Sebelum mula	Get a bottle of 500 cm ³ of drinking water (distilled water) from a shop Mendapat sebotol air minuman (air suling) berisipada 500 cm ³ dari kedai
Chemicals Bahan kimia	Sodium carbonate, Na ₂ CO ₃ solution prepared from Activity 1 and distilled water (drinking water) Larutan natrium karbonat, Na ₂ CO ₃ yang disediakan daripada Aktiviti 1 dan air suling (air minuman)
Apparatus Alat radas	5 cm ³ pipette and pump, 50 cm ³ volumetric flask, dropper, washing bottle, beaker Pipet 5cm ³ dan pam, kelalang volumetrik 50 cm ³ , corong turas, penitis, botol pencuci, bikar.
Procedure Prosedur	- Calculate the volume of 1.0 mol dm⁻³ Na₂CO₃, V_1 required to prepare 0.1 mol dm⁻³ Na₂CO₃ in a 50 cm³ volumetric flask. Use the empty space below for calculation. [Use formula: $M_1V_1 = M_2V_2$] - Pour the Na₂CO₃ solution from Activity 1 into a beaker. - Suck V_1 cm³ of Na₂CO₃ using a pipette and pump, then transfer it into a 50 cm³ volumetric flask. - Using a washing bottle, add distilled water to the volumetric flask until near the graduation mark. (Precaution: make sure the water added does not exceed 50 cm³) - Use a dropper to add water slowly in the volumetric flask up to the graduation mark. - Stopper the flask. - Shake the volumetric flask by inverting it several times to get the homogenous solution. The standard solution prepared is the 0.1 mol dm⁻³ Na₂CO₃ solution. - Kirakan isipadu bagi 1.0 mol dm⁻³ Na₂CO₃, V_1 yang diperlukan untuk menyediakan 0.1 mol dm⁻³ Na₂CO₃ dalam kelalang volumetrik 50 cm³. . Gunakan ruangan kosong di bawah untuk pengiraan. [Guna formula: $M_1V_1 = M_2V_2$] - Tuangkan larutan Na₂CO₃ dari Aktiviti 1 ke dalam bikar. - Sedutkan V_1 cm³ larutan Na₂CO₃ dengan menggunakan pipet dan pam, kemudian pindahkan ke dalam kelalang volumetrik 50 cm³. - Bilaskan bikar dengan air suling dan pindahkan kandungan tersebut ke dalam kelalang volumetrik. (Langkah berjaga-jaga: pastikan paras air tidak melepasi 50 cm³) - Tambahkan air suling, titis demi titis dengan menggunakan penitis untuk menjadikan isipadu tepat dengan aras senggatan 50 cm³. - Tutup kelalang volumetrik dengan menggunakan penutup. - Goncangkan kelalang volumetrik dengan telangkupkan beberapa kali sehingga larutan bercampur dengan sekata. Larutan piawai yang disediakan adalah 0.1 mol dm⁻³ larutan Na₂CO₃.
Discussion Perbincangan	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u>

	Nitric acid, HNO_3 is a strong and corrosive acid. When ordered from a chemical supply company, its molarity is 16 mol dm^{-3}. How much of the stock solution of nitric acid is needed to prepare 8000 cm^3 of a 0.50 mol dm^{-3} solution? <i>Asid nitrik, HNO_3 adalah asid kuat dan menghakis. Apabila dipesan dari pembekal bahan kimia, kemolarannya ialah 16 mol dm^{-3}. Berapa isipadu larutan stok asid nitrik yang diperlukan untuk menghasilkan 8000 cm^3 larutan HNO_3 0.50 mol dm^{-3}?</i>
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Activity/ Aktiviti	3	
Title / Tajuk	Solubility of salt in water <i>Keterlarutan garam dalam air</i>	
Objective / Objektif	• To test the solubility of salts • Classify salts into soluble salts and insoluble salts • <i>Untuk menguji keterlarutan garam</i> • <i>Kelaskan garam terlarutkan dan garam tak terlarutkan</i>	
Background Knowledge <i>Pengetahuan Latar Belakang</i>	Salt is an ionic compound. Soluble salts are salts that dissolve in water at room temperature and insoluble salts are salts that do not dissolve in water at room temperature. <i>Garam adalah sebatian ionik. Garam terlarutkan adalah garam yang larut dalam air pada suhu bilik dan garam tak terlarutkan adalah garam yang tidak larut dalam air pada suhu bilik.</i>	
Aim <i>Tujuan</i>	To investigate the solubility of various salts in water <i>Untuk mengkaji kelarutan pelbagai garam di dalam air</i>	
Before start <i>Sebelum mula</i>	The residue produced can be disposed as regular domestic waste into the bin. The solution can be poured down the drain with plenty of water. <i>Residu yang dihasilkan dapat dibuang sebagai sampah domestik biasa ke tong sampah. Larutan boleh dibuang ke dalam longkang dengan banyak air.</i>	
Chemicals <i>Bahan kimia</i>	Lead (II) nitrate, Pb(NO ₃) ₂ , potassium iodide, KI, lead (II) chloride, PbCl ₂ , barium chloride, BaCl ₂ , ammonium sulphate, (NH ₄) ₂ SO ₄ , sodium hydroxide, NaOH, copper (II) sulphate, CuSO ₄ , distilled water (drinking water). <i>Plumbum (II) nitrat, Pb(NO₃)₂, Kalium iodida, KI, plumbum (II) klorida, PbCl₂, barium klorida, BaCl₂, amonium sulfat, (NH₄)₂SO₄, natrium hidroksida, NaOH, kuprum (II) sulfat, CuSO₄, air suling (air minuman).</i>	
Apparatus <i>Alat radas</i>	Beaker, spatula, glass rod <i>Bikar, spatula, rod kaca</i>	
Procedure <i>Prosedur</i>	1. Add 20 cm³ of distilled water into a beaker. 2. Add a spatula of Pb(NO₃)₂ into the beaker. 3. Stir the mixture with glass rod. 4. Observe and record the solubility of the salt. 5. Clean the beaker. 6. Repeat step 1 to 5 using KI, PbCl₂, BaCl₂, (NH₄)₂SO₄, NaOH and CuSO₄, BaSO₄ and CaCO₃. <i>1. Masukkan 20 cm³ air suling ke dalam bikar.</i> <i>2. Masukkan spatula Pb (NO₃)₂ ke dalam bikar.</i> <i>3. Kacau campuran dengan batang kaca.</i> <i>4. Perhatikan dan catat keterlarutan garam.</i> <i>5. Bersihkan bikar.</i> <i>6. Ulangi langkah 1 hingga 5 menggunakan KI, PbCl₂, BaCl₂, (NH₄)₂SO₄, NaOH and CuSO₄, BaSO₄ dan CaCO₃.</i>	
Observation <i>Pemerhatian</i>	Salts / Garam	Solubility in water / Keterlarutan dalam air
	Pb(NO ₃) ₂ KI PbCl ₂ BaCl ₂ (NH ₄) ₂ SO ₄ NaOH CuSO ₄	

	BaSO ₄ CaCO ₃	
Discussion Perbincangan	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> Based on the result, classify the salts into soluble and insoluble salts. <i>Berdasarkan keputusan, kelaskan garam kepada garam terlarutkan dan garam tidak terlarutkan.</i>	
	Soluble salts <i>Garam terlarutkan</i>	Insoluble salts <i>Garam tidak terlarutkan</i>

Activity/ Aktiviti	4
Title / Tajuk	Precipitation reaction (Double decomposition reaction) <i>Tindak balas pemendakan (Tindak balas penguraian ganda dua)</i>
Objective / Objektif	- To perform and observe the results of a precipitation reaction - To identify the products formed in the precipitation reactions - To write a balance chemical equation for the reaction <i>Untuk melakukan dan memerhatikan hasil tindak balas pemendakan</i> <i>Untuk mengenal pasti hasil yang terbentuk dalam tindak balas pemendakan</i> <i>Untuk menulis persamaan kimia yang seimbang bagi tindak balas</i>
Background Knowledge Pengetahuan Latar Belakang	A precipitation reaction is a reaction in which the positive and negative ions of two ionic compounds exchange places to form two new compounds. The general form of a precipitation (double decomposition) reaction is: $AB + CD \rightarrow AD + CB$ Here AB and CD are usually aqueous ionic compounds (or acids) consisting of aqueous ions (A⁺ and B⁻, C⁺ and D⁻). When a precipitation reaction occurs, the cations and anions switch partners, resulting in the formation of two new ionic compounds AD and CB, one of which is in the solid state. This solid product is an insoluble ionic compound called a precipitate. <i>Tindak balas pemendakan adalah tindak balas di mana ion positif dan negatif dua sebatian ionik bertukar tempat untuk membentuk dua sebatian baru. Bentuk umum tindak balas pemendakan (penguraian ganda dua) adalah:</i> $AB + CD \rightarrow AD + CB$ <i>Di sini AB dan CD biasanya sebatian ionik berair (atau asid) yang terdiri daripada ion berair (A⁺ dan B⁻, C⁺ dan D⁻). Apabila tindak balas pemendakan berlaku, kation dan anion bertukar pasangan, mengakibatkan terbentuknya dua sebatian ion baru AD dan CB, salah satunya berada dalam keadaan pepejal. Produk pepejal ini adalah sebatian ion tidak terlarutkan yang disebut mendakan.</i>
Aim Tujuan	To study the precipitation reaction between lead (II) nitrate, Pb(NO₃)₂ and potassium iodide, KI. <i>Untuk mengkaji tindak balas pemendakan antara plumbum (II) nitrat, Pb(NO₃)₂ dan kalium iodida, KI.</i>
Before start Sebelum mula	Prepare tissue paper to clean spillage. <i>Sediakan kertas tisu untuk membersihkan tumpahan.</i>
Chemicals Bahan kimia	Lead (II) nitrate, Pb(NO₃)₂, Potassium iodide, KI <i>Plumbum (II) nitrat, Pb(NO₃)₂ dan kalium iodida, KI.</i>
Apparatus Alat radas	Spatula, weighing boat, weighing scale, 50 cm ³ beaker, measuring cylinder 25 cm ³ , glass rod

	<i>Spatula, botol penimbang, penimbang berat, bikar 50 cm³, kelalang kon 25 cm³, rod kaca.</i>		
Procedure <i>Prosedur</i>	1. Use a spatula to take 0.5 g of Pb(NO₃)₂ into a weighing boat. Add it into a 50 cm³ beaker and labelled A. 2. Clean the spatula and weighing boat before carry out step 3. 3. Use a spatula to take 0.5 g of KI into weighing boat. Put it into another 50 cm³ beaker labelled B. 4. Using washing bottle, measure 20 cm³ of distilled water by using measuring cylinder and pour into both beakers respectively and stir to dissolve all the salts (Until no solid remains in the beaker). (Precaution: Wash the glass rod first before stir the another solution). 5. Pour the solution in beaker A into beaker B and stir. 6. Record the observation in the following table. 7. The mixture produced is used for Activity 5. 1. <i>Gunakan spatula untuk memasukkan 0.5 g Pb(NO₃)₂ ke dalam botol penimbang. Masukkan ke dalam bikar 50 cm³ dan berlabel A.</i> 2. <i>Bersihkan spatula dan kapal penimbang sebelum menjalankan langkah 3.</i> 3. <i>Gunakan spatula untuk mengambil 0.5 g KI ke botol penimbang. Masukkan ke dalam bikar 50 cm³ yang berlabel B.</i> 4. <i>Dengan menggunakan botol pencuci, ukur 20 cm³ air suling dengan menggunakan silinder penyukat dan tuangkan ke dalam kedua-dua bikar dan kacau untuk melarutkan semua garam (Sehingga tidak ada pepejal yang tinggal di dalam bikar). (Perhatian: Bersihkan rod kaca sebelum kacau larutan yang kedua).</i> 5. <i>Tuangkan larutan dalam bikar A ke dalam bikar B dan kacau.</i> 6. <i>Catatkan pemerhatian dalam jadual berikut.</i> 7. <i>Campuran yang dihasilkan digunakan untuk Aktiviti 5.</i>		
Observation <i>Pemerhatian</i>	Beakers <i>Bikar</i>	Observation <i>Pemerhatian</i>	Inference <i>Inferens</i>
	A + B		
Discussion <i>Perbincangan</i>	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> 1. State the reactants and products for the experiment. <i>Nyatakan bahan tindak balas dan hasil tindak balas bagi eksperimen ini.</i> 2. State the physical state of each reactant and product. <i>Nyatakan keadaan fizikal bagi bahan dan hasil tindak balas.</i> 3. Write the balanced chemical equation for the reaction. <i>Tuliskan persamaan tindak balas yang seimbang bagi tindak balas ini.</i>		

Activity/Aktiviti	5
Title / Tajuk	Preparation of Insoluble Salt / <i>Penyediaan garam tak terlarutkan</i>
Objective / <i>Objektif</i>	• To perform and observe the results of a preparation of insoluble salt • To write a balance chemical equations for the reaction studied • <i>Melakukan dan memerhatikan penyediaan garam tak terlarutkan</i> • <i>Menulis persamaan kimia yang seimbang bagi tindak balas terlibat</i>
Background Knowledge <i>Pengetahuan Latar Belakang</i>	Soluble salts are salts that dissolve in water at room temperature and non-soluble salts are salts that do not dissolve at room temperature. Insoluble salts can be prepared through the double decomposition reaction. In this process, two salt solutions that contain insoluble salt ions are needed. In the double decomposition reaction, the ions in both aqueous solutions exchange with each other to form a new aqueous solution and a precipitate. The ionic equation for the

	formation of barium sulphate, BaSO_4 can be derived from the balanced chemical equations as shown below: <i>Garam terlarutkan adalah garam yang larut dalam air pada suhu bilik dan garam tak terlarutkan adalah garam yang tidak larut pada suhu bilik. Garam tak terlarutkan boleh disediakan melalui tindak balas penguraian ganda dua. Dalam proses ini, dua larutan garam yang mengandungi ion garam tak terlarutkan diperlukan.</i> <i>Dalam tindak balas penguraian ganda dua, ion dalam kedua-dua larutan bertukar antara satu sama lain untuk membentuk larutan baru dan mendakan. Persamaan ion untuk pembentukan barium sulfat, BaSO_4 dapat berasal dari persamaan kimia seimbang seperti yang ditunjukkan di bawah:</i> Chemical equation/ Persamaan kimia: $\text{BaCl}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NaCl}(\text{aq})$ $\text{Ba}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq}) + 2\text{Na}^{+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{Na}^{+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$ Ions in barium chloride Ions in sodium sulphate Precipitate Ions in sodium chloride Ionic Equation/ Persamaan ionik: $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$		
Aim/ Tujuan	To prepare insoluble salt of lead (II) iodide, PbI_2 <i>Untuk menyediakan garam plumbum (II) iodida yang tak terlarutkan, PbI_2</i>		
Before start Sebelum mula	The precipitate produced can be disposed as regular domestic waste into the bin. The solution can be poured down the drain with plenty of water. <i>Mendakan yang dihasilkan dapat dibuang sebagai sampah domestik biasa ke tong sampah. Larutan boleh dibuang ke dalam longkang dengan banyak air.</i>		
Chemicals Bahan kimia	Mixture of lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2$ and potassium iodide, KI (from Activity 4) <i>Campuran plumbum(II) nitrat, $\text{Pb}(\text{NO}_3)_2$ dan kalium iodida, KI (dari Aktiviti 4)</i>		
Apparatus Alat radas	Beakers, glass rods, conical flasks, filter funnels and filter papers <i>Bikar, rod kaca, kelalang kon, corong turas dan kertas turas.</i>		
Procedure Prosedur	1. Use the mixture solution from Activity 4. 2. Stir the mixture thoroughly with a glass rod. 3. Filter the mixture to obtain salt using the filter paper, funnel and conical flask. 4. Using washing bottle, rinse the beaker and glass rod with distilled water and pour it into the filter funnel. 5. Dry the residue by pressing between two pieces of filter papers. <i>1. Gunakan larutan campuran dari Aktiviti 4.</i> <i>2. Kacau campuran hingga sehati dengan rod kaca.</i> <i>3. Tapis campuran untuk mendapatkan garam menggunakan kertas turas, corong turas dan kelalang kon.</i> <i>4. Dengan menggunakan botol pencuci, bilas bikar dan batang kaca dengan air suling dan tuangkan ke corong turas.</i> <i>5. Keringkan residu dengan menekan antara dua keping kertas turas.</i>		
Observation Pemerhatian	Beakers/ Bikar	Observation/ Pemerhatian	Inference/ Inferens
	$\text{Pb}(\text{NO}_3)_2 + \text{KI}$	Observation:	
Discussion Perbincangan	Answer the following questions / Jawab soalan-soalan yang berikut: 1. State the name and colour of the insoluble salt produced.		

	Nyatakan nama dan warna bagi garam tak terlarutkan yang terhasil.
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Activity/ Aktiviti	6		
Title / Tajuk	The role of water in showing acidic property <i>Peranan air dalam menunjukkan sifat asid.</i>		
Objective / Objektif	- To determine the role of water in showing acidic properties. <i>Untuk menentukan peranan air dalam menunjukkan sifat asid.</i>		
Background Knowledge <i>Pengetahuan Latar Belakang</i>	Acids only show acidic properties in the presence of water. When an acid is dissolved in water, acid molecules will ionize to produce hydrogen ions, H^+ . The presence of H^+ allows the acid to show its acidic properties. Therefore, blue litmus paper changes to red. Without water, acids only exist as molecules, H^+ are not present. Thus, the colour of blue litmus paper remains unchanged. <i>Asid hanya menunjukkan sifat asid sekiranya terdapat air. Apabila asid dilarutkan di dalam air, molekul asid akan mengion untuk menghasilkan ion hidrogen, H^+. Kehadiran H^+ membolehkan asid menunjukkan sifat asidnya. Oleh itu, kertas litmus biru berubah menjadi merah. Tanpa air, asid hanya wujud sebagai molekul, H^+ ion tidak hadir. Oleh itu, warna kertas litmus biru tidak berubah.</i>		
Aim <i>Tujuan</i>	To investigate whether water is needed for an acid to show its acidic properties. <i>Untuk menyiasat sama ada air diperlukan untuk asid untuk menunjukkan sifat asidnya.</i>		
Before start <i>Sebelum mula</i>	The solution produced in this activity can be poured down the drain with plenty of water. <i>Larutan yang terhasil dalam aktiviti ini boleh dibuang ke dalam longkang dengan banyak air.</i>		
Chemicals <i>Bahan kimia</i>	Solid oxalic acid, $C_2H_2O_4$, distilled water and blue litmus paper, tissue paper <i>Asid oksalik pepejal, $C_2H_2O_4$, air suling dan kertas litmus biru, kertas tisu</i>		
Apparatus <i>Alat radas</i>	50 cm^3 beaker, glass rod <i>Bikar 50 cm^3, rod kaca</i>		
Procedure <i>Prosedur</i>	- Add a spatula of oxalic acid, $C_2H_2O_4$ solid into a beaker (make sure the beaker is dry - wipe using a tissue paper). - Dip a piece of dry blue litmus paper into the beaker. - Observe any changes to the colour of the blue litmus paper. - Record your observation. - After that, add 5 cm^3 distilled water and stir with glass rod. - Observe any changes in the colour of the blue litmus paper. - Record your observation. <i>Tambahkan spatula pepejal oksalik, $C_2H_2O_4$ ke dalam bikar (pastikan bikar kering - lap menggunakan kertas tisu).</i> <i>Celupkan sekeping kertas litmus biru kering ke dalam bikar.</i> <i>Perhatikan perubahan pada warna kertas litmus biru.</i> <i>Catatkan pemerhatian anda.</i> <i>Selepas itu, tambahkan 5 cm^3 air suling dan kacau dengan rod kaca.</i> <i>Perhatikan perubahan warna kertas litmus biru.</i> <i>Rekodkan pemerhatian anda.</i>		
Observation <i>Pemerhatian</i>	Mixture <i>Campuran</i>	Observation <i>Pemerhatian</i>	Inference <i>Inferens</i>
	Solid $C_2H_2O_4$ <i>Pepejal $C_2H_2O_4$</i>		
	Solid $C_2H_2O_4$ + water <i>Pepejal $C_2H_2O_4$ + air</i>		
Discussion <i>Perbincangan</i>	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> - Name the ion that is responsible for the acidic properties. <i>Namakan ion yang berperanan menunjukkan sifat asid.</i> - Explain the why there are different observation in this activity. <i>Terangkan mengapa terdapat pemerhatian yang berbeza dalam aktiviti ini.</i>		

Activity/ Aktiviti	7		
Title / Tajuk	The role of water in showing alkaline property <i>Peranan air dalam menunjukkan sifat alkali</i>		
Objective / Objektif	- To determine the role of water in showing alkaline properties. <i>Untuk menentukan peranan air dalam menunjukkan sifat alkali.</i>		
Background Knowledge <i>Pengetahuan Latar Belakang</i>	Akalis only shows alkaline properties when they are dissolved in water. Without water, hydroxide ions, OH^- in the sodium hydroxide pellet, NaOH cannot move freely and are still tied in its lattice structure. So, the pellet of NaOH does not show alkaline properties. The red litmus paper cannot change colour. When a pellet of NaOH is dissolved in water, OH^- are produced and able to move freely in water. Thus, NaOH solution shows alkaline properties. Hence, the moist red litmus paper turns blue. <i>Akali hanya menunjukkan sifat alkali apabila dilarutkan di dalam air. Tanpa air, ion hidroksida, OH^- dalam pelet natrium hidroksida, NaOH tidak dapat bergerak dengan bebas dan masih terikat dalam struktur kekisinya. Jadi, pelet NaOH tidak menunjukkan sifat alkali. Kertas litmus merah tidak boleh berubah warna. Apabila pelet NaOH dilarutkan dalam air, OH^- dihasilkan dan dapat bergerak dengan bebas di dalam air. Oleh itu, larutan NaOH menunjukkan sifat alkali. Oleh itu, kertas litmus merah lembap bertukar menjadi biru.</i>		
Aim <i>Tujuan</i>	To investigate whether water is needed for an alkali to show its alkaline properties. <i>Untuk menyiasat sama ada air diperlukan untuk alkali untuk menunjukkan sifat alkali</i>		
Before start <i>Sebelum mula</i>	The solution produced in this activity can be poured down the drain with plenty of water. <i>Larutan yang terhasil dalam aktiviti ini boleh dibuang ke dalam longkang dengan banyak air.</i>		
Chemicals <i>Bahan kimia</i>	Sodium hydroxide, NaOH pellet, distilled water and red litmus paper, tissue paper <i>Pelet natrium hidroksida, NaOH, air suling dan kertas litmus merah, kertas tisu</i>		
Apparatus <i>Alat radas</i>	50 cm ³ beaker, glass rod <i>Bikar 50 cm³, rod kaca</i>		
Procedure <i>Prosedur</i>	- Add 4-5 NaOH pellets in a dry beaker (make sure it is dry - wipe using a tissue paper). - Dip a piece of dry red litmus paper into the beaker. - Observe any changes to the colour of the red litmus paper. - Record your observation. - After that, add 5 cm³ distilled water and stir with glass rod. - Observe any changes to the colour of the red litmus paper. - Record your observation. <i>1. Masukkan 4-5 pelet NaOH ke dalam bikar kering (pastikan ia kering - lap menggunakan kertas tisu).</i> <i>2. Celupkan sekeping kertas litmus merah kering ke dalam bikar.</i> <i>3. Perhatikan apa-apa perubahan pada warna kertas litmus merah.</i> <i>4. Catatkan pemerhatian anda.</i> <i>5. Selepas itu, tambahkan air suling 5 cm³ dan kacau dengan batang kaca.</i> <i>6. Perhatikan apa-apa perubahan pada warna kertas litmus merah.</i> <i>7. Rekodkan pemerhatian anda.</i>		
Observation <i>Pemerhatian</i>	Mixture <i>Campuran</i>	Observation <i>Pemerhatian</i>	Inference <i>Inferens</i>
	NaOH pellet <i>Pelet NaOH</i>		
	NaOH pellet + water <i>Pelet NaOH + air</i>		
Discussion <i>Perbincangan</i>	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> - Name the ion that is responsible for the alkaline properties. <i>Namakan ion yang berperanan menunjukkan sifat alkali.</i> - Explain the difference in observation between using a pellet of sodium hydroxide, NaOH and sodium hydroxide solution, NaOH.		

	Terangkan perbezaan pemerhatian antara pelet natrium hidroksida, NaOH dan larutan natrium hidroksida, NaOH.
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Activity/ Aktiviti	8
Title / Tajuk	Exothermic and endothermic reactions <i>Tindak balas eksotermik dan endotermik</i>
Objective / Objektif	- To determine exothermic and endothermic reactions <i>Untuk menentukan tindak balas eksotermik dan endotermik</i>
Background Knowledge Pengetahuan Latar Belakang	There is a change of energy when a chemical reaction occurs, and usually involves heat energy. Heat energy is either released or absorbed during a chemical reaction. <u>Exothermic reaction:</u> - Heat released to the surroundings causes the surrounding temperature to rise. - The container becomes hot. - Examples: respiration, oxidation of metals, neutralization reaction, combustion of fuel, production of ammonia, and dissolving sodium hydroxide in water. <u>Endothermic reaction:</u> - Chemical reactions that absorb heat from the surroundings. - Heat absorbed from the surroundings causes the temperature to drop. - The container becomes cold. - Examples: photosynthesis, decomposition of metal carbonate when heated, decomposition of metal nitrates when heated and dissolving ammonium salts in water. <i>Terdapat perubahan tenaga apabila tindak balas kimia berlaku, dan biasanya melibatkan tenaga haba. Tenaga haba dibebaskan atau diserap semasa tindak balas kimia.</i> <u>Tindak balas eksotermik:</u> <i>Haba dilepaskan ke persekitaran menyebabkan suhu di sekitarnya meningkat.</i> <i>Bekas menjadi panas.</i> <i>Contoh: pernafasan, pengoksidaan logam, tindak balas peneutralan, pembakaran bahan bakar, penghasilan ammonia, dan larutkan natrium hidroksida di dalam air.</i> <u>Tindak balas endotermik:</u> <i>Tindak balas kimia yang menyerap haba dari persekitaran menyebabkan suhu turun.</i> <i>Bekas menjadi sejuk.</i> <i>Contoh: fotosintesis, penguraian logam karbonat ketika dipanaskan, penguraian logam nitrat apabila dipanaskan dan melarutkan garam ammonium di dalam air.</i>
Aim Tujuan	To identify exothermic and endothermic reactions <i>Untuk mengenal pasti tindak balas eksotermik dan endotermik</i>
Before start Sebelum mula	The solution produced in this activity can be poured down the drain with plenty of water. <i>Larutan yang terhasil dalam aktiviti ini boleh dibuang ke dalam longkang dengan banyak air.</i>
Chemicals Bahan kimia	Sodium hydroxide, NaOH pellet, ammonium sulphate, (NH ₄) ₂ SO ₄ powder. <i>Pelet natrium hidroksida, NaOH, serbuk amonium sulfat, (NH₄)₂SO₄</i>
Apparatus Alat radas	Polystyrene cup with lid, thermometer and spatula. <i>Cawan polistirena dengan penutup, termometer dan spatula.</i>
Procedure Prosedur	- Using a measuring cylinder, measure 25 cm³ of water and pour into a polystyrene cup with lid. - Place a thermometer in the water and measure the temperature of water. - Add 3 spatula of NaOH pellet into the polystyrene cup with lid. - Stir it slowly with the thermometer to dissolve the NaOH pellet. - Record the temperature change obtained. - Repeat steps 1 to 4 are using (NH₄)₂SO₄ powder instead of NaOH pellet. - Record the temperature change obtained. <i>1. Dengan menggunakan silinder penyukat, ukur 25 cm³ air dan tuangkan ke dalam Cawan polistirena dengan penutup.</i> <i>2. Letakkan termometer di dalam air dan ukur suhu air.</i> <i>3. Masukkan 3 spatula pelet NaOH ke dalam Cawan polistirena dengan penutup.</i>

	4. Kacau perlahan-lahan dengan termometer untuk melarutkan pelet NaOH. 5. Catat perubahan suhu yang diperoleh. 6. Ulangi langkah 1 hingga 4 dengan menggunakan serbuk $(\text{NH}_4)_2\text{SO}_4$ untuk menggantikan pelet NaOH. 7. Catat perubahan suhu yang diperoleh.		
Observation Pemerhatian	Mixture/ Campuran NaOH + water NaOH + air $(\text{NH}_4)_2\text{SO}_4$ + water $(\text{NH}_4)_2\text{SO}_4$ + air	Observation/ Pemerhatian	Inference/ Inferens
Discussion Perbincangan	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> 1. How do you classify a reaction as an exothermic reaction? Bagaimana anda mengelaskan tindak balas eksotermik? 2. How do you classify a reaction as an endothermic reaction? Bagaimana anda mengelaskan tindak balas endotermik?		

Activity/ Aktiviti	9
Title / Tajuk	Displacement reaction Tindak balas penyesaran
Objective / Objektif	- To predict and identify the products formed in the reaction - To write a balance chemical equation for the reaction - Untuk meramalkan dan mengenal pasti produk yang terbentuk dalam tindak balas - Untuk menulis persamaan kimia yang seimbang bagi tindak balas
Background Knowledge Pengetahuan Latar Belakang	Displacement reactions have the general form: $\text{A} + \text{BC} \rightarrow \text{B} + \text{AC}$ Here, A is an element and BC is usually an aqueous ionic compound or an acid (consisting of B^+ and C^- aqueous ions). Element A displaces element B in the compound BC; this results in the formation of a new element B and a new ionic compound or acid, AC. If the new element B is a metal, it will appear as a metallic deposit. If it is a gas, it will appear as bubbles. An Electrochemical series of elements is often used to determine if A will displace B in a displacement reaction. As a rule, if A has a higher electropositivity than B, a displacement reaction will occur. However, if A has lower electropositivity than B, a displacement reaction will not occur. Tindak balas penyesaran mempunyai bentuk umum: $\text{A} + \text{BC} \rightarrow \text{B} + \text{AC}$ Di sini, A adalah unsur dan BC biasanya larutang sebatian ionik atau asid (terdiri daripada ion B^+ dan C^- berair). Unsur A menggantikan unsur B dalam sebatian BC; ini menghasilkan pembentukan unsur baru B dan sebatian ion atau asid baru, AC. Sekiranya unsur baru B adalah logam, ia akan muncul sebagai logam. Sekiranya ia adalah gas, ia akan kelihatan seperti gelembung. Rangkaian Siri Elektrokimia sering digunakan untuk menentukan sama ada A akan menggantikan B dalam tindak balas penyesaran. Sebagai peraturan, jika A mempunyai lebih elektropositif daripada B, tindak balas penyesaran akan berlaku. Walau bagaimanapun, jika A kurang elektropositif daripada B, tindak balas penyesaran tidak akan berlaku.

	More electropositive <i>Lebih elektropositif</i>		$K^+ + e^- \rightleftharpoons K$ $Ca^{2+} + 2e^- \rightleftharpoons Ca$ $Na^+ + e^- \rightleftharpoons Na$ $Mg^{2+} + 2e^- \rightleftharpoons Mg$ $Al^{3+} + 3e^- \rightleftharpoons Al$ $Zn^{2+} + 2e^- \rightleftharpoons Zn$ $Fe^{2+} + 2e^- \rightleftharpoons Fe$ $Sn^{2+} + 2e^- \rightleftharpoons Sn$ $Pb^{2+} + 2e^- \rightleftharpoons Pb$ $2H^+ + 2e^- \rightleftharpoons H_2$ $Cu^{2+} + 2e^- \rightleftharpoons Cu$ $Ag^+ + e^- \rightleftharpoons Ag$ $E^0 = -2.92 \text{ V}$ $E^0 = -2.87 \text{ V}$ $E^0 = -2.71 \text{ V}$ $E^0 = -2.38 \text{ V}$ $E^0 = -1.66 \text{ V}$ $E^0 = -0.76 \text{ V}$ $E^0 = -0.44 \text{ V}$ $E^0 = -0.14 \text{ V}$ $E^0 = -0.13 \text{ V}$ $E^0 = 0.00 \text{ V}$ $E^0 = +0.34 \text{ V}$ $E^0 = +0.80 \text{ V}$
Aim <i>Tujuan</i>	To study the displacement of copper by zinc from copper (II) sulphate solution <i>Untuk mengkaji perpindahan kuprum oleh zink dari larutan kuprum (II) sulfat</i>		
Before start <i>Sebelum mula</i>	The precipitate produced can be disposed as regular domestic waste into the bin. The solution can be poured down the drain with plenty of water. <i>Mendakan yang dihasilkan dapat dibuang sebagai sampah domestik biasa ke tong sampah. Larutan boleh dibuang ke dalam longkang dengan banyak air.</i>		
Chemicals <i>Bahan kimia</i>	Copper(II) sulphate, CuSO ₄ powder, zinc, Zn powder <i>Serbuk kuprum (II) sulfat, CuSO₄, serbuk zink, Zn</i>		
Apparatus <i>Alat radas</i>	50 cm ³ beaker, measuring cylinder, weighing boat, weighing scale, glass rod. <i>Bikar 50 cm³, silnder penyukat 25cm³, botol penimbang, penimbang berat, rod kaca.</i>		
Procedure <i>Prosedur</i>	1. Weigh 1 g of CuSO₄ into a weighing boat and place it into a beaker. 2. Using measuring cylinder, add 20 cm³ of distilled water into the beaker. 3. Stir the solution to dissolve all the CuSO₄ solid. 4. Add a spatula of Zn into the beaker. 5. Record the observations after 20 minutes to check if there is: (a) any change in colour of the solution, (b) any deposits of metal. 1. Timbang 1 g CuSO₄ ke dalam botol penimbang dan letakkan ke dalam bikar. 2. Masukkan 20 cm³ air suling ke dalam bikar dengan menggunakan silinder penyukat. 3. Kacau larutan untuk melarutkan semua pepejal CuSO₄. 4. Masukkan satu spatula Zn ke dalam bikar. 5. Rekodkan pemerhatian selepas 20 minit sama ada terdapat: (a) apa-apa perubahan warna larutan, (b) sebarang logam terbentuk.		
Observation <i>Pemerhatian</i>	Solution <i>Larutan</i>	Observation <i>Pemerhatian</i>	Inference <i>Inferens</i>
	Zn + CuSO ₄	a) b)	a) b)
Discussion <i>Perbincangan</i>	Answer the following questions / Jawab soalan-soalan yang berikut: 1) Write a balance chemical equation for the reaction. <i>Tuliskan persamaan kimia yang seimbang bagi tindak balas ini.</i> 2) Explain why zinc can displace copper from its salt solution. <i>Terangkan sebab zinc dapat menyesarkan kuprum daripada larutan garamnya.</i>		

Activity/ Aktiviti	10
Title / Tajuk	Heat of displacement/ <i>Haba penyesaran</i>
Objective / Objektif	- To perform calculation involving heat of displacement - To determine the heat of displacement <i>Untuk pengiraan yang melibatkan haba penyesaran</i> <i>Untuk menentukan haba penyesaran</i>
Background Knowledge <i>Pengetahuan Latar Belakang</i>	Displacement of metal is carried out by adding a metal into a salt solution of another metal. A more electropositive metal is able to displace a less electropositive metal from its salt solution. Displacement reactions also involve heat change. Heat of displacement is the heat change when one mole of a metal is displaced from its salt solution by a more electropositive metal. <i>Penyesaran logam dilakukan dengan menambahkan logam ke dalam larutan garam logam lain. Logam yang lebih elektropositif dapat menyesarkan logam yang kurang elektropositif dari larutan garamnya.</i> <i>Tindak balas penyesaran juga melibatkan perubahan haba. Haba penyesaran adalah perubahan haba apabila satu mol logam disesarkan dari larutan garamnya oleh logam yang lebih elektropositif.</i> <u>Example /Contoh:</u> An excess of magnesium powder, Mg is added into 50 cm³ of 0.50 mol dm⁻³ of iron(II) sulphate, FeSO₄ solution. The temperature of the mixture increases by 6.0 °C. Calculate the heat of displacement of iron, Fe from its salt solution. [Given: Specific heat capacity of solution, c = 4.2 J g⁻¹°C⁻¹, density of solution = 1 gcm⁻³] <i>Serbuk magnesium, Mg ditambahkan secara berlebihan ke dalam 50 cm³ larutan ferum (II) sulfat 0.50 mol dm⁻³, FeSO₄. Suhu campuran meningkat sebanyak 6.0 °C. Hitung haba penyesaran ferum, Fe dari larutan garamnya. [Diberi: haba muatan tentu larutan, c = 4.2 J g⁻¹ °C⁻¹, ketumpatan larutan = 1 g cm⁻³]</i> <u>Solution / Penyelesaian:</u> $\text{Mg} + \text{FeSO}_4 \rightarrow \text{Fe} + \text{MgSO}_4$ Number of mol of FeSO₄ solution, $n = MV/1000$ <i>Bilangan mol FeSO₄ = 0.50(50)/1000 = 0.03 mol</i> From the equation, 1 mol of iron, Fe is displaced from 1 mol of FeSO₄ solution. Therefore, 0.03 mol of iron, Fe is displaced from 0.03 mol of FeSO₄ solution. <i>Dari persamaan, 1 mol ferum, Fe disesarkan dari 1 mol larutan FeSO₄. Oleh itu, 0.03 mol ferum, Fe disesarkan dari 0.03 mol larutan FeSO₄.</i> Mass of solution, $m = 50 \text{ cm}^3 \times 1 \text{ g cm}^{-3} = 50 \text{ g}$ <i>Jisim larutan</i> Heat energy released, $Q = mc\theta$ [m= Total volume of mixture, c=specific heat capacity of solution, 4.2J g⁻¹°C⁻¹, θ=temperature change] <i>Tenaga haba dibebaskan, Q = mcθ</i> [m=jumlah isipadu larutan, c=muatan haba tentu, 4.2J g⁻¹°C⁻¹, θ=perubahan suhu] $Q = 50 \times 4.2 \times 6.0 = 1260 \text{ J} = 1.26 \text{ kJ}$ Heat of displacement, $\Delta H = \frac{Q}{n} = \frac{1.26}{0.03} = 42 \text{ kJ mol}^{-1}$ <i>Haba penyesaran</i> Heat of displacement of Fe by Mg, $\Delta H = -42 \text{ kJ mol}^{-1}$ (The negative sign shows this is an exothermic reaction) <i>Haba penyesaran Fe oleh Mg, $\Delta H = -42 \text{ kJ mol}^{-1}$ (tanda negatif menunjukkan ini adalah tindak balas eksotermik)</i>
Aim <i>Tujuan</i>	To determine the heat of displacement of copper by zinc <i>Untuk menentukan haba penyesaran kuprum oleh zink</i>
Before start <i>Sebelum mula</i>	The precipitate produced can be disposed as regular domestic waste into the bin. The solution can be poured down the drain with plenty of water. <i>Mendakan yang dihasilkan dapat dibuang sebagai sampah domestik biasa ke tong sampah. Larutan boleh dibuang ke dalam longkang dengan banyak air.</i>
Chemicals <i>Bahan kimia</i>	Copper(II) sulphate, CuSO ₄ powder, zinc, Zn powder <i>Serbuk kuprum (II) sulfat, CuSO₄, serbuk zink, Zn</i>

Apparatus <i>Alat radas</i>	Polystyrene cup with lid, thermometer, 25 cm ³ measuring cylinder, 50 cm ³ beaker, 25 cm ³ volumetric flask, weighing scale, weighing boat, filter funnel, dropper, washing bottle with distilled water (drinking water) <i>Cawan polistirena dengan penutup, termometer, silinder penyukat 25 cm³, bikar 50 cm³, kelalang volumetrik 25 cm³, penimbang berat, botol penimbang, botol pencuci berisi air suling (air minuman)</i>	
Procedure <i>Prosedur</i>	- Calculate and measure the mass of CuSO₄ powder to prepare 25 cm³ 1.0 mol dm⁻³ CuSO₄ solution. [Hint: Refer to steps in Activity 1. Copper (II) sulphate, CuSO₄ [Molar Mass =160] Mass needed to prepare 25 cm³ of 1.0 mol dm⁻³ CuSO₄ solution: Number of mol of solution, $n = MV/1000$ [M=concentration, V=volume] Mass of CuSO₄ required, $x = \text{Number of moles} \times \text{molar mass of CuSO}_4$ - Using a measuring cylinder, measure 25.0 cm³ of 1.0 mol dm⁻³ copper (II) sulphate solution and pour it into a polystyrene cup with lid. - Measure and record the temperature of the solution with a thermometer after 5 minutes. - Add a spatula of zinc powder into copper (II) sulphate solution in the polystyrene cup with lid. - Stir the contents of the polystyrene cup with lid with a thermometer. - Record the highest temperature reached. - Calculate the heat of displacement. <i>Hitung dan timbang jisim serbuk CuSO₄ untuk menyediakan larutan CuSO₄ 25 cm³ 1.0 mol dm⁻³. [Petunjuk: Rujuk langkah-langkah dalam Aktiviti 1. Kuprum (II) sulfat, CuSO₄ [Jisim molar = 160] Jisim diperlukan untuk menyediakan 25 cm³ larutan CuSO₄ 1.0 mol dm⁻³: Bilangan mol larutan, $n = MV/1000$ [M=kemolaran, V=isipadu] Jisim CuSO₄ diperlukan, $x = \text{bilangan mol} \times \text{jisim molar CuSO}_4$</i> <i>Dengan menggunakan silinder penyukat, ukur 25.0 cm³ larutan CuSO₄ 1.0 mol dm⁻³ dan tuangkan ke dalam cawan polistirena dengan penutup.</i> <i>Ukur dan catat suhu larutan dengan termometer selepas 5 minit.</i> <i>Masukkan satu spatula serbuk zink ke dalam larutan CuSO₄ dalam cawan polistirena dengan penutup.</i> <i>Kacau campuran cawan polistirena dengan penutup dengan termometer.</i> <i>Catatkan suhu tertinggi yang dicapai.</i> <i>Hitungkan haba penyesaran.</i>	
Observation <i>Pemerhatian</i>	Solution / <i>Larutan</i>	Copper(II)sulphate, CuSO ₄ <i>Kuprum (II) sulfat, CuSO₄</i>
	Initial temperature / °C <i>Suhu awal</i>	
	The highest temperature of mixture / °C <i>Suhu tertinggi campuran</i>	
Discussion <i>Perbincangan</i>	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> Calculate the heat of displacement in the activity. <i>Kirakan haba penyesaran dalam aktiviti ini.</i> (c=specific heat capacity of solution, 4.2J g ⁻¹ °C ⁻¹) Heat energy released, $Q = mc\theta =$ <i>Tenaga haba dibebaskan</i> Number of mol of CuSO ₄ , $n =$ <i>Bilangan mol</i> Heat of displacement, $\Delta H = \frac{Q}{n} =$ <i>Haba penyesaran</i>	

Activity/ Aktiviti	11
Title / Tajuk	Heat of precipitation / Haba pemendakan
Objective / Objektif	- To perform calculation involving heat of precipitation - To determine the heat of precipitation - Untuk pengiraan yang melibatkan haba pemendakan - Untuk menentukan haba pemendakan
Background Knowledge Pengetahuan Latar Belakang	Insoluble salts are formed by a double decomposition reaction that involves heat change, which is known as heat of precipitation. Heat of precipitation is the heat change when 1 mol of precipitate is formed from their ions in an aqueous solution. <i>Garam tak terlarutkan terbentuk daripada tindak balas penguraian ganda dua yang melibatkan perubahan haba, yang dikenali sebagai haba pemendakan. Haba pemendakan adalah perubahan haba apabila 1 mol mendakan terbentuk dari ionnya dalam larutan.</i> Example / Contoh: 100 cm³ of 1.0 mol dm⁻³ of lead (II) nitrate, Pb(NO₃)₂ solution is added to 100 cm³ of 1.0 mol dm⁻³ of sodium sulphate, Na₂SO₄ solution. The temperature of the mixture rises from 30.0 °C to 35.0 °C. Calculate the heat of precipitation of lead (II) sulphate, PbSO₄. [Given: Specific heat capacity of solution, c = 4.2 J g⁻¹°C⁻¹, density of solution = 1 g cm⁻³] 100 cm³ larutan plumbum (II) nitrat 1.0 mol dm⁻³, larutan Pb(NO₃)₂ ditambahkan kepada 100 cm³ larutan natrium sulfat 1.0 mol dm⁻³, larutan Na₂SO₄. Suhu campuran meningkat dari 30.0 °C hingga 35.0 °C. Hitungkan haba pemendakan plumbum (II) sulfat, PbSO₄. [Diberi: Kapasiti haba tentu larutan, c = 4.2 J g⁻¹ °C⁻¹, ketumpatan larutan = 1 g cm⁻³] Solution / Penyelesaian: Chemical equation / Persamaan kimia: Pb(NO₃)₂ + Na₂SO₄ → PbSO₄ + 2 NaNO₃ Number of mol of Pb(NO₃)₂ solution, n = MV/1000 = 1.0(100)/1000 = 0.1 mol Bilangan mol larutan Pb(NO₃)₂ Number of mol of Na₂SO₄ solution, n = MV/1000 = 1.0(100)/1000 = 0.1 mol Bilangan mol larutan Na₂SO₄ Ionic equation: Pb²⁺ + SO₄²⁻ → PbSO₄ Persamaan ionik From equation, 1 mol of Pb²⁺ reacts with 1 mol of SO₄²⁻ to produce 1 mol of PbSO₄ Therefore, 0.1 mol of Pb²⁺ reacts with 0.1 mol of SO₄²⁻ to produce 0.1 mol of PbSO₄ Dari persamaan ion, 1 mol Pb²⁺ bertindak balas dengan 1 mol SO₄²⁻ untuk menghasilkan 1 mol PbSO₄ Oleh itu, 0.1 mol Pb²⁺ bertindak balas dengan 0.1 mol SO₄²⁻ untuk menghasilkan 0.1 mol PbSO₄ Mass of solution, m = (100 + 100) cm³ × 1 g cm⁻³ = 200 g Jisim bagi larutan Heat energy released, Q = mcθ Tenaga haba dibebaskan [m= Total volume of mixture, c=specific heat capacity of solution, 4.2 Jg⁻¹°C⁻¹, θ=temperature change] [m=jumlah isipadu larutan, c=muatan haba tentu larutan, 4.2 Jg⁻¹°C⁻¹, θ=perubahan suhu] $Q = 200 \times 4.2 \times (35 - 30) = 4200 \text{ J} = 4.2 \text{ kJ}$ Heat of precipitation, $\Delta H = \frac{Q}{n} = \frac{4.2}{0.1} = 42 \text{ kJ mol}^{-1}$ Haba pemendakan Heat of precipitation of PbSO₄, $\Delta H = -42 \text{ kJ mol}^{-1}$ (The negative sign shows this is an exothermic reaction) Haba pemendakan PbSO₄, $\Delta H = -42 \text{ kJ mol}^{-1}$ (tanda negatif menunjukkan ini adalah tindak balas eksotermik)
Aim Tujuan	To determine the heat of precipitation of lead (II) iodide Untuk menentukan haba pemendakan plumbum (II) iodida

Before start <i>Sebelum mula</i>	The precipitate produced can be disposed as regular domestic waste into the bin. The solution can be poured down the drain with plenty of water. <i>Mendakan yang dihasilkan dapat dibuang sebagai sampah domestik biasa ke tong sampah. Larutan boleh dibuang ke dalam longkang dengan banyak air.</i>
Chemicals <i>Bahan kimia</i>	Lead (II) nitrate ($\text{Pb}(\text{NO}_3)_2$), potassium iodide (KI) <i>Plumbum (II) nitrat, $\text{Pb}(\text{NO}_3)_2$, kalium iodide, KI</i>
Apparatus <i>Alat radas</i>	Polystyrene cup with lid, thermometer, measuring cylinder, 25 cm^3 beaker <i>Cawan polistirena dengan penutup, termometer, silinder penyukat, bikar 25 cm^3</i>
Procedure <i>Prosedur</i>	- Calculate and measure the mass of $\text{Pb}(\text{NO}_3)_2$ powder and KI powder to prepare 25 cm^3 0.2 mol dm^{-3} $\text{Pb}(\text{NO}_3)_2$ and 50 cm^3 0.2 mol dm^{-3} KI solution. [Hint: Refer to steps in Activity 1.] Lead (II) nitrate, $\text{Pb}(\text{NO}_3)_2$ [Molar mass = 331 g/mol] Mass needed to prepare 25 cm^3 of 0.2 mol dm^{-3} $\text{Pb}(\text{NO}_3)_2$ solution: Number of mol of solution, $n = MV/1000$ [M=concentration, V=volume] Mass of $\text{Pb}(\text{NO}_3)_2$ required, $x = \text{Number of moles} \times \text{molar mass of } \text{Pb}(\text{NO}_3)_2$ Potassium iodide, KI [Molar mass = 166 g mol^{-1}] Mass of KI needed to prepare 50 cm^3 of 0.2 mol dm^{-3} KI solution: Number of mol of solution, $n = MV/1000$ [M=concentration, V=volume] Mass of KI required, $x = \text{Number of moles} \times \text{molar mass of KI}$ - Using a clean measuring cylinder, measure 25.0 cm^3 of 0.2 mol dm^{-3} $\text{Pb}(\text{NO}_3)_2$ solution and pour it into a polystyrene cup with lid labelled A. - Clean the measuring cylinder before using it again later. - Measure and record the temperature of the solution with a thermometer. - Clean the thermometer before using it again later. - Use a clean measuring cylinder, measure 25.0 cm^3 of 0.2 mol dm^{-3} KI solution and pour it into a polystyrene cup with lid labelled B. - Measure and record the temperature of the solution with a thermometer. - Add solution in polystyrene cup A into polystyrene cup B with lid. - Stir the solution with a thermometer. - Record the highest temperature reached. - Calculate the heat of precipitation. <i>Hitung dan ukur jisim serbuk $\text{Pb}(\text{NO}_3)_2$ dan serbuk KI untuk menyediakan 25 cm^3 0.2 mol dm^{-3} larutan $\text{Pb}(\text{NO}_3)_2$ dan 50 cm^3 0.2 mol dm^{-3} larutan KI. [Petunjuk: Rujuk langkah-langkah dalam Aktiviti 1.] Plumbum (II) nitrat, $\text{Pb}(\text{NO}_3)_2$ [jisim molar = 331 g/mol] Jisim diperlukan untuk menyediakan 25 cm^3 larutan $\text{Pb}(\text{NO}_3)_2$ 0.2 mol dm^{-3} Bilangan mol larutan, $n = MV/1000$ [M=kemolaran, V=isipadu] Jisim $\text{Pb}(\text{NO}_3)_2$ diperlukan, $x = \text{bilangan mol} \times \text{jisim molar } \text{Pb}(\text{NO}_3)_2$ Kalium iodide, KI [Jisim molar = 166 g mol^{-1}] Jisim diperlukan untuk menyediakan 50 cm^3 larutan KI 0.2 mol dm^{-3} Bilangan mol larutan, $n = MV/1000$ [M=kemolaran, V=isipadu] Jisim KI diperlukan, $x = \text{bilangan mol} \times \text{jisim molar KI}$</i> <i>Dengan menggunakan silinder penyukat yang bersih, ukur 25.0 cm^3 larutan $\text{Pb}(\text{NO}_3)_2$ 0.2 mol dm^{-3} dan tuangkan ke dalam cawan polistirena dengan penutup berlabel A.</i> <i>Bersihkan silinder penyukat sebelum digunakan lagi kemudian.</i> <i>Ukur dan catat suhu larutan dengan termometer.</i> <i>Bersihkan termometer sebelum digunakan lagi.</i> <i>Gunakan silinder penyukat yang bersih, ukur 25.0 cm^3 larutan KI 0.2 mol dm^{-3} dan tuangkan ke dalam cawan polistirena dengan penutup berlabel B.</i> <i>Ukur dan catat suhu larutan dengan termometer.</i> <i>Tuangkan larutan dalam cawan polistirena ke dalam cawan polistirena dengan penutup B.</i> <i>Kacau larutan dengan termometer.</i> <i>Catatkan suhu tertinggi yang dicapai.</i> <i>Hitung haba pemendakan.</i>

Observation <i>Pemerhatian</i>	Solution / <i>Larutan</i>	Temperature / °C <i>Suhu / °C</i>	
	Initial temperature/Pb(NO ₃) ₂ <i>Suhu awal / Pb(NO₃)₂</i>		
	Initial temperature/KI <i>Suhu awal / KI</i>		
	Average initial temperature <i>Purata suhu awal</i>		
	The highest temperature of mixture <i>Suhu tertinggi campuran</i>		
Discussion <i>Perbincangan</i>	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> Calculate the heat of precipitation in the activity. <i>Kirakan haba pemendakan dalam aktiviti ini.</i> (c=specific heat capacity of solution, 4.2 Jg ⁻¹ °C ⁻¹) Heat energy released, Q = mcθ = <i>Haba dibebaskan</i> Number of mol, n = <i>Bilangan mol</i> Heat of precipitation, ΔH = $\frac{Q}{n}$ = <i>Haba pemendakan</i>		

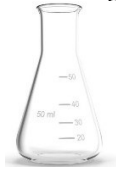
Activity/ <i>Aktiviti</i>	12
Title / <i>Tajuk</i>	Heat of neutralisation between strong alkali and weak acid <i>Haba peneutralan antara alkali kuat dan asid lemah</i>
Objective / <i>Objektif</i>	- To perform calculation involving heat of neutralisation - To determine the heat of neutralization <i>Untuk pengiraan yang melibatkan haba peneutralan</i> <i>Untuk menentukan haba peneutralan</i>
Background Knowledge <i>Pengetahuan Latar Belakang</i>	Neutralisation is a reaction between an acid and an alkali to produce only salt and water. Neutralisation reaction is an exothermic reaction. Hydrogen ions, H⁺ from acid reacts with hydroxide ions, OH⁻ from alkali to form water, H₂O molecules. The ionic equation is as follows: H⁺ + OH⁻ → H₂O The heat of neutralization is the heat change when one mole of water is formed from the reaction between an acid and an alkali. <i>Peneutralan adalah tindak balas antara asid dan alkali untuk menghasilkan garam dan air sahaja.</i> <i>Tindak balas peneutralan adalah tindak balas eksotermik. Ion hidrogen, H⁺ dari asid bertindak balas dengan ion hidroksida, OH⁻ dari alkali untuk membentuk air, molekul H₂O. Persamaan ion adalah seperti berikut:</i> <i>H⁺ + OH⁻ → H₂O</i> <i>Haba peneutralan adalah perubahan haba apabila satu mol air terbentuk dari tindak balas antara asid dan alkali.</i> <u>Example / Contoh:</u> 50 cm³ of 2.0 mol dm⁻³ of sodium hydroxide, NaOH solution is added into 50 cm³ of 2.0 mol dm⁻³ of ethanoic acid, CH₃COOH. The highest temperature of the mixture is 39.0°C. The initial temperature of sodium hydroxide, NaOH solution is 28.0°C, and ethanoic acid, CH₃COOH solution is 28.0 °C. Calculate the heat of neutralisation. 50 cm³ larutan natrium hidroksida, NaOH 2.0 mol dm⁻³ ditambahkan ke dalam 50 cm³ asid etanoik, CH₃COOH 2.0 mol dm⁻³. Suhu tertinggi campuran ialah 39.0 °C. Suhu awal larutan NaOH ialah 28.0 °C, dan CH₃COOH ialah 28.0 °C. Hitungkan haba peneutralan. <u>Solution / Penyelesaian:</u> Chemical equation / Persamaan kimia: CH₃COOH + NaOH → CH₃COONa + H₂O

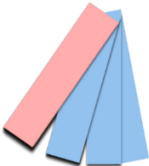
	Number of mol of CH_3COOH, $n = \text{MV}/1000 = 2.0(50)/1000 = 0.1 \text{ mol}$ <i>Bilangan mol CH_3COOH</i> Number of mol of NaOH solution, $n = \text{MV}/1000 = 2.0(50)/1000 = 0.1 \text{ mol}$ <i>Bilangan mol larutan NaOH</i> Ionic equation / <i>Persamaan ionik</i>: $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ From ionic equation, 1 mol of H^+ reacts with 1 mol OH^- of to produce 1 mol of H_2O Therefore, 0.1 mol of H^+ reacts with 0.1 mol OH^- of to produce 0.1 mol of H_2O <i>Dari persamaan ion, 1 mol H^+ bertindak balas dengan 1 mol OH^- untuk menghasilkan 1 mol H_2O</i> <i>Oleh itu, 0.1 mol H^+ bertindak balas dengan 0.1 mol OH^- untuk menghasilkan 0.1 mol H_2O</i> Mass of solution, $m = (50 + 50) \text{ cm}^3 \times 1 \text{ g cm}^{-3} = 100 \text{ g}$ <i>Jisim bagi larutan</i> Heat energy released, $Q = mc\theta$ <i>Tenaga haba dibebaskan</i> $[m = \text{Total volume of mixture, } c = \text{specific heat capacity of solution, } 4.2 \text{ J g}^{-1}\text{ }^\circ\text{C}^{-1}, \theta = \text{temperature change}]$ $[m = \text{jumlah isipadu larutan, } c = \text{muatan haba tentu larutan, } 4.2 \text{ Jg}^{-1}\text{ }^\circ\text{C}^{-1}, \theta = \text{perubahan suhu}]$ $Q = 100 \times 4.2 \times (39 - 28) = 4620 \text{ J} = 4.62 \text{ kJ}$ Heat of neutralisation, $\Delta H = \frac{Q}{n} = \frac{4.62}{0.1} = 46.2 \text{ kJ mol}^{-1}$ <i>Haba peneutralan</i> Heat of neutralisation, $\Delta H = -46.2 \text{ kJ mol}^{-1}$ (The negative sign shows this is an exothermic reaction) <i>Haba peneutralan, $\Delta H = -46.2 \text{ kJ mol}^{-1}$ (tanda negatif menunjukkan ini adalah tindak balas eksotermik)</i>
Aim <i>Tujuan</i>	To determine the heat of neutralization between sodium hydroxide and oxalic acid <i>Untuk menentukan haba peneutralan antara natrium hidroksida dan asid oksalik</i>
Before start <i>Sebelum mula</i>	The solution produced in this activity can be poured down the drain with plenty of water. <i>Larutan yang terhasil dalam aktiviti ini boleh dibuang ke dalam longkang dengan banyak air.</i>
Chemicals <i>Bahan kimia</i>	Sodium hydroxide, NaOH pellet, oxalic acid, $\text{C}_2\text{H}_2\text{O}_4$ powder <i>Pelet natrium hidroksida, NaOH, serbuk asid oksalik $\text{C}_2\text{H}_2\text{O}_4$</i>
Apparatus <i>Alat radas</i>	Polystyrene cup with lid, thermometer, measuring cylinder <i>Cawan polistirena dengan penutup, thermometer, silinder penyukat</i>
Procedure <i>Prosedur</i>	1. Prepare 50 cm^3 of 2.0 mol dm^{-3} sodium hydroxide solution and 25 cm^3 of 1.0 mol dm^{-3} oxalic acid. [Hint: Refer to steps in Activity 1]. Sodium hydroxide, NaOH [Molar mass = 40 g mol^{-1}] Mass needed to prepare 50 cm^3 of 2.0 mol dm^{-3} NaOH solution: Number of mol of solution, $n = \text{MV}/1000$ [M=concentration, V=volume] Mass of NaOH, $x = \text{Number of moles} \times \text{molar mass of NaOH}$ Oxalic acid, $\text{C}_2\text{H}_2\text{O}_4$ [Molar mass = 90 g mol^{-1}] Mass needed to prepare 25 cm^3 of 1.0 mol dm^{-3} $\text{C}_2\text{H}_2\text{O}_4$ solution: Number of mol of solution, $n = \text{MV}/1000$ [M=concentration, V=volume] Mass of $\text{C}_2\text{H}_2\text{O}_4$ required, $x = \text{Number of moles} \times \text{molar mass of } \text{C}_2\text{H}_2\text{O}_4$ 2. Using a clean measuring cylinder, measure 25.0 cm^3 of 1.0 mol dm^{-3} sodium hydroxide solution and pour it into a polystyrene cup with lid labelled A. 3. Clean the measuring cylinder before using it again later. 4. Measure and record the temperature of the solution with a thermometer after 5 minutes. 5. Clean the thermometer before using it again later. 6. Using a clean measuring cylinder, measure 25.0 cm^3 of 1.0 mol dm^{-3} oxalic acid and pour it into another polystyrene cup with lid labelled B. 7. Measure and record the temperature of the solution with a thermometer after 5 minutes. 8. Add solution A in polystyrene cup into polystyren cup with lid B.

	9. Stir the contents of the polystyrene cup with lid with a thermometer. 10. Record the highest temperature reached. 11. Calculate the heat of neutralisation. 1. Sediakan 50 cm ³ larutan natrium hidroksida 2.0 mol dm ⁻³ dan 25 cm ³ asid oksalik 1.0 mol dm ⁻³ . [Petunjuk: Rujuk langkah-langkah dalam Aktiviti 1]. Natrium hidroksida, NaOH [Jisim molar = 40 g mol ⁻¹] Jisim diperlukan bagi menyediakan 50 cm ³ larutan NaOH 2.0 mol dm ⁻³ : Bilangan mol larutan, $n = MV/1000$ [M=kemolaran, V=isipadu] Jisim NaOH, $x = \text{nombor mol} \times \text{jisim molar bagi NaOH}$ Asid oksalik, C ₂ H ₂ O ₄ [Jisim molar = 90 g mol ⁻¹] Jisim diperlukan bagi menyediakan 25 cm ³ larutan C ₂ H ₂ O ₄ 1.0 mol dm ⁻³ : Bilangan mol larutan, $n = MV/1000$ [M=kemolaran, V=isipadu] Jisim C ₂ H ₂ O ₄ , $x = \text{nombor mol} \times \text{jisim molar bagi C}_2\text{H}_2\text{O}_4$ 2. Dengan menggunakan silinder penyukat yang bersih, ukur 25.0 cm ³ larutan NaOH 2.0 mol dm ⁻³ dan tuangkan ke dalam Cawan polistirena dengan penutup berlabel A. 3. Bersihkan silinder penyukat sebelum digunakan lagi. 4. Ukur dan catat suhu larutan dengan termometer selepas 5 minit. 5. Bersihkan termometer sebelum digunakan lagi. 6. Dengan menggunakan silinder penyukat yang bersih, ukur 25.0 cm ³ asid oksalik 2.0 mol dm ⁻³ dan tuangkan ke dalam Cawan polistirena dengan penutup lain yang berlabel B. 7. Ukur dan catat suhu larutan dengan termometer selepas 5 minit. 8. Tuangkan larutan A dalam Cawan polistirena dengan penutup ke dalam Cawan polistirena dengan penutup B. 9. Kacau isi Cawan polistirena dengan penutup dengan termometer. 10. Catatkan suhu tertinggi yang dicapai. 11. Hitungkan haba peneutralan.		
Observation Pemerhatian	Solution / Larutan	Temperature / °C Suhu / °C	
	Initial temperature /NaOH Suhu awal / NaOH		
	Initial temperature/ C ₂ H ₂ O ₄ Suhu awal / C ₂ H ₂ O ₄		
	Average initial temperature Purata suhu awal		
	The highest temperature of mixture Suhu tertinggi campuran		
Discussion Perbincangan	<u>Answer the following questions / Jawab soalan-soalan yang berikut:</u> Calculate the heat of neutralisation in the activity. Kirakan haba peneutralan dalam aktiviti ini. (c=specific heat capacity of solution, 4.2J g ⁻¹ °C ⁻¹) Heat energy released, $Q = mc\theta =$ Tenaga haba dibebaskan Number of mol, $n =$ Bilangan mol Heat of neutralisation, $\Delta H = \frac{Q}{n} =$ Haba peneutralan		

Appendix B

List of apparatus and their uses / *Senarai alat radas dan fungsi*

Apparatus / <i>Alat radas</i>	Uses / <i>Fungsi</i>
Beaker / <i>Bikar</i> 	As a reaction container or to hold liquid or solid samples. They are also used to catch liquids from titrations and filtrates from filtering operations. <i>Digunakan sebagai bekas tindak balas atau untuk memegang sampel cecair atau pepejal. Ia juga digunakan untuk tuangkan cecair dari turasan dan filtrat dari penapisan.</i>
Brush / <i>Berus</i> 	To clean all laboratory glassware. <i>Untuk membersihkan semua peralatan kaca makmal.</i>
Conical flask/ <i>Kelalang kon</i> 	To contain reactions or to hold liquid samples. They are also useful to catch filtrates. <i>Digunakan untuk menahan tindak balas atau memegang sampel cecair. Mereka juga berguna untuk menuangkan filtrat.</i>
Dropper / <i>Penitis</i> 	For addition of liquids drop by drop. <i>Untuk penambahan cecair secara bertahap.</i>
Filter funnel / <i>Corong turas</i> 	For funneling liquids from one container to another or for filtering when equipped with filter paper. <i>Untuk menyalurkan cecair dari satu bekas ke bekas lain atau untuk penapisan.</i>
Filter paper / <i>Kertas Turas</i> 	Used to separate fine solid particles from liquids or gases. <i>Digunakan untuk memisahkan zarah pepejal halus dari cecair atau gas.</i>
Glass rod / <i>Rod Kaca</i> 	Used for stirring and mixing. <i>Digunakan untuk mengacau dan mencampur.</i>
Hand gloves / <i>Sarung tangan</i> 	Protect against skin absorption of chemicals, chemical burns, thermal burns, lacerations, and cryogenic liquid exposure. <i>Melindungi daripada penyerapan bahan kimia pada kulit, luka bakar kimia, luka pembakaran, laserasi, dan pendedahan cecair kriogenik.</i>

Litmus paper / <i>Kertas litmus</i> 	To test whether a solution is acidic or basic. Light Blue litmus paper turns red under acidic conditions and red litmus paper turns blue under basic or alkaline conditions. <i>Untuk menguji sama ada larutan itu berasid atau beralkali. Kertas litmus Biru bertukar menjadi merah dalam keadaan berasid dan kertas litmus merah bertukar menjadi biru di bawah keadaan beralkali.</i>
Measuring cylinder / <i>Silinder penyukat</i> 	For measurement of an amount of liquid. The volume of liquid can be estimated to the nearest 0.1 cm³. <i>Untuk pengukuran jumlah cecair. Isipadu cecair dapat dianggarkan dengan 0.1 cm³.</i>
Polystyrene cup with lid / <i>Cawan polistirena dan penutup</i> 	To reduce the heat loss to surrounding during a chemical reaction. <i>Untuk mengurangkan kehilangan haba ke sekeliling semasa tindak balas kimia.</i>
Reagent bottle / <i>Botol reagen</i> 	Also known as media bottles or graduated bottles, are containers made of glass, plastic, borosilicate or related substances, and topped by special caps or stoppers. They are intended to contain chemicals in liquid or powder form for laboratories and stored in cabinets or on shelves. <i>Juga dikenali sebagai botol media atau botol bergraduasi, adalah bekas yang terbuat dari kaca, plastik, borosilikat atau bahan yang berkaitan, dan diisi dengan penutup atau penutup khas. Ia digunakan untuk menyimpan bahan kimia dalam bentuk cecair atau serbuk untuk makmal dan disimpan di kabinet atau di rak.</i>
Spatula / <i>Spatula</i> 	A broad, flat, flexible blade used to mix, spread and lift material including foods, drugs, plaster and paints. <i>Sudu lebar, rata, fleksibel yang digunakan untuk mencampurkan, menyebarkan dan mengambil bahan termasuk makanan, ubat-ubatan, plaster dan cat.</i>
Safety goggles/ <i>Cermin mata keselamatan</i> 	To shield the eyes against liquid or chemical splash, irritating mists, vapors, and fumes. <i>Untuk melindungi mata daripada percikan cecair atau bahan kimia, kabut, wap dan asap.</i>
Pipette and Pump/ <i>Pipet dan Pam</i> 	Used to measure and transfer liquids with accurate volumes up to 5 mL. <i>Digunakan untuk menyukat dan memindah cecair dengan isipadu yang tepat sehingga 5 mL.</i>
Thermometer/ <i>Termometer</i> 	Used to measure temperature in Celsius. <i>Digunakan untuk mengukur suhu dalam Celsius.</i>

Volumetric flask / <i>Kelalang volumetrik</i> 	Used to measure precise volumes or to make precise dilutions. <i>Digunakan untuk mengukur isipadu yang tepat atau untuk membuat pencairan tepat.</i>
Washing bottle /<i>Botol pencuci</i> 	Used for dispensing small quantities of distilled water. <i>Digunakan untuk membekalkan air suling dalam jumlah kecil.</i>
Weighing boat/ <i>Botol penimbang</i> 	Used to weigh substances that will be transferred to another vessel as well as protect the scale tray. <i>Digunakan untuk menimbang bahan yang akan dipindahkan ke bekas lain serta melindungi dulang skala.</i>
Weighing scale / <i>Penimbang berat</i> 	Used for measuring mass. <i>Digunakan untuk mengukur jisim.</i>

Appendix C

Pre-test and Post-test Questions

Part A: Handling of Materials and Apparatus / *Pengendalian Bahan dan Radas*

Proper use of laboratory apparatus is required to work safely with hazardous chemicals. This section discusses the apparatus often used in laboratories.

Penggunaan alat makmal dengan betul diperlukan untuk berfungsi dengan selamat dengan bahan kimia berbahaya. Bahagian ini membincangkan alat yang sering digunakan di makmal.

1. What is the correct name for the following apparatus?

Apakah nama bagi alat radas ini?



- A. Beaker / *Bikar*
- B. Conical Flask / *Kelalang kon*
- C. Filter funnel / *Corong turas*

2. What is the function of the following apparatus?

Apakah fungsi bagi alat radas ini?



- A. To hold liquid samples and to catch filtrates / *Untuk memegang sampel cecair menuangkan filtrat*
- B. To dispense small volume of distilled water / *membekalkan air suling dalam jumlah kecil*
- C. To measure the volume of liquid / *Untuk menyukat isipadu bagi cecair*

3. Which of the followings is the most suitable for stirring and mixing?

Manakah antara berikut adalah paling sesuai digunakan untuk mengacau dan mencampur?

- A. Spatula
- B. Glass rod / *Rod kaca*
- C. Thermometer / *Termometer*

4. What is the correct name for the following apparatus? *Apakah nama bagi alat radas ini?*

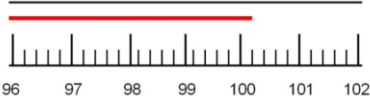


Answer / *Jawapan*: _____

5. What is the apparatus used to measure precise volumes or to make precise dilutions? *Apakah alat radas yang digunakan untuk mengukur isipadu yang tepat atau untuk membuat pencairan tepat?*

Answer / *Jawapan*: _____

Part B: Theoretical Fundamental / Pengetahuan Teori

- What is the standard solution for? *Apakah fungsi bagi larutan piawai?*
 - It is used to balance the concentration of solutes both inside and outside of the cell. / *Ia digunakan untuk menyeimbangkan kepekatan zat terlarut di dalam dan di luar sel.*
 - It is used to resist the change in pH in the solution. / *Ia digunakan untuk menghalang perubahan pH larutan*
 - It is used to determine the concentrations of other substances, such as solutions in titration. / *Ia digunakan untuk menentukan kepekatan bahan lain, seperti larutan dalam pentitratan*
- How do you determine an exothermic reaction? *Bagaimanakah anda menentukan tindak balas eksotermik?*
 - A reaction that release heat to surrounding and cause the temperature to rise / *Tindak balas yang membebaskan haba ke persekitaran dan mengakibatkan suhu meningkat*
 - A reaction that absorb heat from surrounding and cause the temperature to drop / *Tindak balas yang menyerap haba dari persekitaran dan mengakibatkan suhu menurun*
- Following picture shows the part of thermometer. What is the correct reading? *Gambar berikut adalah sebahagian daripada termometer. Apakah bacaan yang betul?*
 - 100 °C
 - 100.2 °C
 - 101.2 °C
- What is the method to separate insoluble salt in precipitation reaction? *Apakah kaedah yang sesuai untuk mengasingkan garam tak terlarutkan dalam tindak balas pemendakan?*

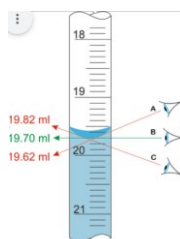
Answer / Jawapan: _____
- Name the ion that is responsible for the acidic properties. *Namakan ion yang berperanan menunjukkan sifat asid.*

Answer / Jawapan: _____

Part C: Practical Knowledge / Pengetahuan dalam Amali

Science practical is one of the fundamental tools to learn scientific knowledge, and how to do science / *Amali adalah asas untuk mempelajari pengetahuan saintifik, dan bagaimana melakukan sains*

- During the preparation of standard solution, why do we need to rinse the beaker with distilled water and transfer the contents into the volumetric flask? *Semasa penyediaan larutan piawai, mengapakah kita perlu bilaskan bikar dengan air suling dan pindahkan kandungan tersebut ke dalam kelalang volumetrik?*
 - To clean the apparatus using distill water / *Untuk membersihkan semua alat radas tersebut dengan air suling*
 - To ensure all the remaining Na_2CO_3 is washed into volumetric flask / *Untuk memastikan semua Na_2CO_3 dibersihkan ke dalam kelalang volumetrik*
 - To add in extra water into the volumetric flask / *Untuk menambahkan air dalam kelalang volumetrik*
- During the preparation of standard solution, why we need to shake the volumetric flask by inverting it several times? *Semasa penyediaan larutan piawai, mengapa kita perlu menggoncangkan kelalang volumetrik dengan membalikkannya beberapa kali?*
 - To get the homogenous solution / *Untuk mendapatkan larutan yang sekata*
 - To get the accurate volume of the solution / *Untuk mendapatkan isipadu yang tepat bagi larutan*
 - To get the stable volume and concentration / *Untuk mendapatkan isipadu dan kepekatan yang stabil*
- Which position is correct to take the accurate reading? *Manakah posisi mata yang betul untuk mengambil bacaan dengan tepat?*



4. Why do we use the polystyrene cup with lid instead of beaker when conducting the experiment to determine the heat of neutralisation? *Mengapakah kita menggunakan cawan polistirena dengan penutup dan bukannya bikar semasa menjalankan eksperimen bagi menentukan haba peneutralan?*

Answer / Jawapan: _____

5. What is the suitable apparatus use to add water slowly in the volumetric flask up to the graduation mark? *Apakah alat yang sesuai bagi menambahkan air secara perlahan-lahan ke dalam kelalang volumetrik sehingga mencapai aras senggatan?*

Answer / Jawapan: _____

Part D: Laboratory Safety Rules / Peraturan Keselamatan Makmal

These basic rules provide behavior, hygiene, and safety information to avoid accidents in the laboratory / Peraturan asas ini memberikan maklumat tingkah laku, kebersihan, dan keselamatan untuk mengelakkan kemalangan di makmal.

- What is the step need to be taken if your finger accidentally touch the alkaline such as sodium hydroxide solution? *Apakah langkah yang diambil sekiranya jari anda terkena dengan alkali kuat seperti larutan natrium hidroksida?*
 - Shout to attract attention / *Menjerit untuk mendapatkan perhatian*
 - Search acid to neutralise the alkaline / *Mencari asid untuk meneutralkan alkali tersebut*
 - Wash with plenty of water and inform teacher in-charge / *Mencuci dengan air yang banyak dan memberitahu guru yang bertugas*
- How to dispose the solid chemical waste produced in the laboratory? *Bagaimana membuang sisa kimia pepejal yang dihasilkan di makmal?*
 - Store chemical wastes in appropriate containers such as plastic bottles or glass bottles / *Menyimpan bahan kimia tersebut ke dalam bekas yang sesuai seperti botol plastik atau botol kaca*
 - Dispose it into dustbin / *Buang ke dalam tong sampah*
- How do you identify if a chemical is hazardous? *Bagaimana anda mengenalpasti jika bahan kimia berbahaya?*
 - Check the product's container label and the Safety Data Sheet (SDS) which is available from the supplier / *Semak label bekas produk dan Helaian Data Keselamatan (SDS) yang tersedia dari pembekal.*
 - Ask your teacher about it / *Tanya guru anda tentang perkara ini*
 - All chemicals should be safe, otherwise it won't be used in school / *Semua bahan kimia harus selamat digunakan, jika tidak, ia tidak akan digunakan di sekolah*
- Hazard pictograms alert us to the presence of a hazardous chemical. The pictograms help us to know that the chemicals we are using might cause harm to people or the environment. What is the meaning of hazard pictogram given? *Piktogram bahaya menyedarkan kita akan adanya bahan kimia berbahaya. Piktogram membantu kita mengetahui bahawa bahan kimia yang kita gunakan boleh menyebabkan bahaya kepada orang atau persekitaran. Antara berikut, apakah maksud piktogram bahaya yang diberikan?*



Answer / Jawapan: _____

5. During the preparation of insoluble salt of PbI_2 , the measuring cylinder used to measure $\text{Pb}(\text{NO}_3)_2$ solution need to be washed first before using it again to measure KI solution. Why? *Semasa penyediaan garam tak terlarutkan, silinder penyukat yang digunakan untuk menyukat larutan $\text{Pb}(\text{NO}_3)_2$ perlu dicuci dengan bersih sebelum menyukat larutan KI. Mengapa?*

Answer / Jawapan: _____

Appendix D

Attitude Survey Questionnaire (Pre and Post)

No	Item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	Performing experiments in chemistry increases my interest in the subject. <i>Melakukan eksperimen meningkatkan minat saya terhadap subjek kimia.</i>	1	2	3	4	5
2	Practical work in chemistry is boring and routine. <i>Kerja amali dalam kimia membosankan dan rutin.</i>	1	2	3	4	5
3	Performing experiments in chemistry is a waste of money. <i>Menjalankan eksperimen dalam kimia membazirkan wang.</i>	1	2	3	4	5
4	I enjoy seeing things for myself during practical. <i>Saya seronok memerhatikan perubahan semasa kerja amali.</i>	1	2	3	4	5
5	I prefer doing experiments myself to watching the teacher demonstrate them. <i>Saya lebih suka melakukan eksperimen sendiri daripada melihat guru menunjukkannya.</i>	1	2	3	4	5
6	More time should be devoted to chemistry practical work. <i>Lebih banyak masa harus diperuntukkan untuk kerja amali kimia.</i>	1	2	3	4	5
7	I learn more when I do the experiment myself. <i>Saya dapat belajar lebih banyak semasa saya melakukan eksperimen itu sendiri.</i>	1	2	3	4	5
8	If I do many experiments myself, I will do better in the exam. <i>Sekiranya saya melakukan banyak eksperimen sendiri, saya akan melakukan dengan lebih baik dalam peperiksaan.</i>	1	2	3	4	5
9	I prefer reading my chemistry book to doing experiments. <i>Saya lebih suka membaca buku kimia saya daripada melakukan eksperimen.</i>	1	2	3	4	5
10	Periods for practical are a waste of time. <i>Waktu amali adalah membuang masa.</i>	1	2	3	4	5
11	Chemistry can be learnt and understood without practical. <i>Kimia dapat dipelajari dan difahami tanpa amali</i>	1	2	3	4	5
12	I enjoy handling equipment and chemicals. <i>Saya gemar mengendalikan peralatan dan bahan kimia.</i>	1	2	3	4	5
13	Viewing videos which show experiments being performed is better than doing the experiment myself. <i>Menonton video yang menunjukkan eksperimen yang dilakukan lebih baik daripada melakukan eksperimen itu sendiri.</i>	1	2	3	4	5
14	I understand basic concepts better when I perform the experiment myself. <i>Saya memahami konsep asas dengan lebih baik semasa saya melakukan eksperimen itu sendiri.</i>	1	2	3	4	5
15	Learning chemistry without practical is uninteresting. <i>Mempelajari kimia tanpa amali adalah tidak menarik.</i>	1	2	3	4	5
16	Performing chemistry experiments is too complicated for me. <i>Melakukan eksperimen kimia terlalu rumit/sukar bagi saya.</i>	1	2	3	4	5
17	Practical work remains important even after the novelty wears off. <i>Kerja praktikal tetap penting walaupun anda berhenti berasa minat atau teruja dengannya.</i>	1	2	3	4	5
18	Performing experiments help me understand the theory better. <i>Melakukan eksperimen membantu saya memahami teori dengan lebih baik.</i>	1	2	3	4	5
19	Chemistry practical work is very tiring. <i>Kerja amali kimia sangat memenatkan.</i>	1	2	3	4	5
20	I am looking forward to the next chemistry experiment. <i>Saya menantikan eksperimen kimia yang seterusnya.</i>	1	2	3	4	5
21	The more time I spend on chemistry practical work the greater my interest. <i>Semakin banyak masa yang saya habiskan untuk kerja amali kimia, semakin besar minat saya.</i>	1	2	3	4	5
22	It is sufficient for one pupil to perform the experiment and the rest to get the results from. <i>Adalah mencukupi bagi seorang murid melakukan eksperimen dan selebihnya untuk mendapatkan hasilnya.</i>	1	2	3	4	5
23	I prefer lessons given by the teacher because practical work is unorganised. <i>Saya lebih suka pelajaran yang diberikan oleh guru kerana kerja amali tidak tersusun.</i>	1	2	3	4	5
24	There is no sense of redoing experiments that scientists have done in the past. <i>Adalah tiada keperluan untuk mengulangi eksperimen yang telah dilakukan oleh saintis pada masa lalu.</i>	1	2	3	4	5
25	I do not like chemistry experiments because the observations are never exact. <i>Saya tidak suka eksperimen kimia kerana pemerhatiannya tidak pernah tepat.</i>	1	2	3	4	5
26	With the help of practical work, chemistry come alive. <i>Dengan bantuan kerja amali, kimia menjadi "hidup".</i>	1	2	3	4	5
27	Chemistry practical work too relevant with my daily life. <i>Kerja amali kimia sangat relevan dengan kehidupan seharian saya.</i>	1	2	3	4	5
28	Doing chemistry practical work can apply chemistry knowledge in solving problems. <i>Melakukan kerja amali kimia dapat mengaplikasikan pengetahuan kimia dalam menyelesaikan masalah.</i>	1	2	3	4	5

Appendix E

Students' opinion about the practical kit

No	Item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	I like to use the practical kit. <i>Saya suka menggunakan kit amali.</i>	1	2	3	4	5
2	The practical kit helps me to improve my skills in handling chemicals and apparatus in practical exam. <i>Kit amali membantu saya meningkatkan kemahiran dalam mengendalikan bahan kimia dan radas dalam peperiksaan amali.</i>	1	2	3	4	5
3	It is difficult to handle the materials and apparatus in the kit. <i>Adalah Sukar untuk mengendalikan bahan dan radas dalam kit.</i>	1	2	3	4	5
4	The practical kit boosts my interest in learning chemistry. <i>Kit amali meningkatkan minat saya untuk mempelajari kimia</i>	1	2	3	4	5
5	I hope my teacher can use the practical kit in my school. <i>Saya berharap guru saya dapat menggunakan kit amali di sekolah saya.</i>	1	2	3	4	5
6	Doing the experiment in the kit makes me understand chemistry concepts better. <i>Melakukan eksperimen dalam kit membantu saya lebih memahami konsep kimia.</i>	1	2	3	4	5
7	The result of experiments cannot be observed easily. <i>Keputusan eksperimen tidak boleh diperhatikan dengan mudah.</i>	1	2	3	4	5
8	I was afraid to try out the experiments using the kit. <i>Saya takut untuk mencuba eksperimen menggunakan kit.</i>	1	2	3	4	5
9	The experiments in the kit can be completed quickly. <i>Amali dalam kit boleh dilakukan dengan cepat.</i>	1	2	3	4	5
10	It is fun to do the experiments using the kit. <i>Adalah seronok melakukan eksperimen menggunakan kit.</i>	1	2	3	4	5
11	I am willing to do more experiments. <i>Saya bersedia untuk melakukan lebih banyak eksperimen.</i>	1	2	3	4	5
12	I am more aware about the safety of chemicals after using the kit. <i>Saya lebih sedar tentang keselamatan bahan kimia selepas menggunakan kit.</i>	1	2	3	4	5
13	The practical kit gives me more opportunity to use the chemicals and apparatus than before. <i>Kit amali memberi saya lebih banyak peluang untuk menggunakan bahan kimia dan radas berbanding sebelum ini.</i>	1	2	3	4	5
14	The practical kit makes me feel that I am working like a chemist. <i>Kit amali membuatkan saya rasa saya bekerja seperti ahli kimia.</i>	1	2	3	4	5
15	I think the practical exam is easier when my teacher use the practical kit in school. <i>Saya rasa peperiksaan amali lebih mudah apabila guru saya menggunakan kit amali di sekolah.</i>	1	2	3	4	5
16	I will buy this practical kit if it is available in the market. <i>Saya akan membeli kit amali ini jika ada di pasaran.</i>	1	2	3	4	5

Appendix F

Reflections and Testimonials in Preliminary-Assessment

“The kit consists of numerous apparatus that I usually see in chemistry lab during studying in school. The kit consists of apparatus such as beaker, conical flask, filter funnel, measuring cylinder, volumetric flask, petri dish, electronic balance, spatula, chemical salt and others.”

“Upon receiving the kit, I was given the opportunity to hold glassware and chemicals that I have been unable to see for a very long time. There were many activities that were very relatable to what I have been studying in textbooks. Many of the activities kept me in awe and amazement.”

“The instruction is clear and easy to carry out. I gained understanding towards reaction in chemical substances during the activity. I usually did activity in group in school whereas I didn't have enough time to observe the result. The kit helps in understanding reaction and analysing chemical reaction in a different way at the point it helps me in my academics”.

“This chemistry kit will help me a lot in answering "experiment-like" questions and I believe that it will be able to help many other students as well.”

Appendix G

Students' Comments, Testimonials and Feedback

“By having a chance doing my own experiment with the practical kit, it increases my interest on Chemistry subject. I feel like I am a scientist!”

“I really like the chemistry practical kit. It enhances and makes me interested more in handling experiment on my own with the guidance of the teacher's instruction.”

“In my opinion, this Chemistry Practical kit is really good for me. At first I don't like do experiment because I scared to work with the tools and handle the chemicals but then it's help me to cure that. Also, this kit really boosts my love for chemistry.”

“I really appreciate the opportunity that have been given which is the Chemical practical kit. I am really enjoying myself while conducting the experiment, plus it enables me to make the application of chemistry in daily life. From this practical kit, I can learn and gain some new knowledge. It gives me confident when it comes to chemistry practical because I have done many of the experiment and can predict the result of the experiment. All in all, it is great to do the experiment practice for the preparation of SPM next year. Once again I am really grateful for this chance.”

“Great! Everything needed is just packed inside a box. The conditions of the materials and apparatus is fine with good qualities. I never thought of doing experiments at home before, even in my own room! I really enjoy doing the experiments, as the activities are safe to be carried out a home. I believe this Chemical practical kit will help we students a lot, since we are not really allowed to do experiments at school.”

“I consider this as once in a lifetime opportunity to have first-hand experience with chemistry. It is sad that I do not really get the chance to get my hands on the apparatus while taking chemistry subject for SPM this year. But, through this practical kit, I can learn Chemistry by theories and also by doing experiments. Chemistry is currently my favourite subject.”

Appendix H

Students' Perceptions towards Citizen Scientist Program

No	Item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	I have never heard about Citizen Scientist Program before. <i>Saya tidak pernah mendengar tentang Program Saintis Warganegara sebelum ini.</i>	1	2	3	4	5
2	Citizen scientist program help me to relate what I learnt in textbook with my daily life. <i>Program saintis warganegara membantu saya mengaitkan apa yang saya pelajari dalam buku teks dengan kehidupan seharian saya.</i>	1	2	3	4	5
3	I hope my teacher can promote citizen scientist program in my school. <i>Saya berharap guru saya dapat mempromosikan program saintis warganegara di sekolah saya.</i>	1	2	3	4	5
4	I think the self-reporting approach on food waste volume and composition is a good method to create awareness to reduce the food waste. <i>Saya rasa pendekatan pelaporan sendiri mengenai jumlah dan komposisi sisa makanan adalah kaedah yang baik untuk meningkatkan kesedaran untuk mengurangkan sisa makanan.</i>	1	2	3	4	5
5	I learn the correct method to measure food waste in my house. <i>Saya mempelajari kaedah yang betul untuk mengukur sisa makanan di rumah saya.</i>	1	2	3	4	5
6	Food waste report makes me understand the waste management concepts better. <i>Laporan sisa makanan membuatkan saya lebih memahami konsep pengurusan sisa.</i>	1	2	3	4	5
7	I am more aware about waste management toward environment after using food waste report. <i>Saya lebih sedar tentang pengurusan sisa terhadap alam sekitar selepas menggunakan laporan sisa makanan.</i>	1	2	3	4	5
8	I think this food waste report make me more interest in learning chemistry. <i>Saya rasa laporan sisa makanan ini membuatkan saya lebih berminat untuk mempelajari kimia.</i>	1	2	3	4	5
9	I think the duration for the food waste report should be longer to get more accurate data on food waste. <i>Saya rasa tempoh untuk laporan sisa makanan harus lebih lama untuk mendapatkan data yang lebih tepat tentang sisa makanan.</i>	1	2	3	4	5

Appendix I

Percentage of wasted food in households

Category	Weight (kg)	Percentage (%)
Home cooked food	10.72	26.39
Meat, fish, egg	7.99	19.66
Rice and pasta	6.93	17.06
Vegetables and potatoes	4.20	10.33
Convenience and take away food	3.84	9.45
Others	3.38	8.31
Fruits and berries	1.58	3.90
Bakery and grain products	1.42	3.50
Milk products	0.57	1.40
Total	40.63	100.00

Appendix J

The reasons for the disposing of food

Category	Percentage (%)
Plate leftovers	36.91
Over prepared	21.45
Food not wanted to eat anymore	20.82
Spoiled, mouldy	9.78
Food suspected to be past its best for consumption	4.73
Other	3.79
Best before or used by date has expired	2.52
Total	100.00

Appendix K

Students' comments after citizen scientist program

“We should start from home and then witness the power of collective decision we have made to reduce food waste, save money, minimise the environmental impact of food production and force food production processes to be more efficient.”

“The best way to help reduce waste is to adopt and practise the theme ' Think. Eat. Save.' as a way of saving the environment.”

“Ensure how many family members that wanted to eat before cooked and cook only a suitable amount, don't cook too many.”

“We can record down the amount of food leftover to reduce preparation of food in future and make compost/organic fertilizer out of food leftover.”

“We should make a weekly menu and use the leftovers as an ingredient in the next meal.” “We can give the neighbour some food that accidentally cooks too much before eating.”

“We can feed food leftover to stray cats and dogs to avoid food waste.”