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Assessing Awareness on Laboratory Safety: A Case Study in Pahang, Malaysia

(Penilaian Kesedaran Keselamatan Makmal: Kajian Kes di Pahang, Malaysia)

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ABSTRACT

Science education emphasises on obtaining knowledge, in which includes hands-on knowledge involving experiments conducted in laboratories. However, since experiments require interactions between students, substances, and equipment, laboratories that can pose great risks to users. In this regards, the Ministry of Education Malaysia has taken proactive approach to enhance laboratory safety via School Science Laboratory Management and Safety guidebook, textbooks, and science-based practical workbooks that are used throughout secondary schools in Malaysia. It is challenging to ascertain students' awareness on laboratory safety throughout Malaysia, hence this study selected 8 secondary schools located in Pahang as case study to determine students' awareness on laboratory safety. A questionnaire was developed by focusing on five components, namely work procedure, safety equipment, handling experiments, chemical waste management, and emergency response plan, and then the questionnaire was completed by 558 science stream students from schools located at urban and rural areas. The results of this study indicate that the overall level of students' awareness on laboratory safety is at medium-high level, and this has shown that the existing measures in secondary school to enhance awareness of laboratory safety is adequate. Nevertheless, there are still room for improvement to further enhance students' awareness on laboratory safety in Malaysia.

Keywords: Laboratory safety, awareness, secondary school, Malaysia

ABSTRAK

Pendidikan sains memberi kepentingan kepada pemerolehan ilmu dan memberi penekanan khusus kepada kerja amali yang dijalankan di dalam makmal sains. Memandangkan kerja amali memerlukan interaksi antara pelajar dengan pelbagai bahan dan peralatan, ia menjadikan makmal sains berisiko kepada penggunanya. Sehubungan dengan itu, Kementerian Pendidikan Malaysia telah memperkukuhkan keselamatan makmal melalui garis panduan Pengurusan dan Keselamatan Makmal Sains, buku teks dan buku amali yang digunapakai di sekolah menengah. Ia adalah mencabar untuk menentukan tahap kesedaran keselamatan makmal di seluruh Malaysia, maka kajian ini telah memilih 8 sekolah menengah yang terletak di Pahang sebagai kajian kes. Soal selidik telah dibangunkan dengan memberi fokus kepada lima komponen utama keselamatan makmal sains, iaitu prosedur kerja, peralatan keselamatan, pengendalian eksperimen, pembuangan sisa bahan kimia dan pelan tindakan kecemasan, dan kemudian soal selidik ini telah dijawab oleh 558 pelajar sains dari sekolah bandar dan luar bandar. Hasil kajian menunjukkan bahawa tahap kesedaran keseluruhan untuk keselamatan makmal adalah pada tahap sederhanda-tinggi, dan ini telah menunjukkan kaedah sedia ada di sekolah menengah adalah memadai. Walaubagaimanapun, ia masih terdapat peluang untuk penambahbaikan serta memperkukuhkan tahap kesedaran pelajar terhadap keselamatan makmal di Malaysia.

Kata kunci: Keselamatan makmal, kesedaran, sekolah menengah, Malaysia

Introduction

To ensure science education reflects the latest development in the field, the national school science curriculum in Malaysia has been revised over time. The Education Act 1996, the 60(Science):40(Arts) Policy, the National Science and Technology Policy, and Vision 2020 are instruments that have informed development of the science curriculum (Ministry of Education Malaysia 2010). The acts and policies pertaining to science curriculum emphasised active involvement of students in the process of teaching and learning (Gani et al. 2006). Students must be trained to acquire concepts, principles, facts, skills, and values through hands-on approach.

The teaching and learning of science would only be comprehensive if accompanied with practical work. This statement is affirmed by work done by other researchers where they found practical work could help students to increase their understanding of scientific concepts, develop their observational and manipulative skills, aid their intellectual development, and enhance their inquisitiveness and problem-solving abilities (Hakinson and Ragsdale 2000; Hofstein and Lunetta 2003; Kamarudin et al. 2009; Eguna et al. 2011). Hodson (1998) stressed on the goal of

science education is to provide students with opportunities to (i) learn science, i.e. acquire and develop conceptual and theoretical knowledge; (ii) learn about science, i.e. acquire an understanding of the nature and methods of science, and an awareness of the complex interactions among science, technology, society, and the environment; and (iii) to do science, i.e. engaged in and develop expertise in scientific inquiry and problem-solving.

In Malaysia, practical work, experiments, or laboratory work are usually carried out in student-oriented laboratories. Science education gives importance to the acquisition of knowledge and pays specific emphasis to practical work in science laboratories. Practical work is an activity that aims at making discoveries from scientific inquiry, through the use of scientific skills. In school science laboratories, teachers and students alike can explore scientific concepts through the execution of practical work, in line with the inquiry-discovery approach as emphasised in the teaching and learning of science. The use of science laboratories to test theories and nurture scientific ability is universally acknowledged, according to Adane and Abeje (2012). Furthermore, Hofstein and Rachel (2007) stated that school science laboratories help students build experience through interactions with a host of materials and equipment, so as to better see and understand the natural world.

Given that the practical work carried out in science laboratories requires students to interact with a variety of materials and equipment, there are risks involved (Alaimo et al. 2010). The materials and equipment used in practical work could be dangerous if not handled correctly. To that end, understanding the safety aspect in science laboratories must be a prerequisite before setting foot in a science laboratory (Hill and Finster 2013). According to Ritch and Rank (2001), science laboratory safety at all levels-whether primary, secondary, or tertiary - must be taken seriously by all parties involved. Accidents are commonly reported in science laboratories around the world, in which underlined the need for awareness on the importance of prioritising safety in science laboratories.

According to Leggett (2012), the accident rate in academic chemical laboratories is about 10-50 times higher than in industrial laboratories. Langerman (2009) concluded almost all academic laboratories are unsafe for study or work. This conclusion was made after studying the death of a student in the University of California Los Angles laboratory, 94 laboratory accident cases identified by the Chemical Safety and Hazard Investigation Board, as well as a variety of accidents reported in the news. This situation could have been avoided or minimised if the laboratory management system that emphasised on safety aspect of science laboratories had been strongly reinforced. Tsung et al. (2007) reported the accident rate in university laboratories and colleges in Taiwan are on the rise, with reported cases of electric shocks, blindness, disability, and even the death of a teacher.

Naturally, the majority of reported accident cases occurred in university laboratories due to materials and equipment used there are more challenging and complex. Nevertheless, attention should not be diverted away from school science laboratories, especially those in secondary schools. School science laboratories help students build up confidence and experience before they eventually enter university laboratories. If the culture of safety in science laboratories has already been inculcated in school, students would better understand the risks inherent in university laboratories, and future accidents can be avoided (Martin et al. 2011).

Cognisant of this fact, the Malaysia Ministry of Education (MOE) published School Science Laboratory Management and Safety (SLMS) guidebook, which enabled school administrators and teachers to improve the quality of school science laboratories, and better equipped themselves to handle issues pertaining to their management (Ministry of Education Malaysia 1999). The SLMS guidebook was first published in 1987, subsequently in 1999. It was then revised in 2010, with inclusions and improvements to its contents. The SLMS guidebook detailed two management fields, i.e., the management of science laboratories, and the laboratory safety. Aside from that, the effort to increase science laboratory safety is carried out through the national science curriculum, in terms of improved textbooks and science-based practical workbooks. This includes an emphasis on safety, through the use of icons like warning signs and precautionary measures for every experiment that will be carried out. These efforts proved that the MOE is committed to science education, and that school science laboratory safety is taken seriously.

Seeing as the SLMS guidebook, textbooks, and science-based practical workbooks are used throughout Malaysia, therefore the students' awareness towards laboratory safety in secondary schools are expected to be at least medium-high. In proving this hypothesis, a case study was carried out to ascertain students' awareness towards laboratory safety in selected Malaysian secondary schools.

Methodology

The objective of this study is to gauge the level of students' awareness on laboratory safety in secondary schools, among selected schools in Pahang (one of the State in Malaysia). Based on the information provided by Pahang Education Department, there are 46 schools located in Kuantan District, hence convenience sampling technique was adopted where 8 schools from urban and rural areas were selected as case study. It is important to involve both urban and rural schools in this study as laboratory experiment scales might vary among the urban and rural schools. The groups of Form 4 and 5 students were selected as respondents because they studied science and have conducted practical work in school science laboratories. The students, therefore, are sufficiently equipped to provide an accurate view of the state of school science laboratories.

The main instrument used in this study is the questionnaire that consists five components, namely (1) work procedure, (2) safety equipment, (3) handling experiments, (4) chemical waste management, and (5) emergency response plan, where these components are based on the 5P approach developed by Ali et al. (2014). There are 32 items in the questionnaire that required students to answer based on the likert scale from 1 to 5, where 1 means strongly disagree, 2 means disagree, 3 means moderate, 4 means agree and 5 means strongly agree. The results were analysed using descriptive statistics through Statistical Package for Social Science (SPSS) 20.0 software. The questionnaire was printed in hardcopy and distributed to the students after the briefing session. Students were given 15-20 minutes to complete the questionnaire.

Subsequently, a pilot study was conducted to determine the validity and reliability of the instruments. For the validity of instrument, the questionnaire was sent to three academics from disciplines, namely chemistry, education and social science for comments and improvement. Based on the feedbacks received from the academics, the questionnaire was amended accordingly. For the reliability of the instruments, a pilot study was conducted based on 95 students with similar characteristics as the actual respondents in a secondary school in Pahang. The reliability test shows that the Cronbach Alpha value attained for the questionnaire is 0.832.

Results were then categorised according to a mean interpretation scale adapted from past studies, as shown in Table 1, where Table 1 was adapted from Ngang et al. (2004), Iksan et al. (2006), Ahmad and Tamuri (2010) and Mogopodi et al. (2015). The interpretive scale was used to benchmark respondents' awareness levels towards school science laboratory safety according to the mean score obtained. The awareness levels were divided into four main categories: low, medium-low, medium-high, and high.

TABLE 1. Mean Interpretation Scale

Mean Score	Level of Awareness
$5.0 \leq y < 4.0$	High
$4.0 \leq y < 3.0$	Medium-high
$3.0 \leq y < 2.0$	Medium-low
$2.0 \leq y < 1.0$	Low

Results and Discussion

The respondent profile is as shown in Table 2, where most of the respondents were female, with 338 (60.6%), with 220 (39.4%) being male. The analysis of the awareness on laboratory safety is based on the five components, and students' awareness on laboratory safety is shown in Table 3.

TABLE 2. Respondent's Profile

No.	Demographics	Urban school (n = 293)	Rural school (n = 265)	Total (n = 558)
1	*Gender*			
	Male	111	109	220
	Female	182	156	338
2	*Ethnicity*			
	Malay	190	99	289
	Chinese	65	128	193
	Indian	35	37	72
	Others	3	1	4
3	*Level of study*			
	Form 4	153	125	278
	Form 5	140	140	280

TABLE 3. Students' awareness on laboratory safety

Component		Item	Strongly agree / Agree (%)	Moderate (%)	Strongly disagree/ Disagree (%)
Work procedure	Item 1	The science laboratory in my school is a risky place.	29.6	29.0	41.4
	Item 2	The school science laboratory has clear and easily understandable safety guidelines.	86.8	9.1	4.1
	Item 3	The science laboratory safety and guidelines poster is displayed in a place that is easy to see and read.	78.9	15.2	5.9
	Item 4	The teacher explains science laboratory safety rules at the beginning of the school session.	55.9	24.2	19.9
	Item 5	I adhere to all of the established school science laboratory safety guidelines.	72.0	22.2	5.8
	Item 6	I clean the school science laboratory after conducting an experiment.	78.6	13.3	8.1
	Item 7	I feel safe when in the school science laboratory.	63.6	26.5	9.9

Safety equipment	Item 1	Laboratory coats are prepared in my school science laboratory.	16.1	40.6	43.3
	Item 2	An adequate amount of laboratory coats are prepared in my school science laboratory.	11.5	40.3	48.2
	Item 3	Safety goggles are prepared in my school science laboratory.	11.3	40.0	48.7
	Item 4	An adequate amount of safety goggles are prepared in my school science laboratory.	7.2	41.0	51.8
	Item 5	Working vapour traps are prepared in my school science laboratory.	50.0	33.7	16.3
	Item 6	An adequate amount of experiment equipment is prepared in my school science laboratory to conduct experiments.	60.4	20.1	19.5
	Item 7	The experiment equipment prepared in my school science laboratory to conduct experiments is in good and safe working condition.	75.6	17.6	6.8
	Item 8	The school science laboratory environment is safe for the handling of experiments.	78.5	14.0	7.5
Handling experiments	Item 1	I handle chemical carefully to prevent spills.	92.4	6.3	1.3
	Item 2	I handle chemicals correctly to prevent wastage.	90.5	6.6	2.9
	Item 3	The reagent/chemical bottles in my school science laboratory are clearly labelled.	84.0	12.2	3.8
	Item 4	The labelled reagent/chemical bottles contain clear and easily understandable safety information.	60.3	29.4	10.3
	Item 5	The reagent/chemical bottles in my school science laboratory can be stored in a safe area.	84.6	12.7	2.7
	Item 6	I read up on ways to conduct experiments before entering the school science laboratory.	69.3	18.5	12.2
Chemical waste management	Item 1	The school science laboratory has guidelines for waste disposal.	28.7	48.9	22.4
	Item 2	The teacher explains the procedure of waste disposal.	50.2	34.8	15.0
	Item 3	I realise that chemical waste is hazardous and cannot be disposed of improperly.	87.1	10.2	2.7
	Item 4	I have obtained enough information on the rules of	45.0	38.9	16.1
Emergency response plan	Item 1	In the school science laboratory, the locations of the alarm, telephone, and the exit is clear marked in case of emergency	58.1	27.6	14.3
	Item 2	A fire extinguisher is prepared in the school science laboratory.	86.2	10.9	2.9
	Item 3	An eye wash station is prepared in the school science laboratory.	16.6	53.4	30.0
	Item 4	Poster to operate fire distinguisher is displayed in school science laboratory.	55.9	32.6	11.5
	Item 5	The procedure for emergency aid is prepared in my school science laboratory (e.g., posters, pamphlets, books, etc.)	44.8	42.1	13.1
	Item 6	An emergency aid kit is prepared in my school science laboratory.	71.6	23.5	4.9
	Item 7	The names of officers that should be called in case of emergency is prepared in my school science laboratory.	24.7	52.5	22.8

Work Procedure

Work procedure is one of the first things students are introduced to upon entering a science laboratory. In general, students are briefed on a set of rules that they have to adhere when conducting laboratory activities, and to provide them with enough information to avoid and prevent occurrence of incidents, which could occur if laboratory activities are not carried out carefully.

The work procedure details what can and cannot be done by students when they are in the science laboratory. According to Frazier and Sterling (2005), there are two kinds of science laboratory rules, namely (1) general rules for when in the science laboratory, and (2) safety procedures to follow when in the science laboratory. The latter is prepared to protect students and those around them from injury, as well as to avoid damage to equipment, and to protect the environment.

Therefore, work procedure plays a vital role, and must be prepared in every science laboratory. In this study, majority (86.8%) agreed that their school science laboratory had clear and easily understandable safety guidelines (Item 2), while 55.9% found that teachers had explained science laboratory safety rules at the beginning of the school session (Item 4). This finding concurred with Frazier and Sterling (2005), who stressed that teachers are responsible for delivering knowledge on science laboratory safety to students. Nevertheless, students must be involved and cooperate with teachers, because it is the responsibility of both to adhere to science laboratory safety guidelines, in the effort to encourage positive values in throughout the teaching and learning process.

Safety Equipment

Science laboratory safety equipment refers to equipment used to protect oneself. Safety equipment is prepared in most school science laboratories, given that most practical work required students to interact with a variety of materials and substances. These materials and substances may be dangerous if used incorrectly, thus safety equipment would be able to ensure that students are protected in case of untoward incidents. There are two categories of school science laboratory safety equipment, namely (1) general safety equipment, and (2) personal safety equipment (Ali et al. 2014).

General safety equipment refers to equipment shared by students, such as vapour traps and ventilator systems. Personal safety equipment – or sometimes known as personal protective equipment (PPE) – refers to safety equipment that should be worn by individual students when conducting experiments, such as safety goggles, laboratory coats and gloves. PPE must be made available in every science laboratory, and subjected to established specifications. The failure to prepare adequate safety equipment will place the users of science laboratories at great risk.

The findings of this study showed that there is doubt among students over the standard of general and personal safety equipment in their respective school science laboratories. The majority of students (51.8%) do not agree that an adequate amount of safety goggles were prepared in their school science laboratories (Item 4). This is also true of Item 2, where many (48.2%) do not agree that an adequate amount of laboratory coats was prepared in their school science laboratories. This finding indicated that schools are not preparing enough safety equipment to students when conducting experiments in science laboratories. This is indeed worrying, because many studies have shown that negligence in the usage of safety equipment can cause accidents, or sometimes death (Noorden 2011; Artdej 2012). Therefore, schools must take this issue seriously, by preparing enough safety clothing and goggles, and ensuring that students wear them when conducting experiments in science laboratories.

Handling Experiments

Adequate knowledge and skills amongst students are essential when conducting experiments, so that they achieve their objectives without endangering other users in the science laboratory. The handling of experiments required students to use the correct materials and equipment. If they do not, there is a great risk of an accident occurring. This means that students should know what the appropriate materials and equipment are when conducting experiments. Teachers and laboratory assistants play an important role in this regard. They must provide briefings and monitor students while experiments are taking place, so as to avoid any accidents or waste of materials. Additionally, the equipment prepared should be in good working condition, and materials clearly labelled and stored in a safe and suitable space.

AcarSesen and Mutlu (2014) stated that the negative perceptions that students have towards science laboratory activity usually stemmed from fear. The findings from this study suggested that students feared using chemicals and equipment wrongly, causing accidents, and making mistakes while conducting experiments. They felt this accidents and mistakes would interrupt the teaching and learning process, and in turn would affect their performance in science subjects. One of the methods for improvement suggested is to equip students with adequate knowledge, which is by reading up on experiments to be conducted before entering the science laboratory. Aside from being better able to use the materials and equipment in the science laboratory, students would also feel more confident when carrying out activities.

For the handling experiments component, the present study found that a high percentage of students agreed with

Items 1-6. In general students gave positive feedbacks towards handling of experiments. 84% (Item 3), 84.6% (Item 5), 90.5% (Item 2), and 92.4% (Item 1) of students responded that materials were clearly labelled, stored in safe places, and that they themselves were able to handle materials carefully to avoid accidents and wastage. Also, 69.3% of students agreed that they should read up on ways to conduct experiments before entering the school science laboratory (Item 6). Overall findings illustrated the fact that students interviewed have positive attitudes towards conducting experiments in the science laboratory.

Chemical Waste Management

Kaufman (1990) defined chemical waste as something that is not needed, usually existing in solid, liquid or even gaseous form. According to him, waste can be categorised as dangerous if it is not handled correctly, where it can cause accidents, death, equipment damage, or environmental pollution. This is because of the danger inherent in chemical waste. Generally, chemical waste can be divided into two categories, (1) chemical waste that results from experimental activity and (2) chemical waste that results from expiration. Both categories of chemical waste require correct and safe disposal. The disposal of chemical waste that does not adhere to regulations could potentially have negative effects on users themselves, other people, and the environment.

In this study, students stated that they are aware of the dangers of chemical waste, and importance to adhere rules of disposal. The main contributing factor to this awareness was due to comprehensive explanations given by teachers. 50.2% of students agreed that teachers explained the procedure of waste disposal (Item 2), while 87.1% agreed that they realised that chemical waste is hazardous and cannot be disposed of improperly (Item 3). Nevertheless, the school is still responsible in preparing clear guidelines given that there are students that still unsure of the chemical waste disposal procedures (Item 1). This may be due to a lack of educational campaigns (i.e. posters) on chemical waste disposal in the science laboratory, causing students to be unsure and solely dependent on teachers' explanations.

Emergency Response Plan

The emergency response plan component is vital in case of emergency. The main point of having an emergency response plan is to avoid fatalities and reduce injuries during an emergency. Although the responsibility of carrying out the emergency response plan belongs to teachers and laboratory assistants, students must still be briefed on the plan, because they must be able to response accordingly in case of an emergency. The emergency response plan encompasses two main elements, namely (1) infrastructure, and (2) system (Ali et al. 2014). Infrastructure refers to necessary emergency equipment, such as fire extinguishers, emergency aid kits, eye wash stations, and so forth. System refers to emergency response plan procedures, maps for emergency exits, collection point instructions, marked exits, and an explanation of the correct authorities to call in case of an emergency (Green & Turk 1978; Freeman & Whitehead 1982).

In relation to that, students must be aware of what needs to be done if any incident occurs. The emergency response plan must be comprehensive and ensure that all those involved (including students) know how to use it in case of emergency. In relation to that, students not only be exposed to emergency equipment, but must also be equipped with emergency training, so they do not panic and do react quickly during an emergency. The findings showed that a high percentage of students are still uncertain about the items under the emergency response plan component, saved under Items 2 and 6. This finding clearly indicated that students are still unfamiliar of the infrastructure and system of the emergency response plan available in their own science laboratories. Having said that, 86.2% of students agreed that fire extinguishers (Item 2), and 71.6% emergency aid kits (Item 6) were installed and available in their science laboratories.

Level of Students' Awareness on Laboratory Safety

In order to evaluate level of students' awareness on laboratory safety, average mean scores for each component have been assessed. The analysis results indicate that the level of students' awareness on laboratory safety is ranging from medium-high to high levels (Table 4). It is noted that the safety equipment component has the lowest average score (i.e. 3.07) compare with other components, and one of the possible factors is due to the limited resources were allocated to purchase safety apparatus such as laboratory coats and safety goggles. On the other hand, the handling experiment component recorded the highest average score (i.e. 4.09), and this mainly contributed by the safety precautions stated in the experiment procedure before students conduct the experiment.

The overall level of students' awareness on laboratory safety is at medium-high level, with the score of 3.58 (Table 4). The result has shown that the existing measures to enhance awareness of laboratory safety, such as the School Science Laboratory Management and Safety (SLMS) guidebook, textbooks, and science-based practical workbooks that are used throughout secondary schools in Malaysia are adequate. However, these findings only limited to selected urban and rural schools in the case study. There are still room for improvement to further enhance students' awareness on laboratory safety in Malaysia.

TABLE 4. Level of students' awareness on laboratory safety

Component	Average mean score	Level of awareness
Work procedure	3.74	Medium-high
Safety equipment	3.07	Medium-high
Handling experiments	4.09	High
Chemical waste management	3.52	Medium-high
Emergency response plan	3.48	Medium-high
Overall	3.58	Medium-high

CONCLUSION

Laboratory safety is one of the vital elements in the education curriculum. The education system must ensure students' health and safety are protected while they are conducting scientific experiments to acquire knowledge and skills. In the regards, the Ministry of Education Malaysia has taken proactive approach to enhance laboratory safety via School Science Laboratory Management and Safety (SLMS) guidebook, textbooks, and science-based practical workbooks that are used throughout secondary schools in Malaysia. It is challenging to ascertain students' awareness on laboratory safety throughout Malaysia, however this study has shown that, but limited to selected urban and rural schools in the case study, the existing measures to enhance awareness of laboratory safety are adequate, especially for the five components of chemical safety, namely work procedure, safety equipment, handling experiments, chemical waste management, and emergency response plan. Nevertheless, these findings only limited to selected urban and rural schools in the case study. There are still room for improvement to further enhance students' awareness on laboratory safety in Malaysia.

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