STATUS OF THESIS

Title of thesis: AT-RISK BEHAVIOUR ANALYSIS AND IMPROVEMENT STUDY IN CHEMICAL ENGINEERING LABORATORIES AT UNIVERSITI TEKNOLOGI PETRONAS

I NORAFNEEZA BINTI NORAZAHAR

hereby allow my thesis to be placed at the Information Resource Center (IRC) of Universiti Teknologi PETRONAS (UTP) with the following conditions:

1. The thesis becomes the property of UTP
2. The IRC of UTP may make copies of the thesis for academic purposes only.
3. This thesis is classified as

[ ] Confidential

[√] Non-confidential

If this thesis is confidential, please state the reason:

________________________________________

________________________________________

________________________________________

The contents of the thesis will remain confidential for ____________ years.

Remarks on disclosure:

________________________________________

________________________________________

________________________________________

Endorsed by

__________________________
Signature of Author

Permanent address:
No.18, Lorong SMP 15,
Taman Tunas Mahkota,
26070 Kuantan, Pahang.

Date : ____________________

__________________________
Signature of Supervisor

Name of Supervisor
AP Dr. Azmi Mohd Shariff

Date : ____________________

UNIVERSITI TEKNOLOGI PETRONAS

AT-RISK BEHAVIOUR AND IMPROVEMENT STUDY IN CHEMICAL

ENGINEERING LABORATORIES

AT UNIVERSITI TEKNOLOGI PETRONAS

by

NORAFNEEZA BINTI NORAZAHAR

The undersigned certify that they have read, and recommend to the Postgraduate Studies Programme for acceptance this thesis for the fulfilment of the requirements for the degree stated.

Signature: ______________________________________

Main Supervisor: ______________________________________

Signature: ______________________________________

Head of Department: ______________________________________

Date: ______________________________________

AT-RISK BEHAVIOUR AND IMPROVEMENT STUDY IN CHEMICAL ENGINEERING LABORATORIES AT UNIVERSITI TEKNOLOGI PETRONAS

by

NORAFNEEZA BINTI NORAZAHAR

A Thesis

Submitted to the Postgraduate Studies Programme

as a Requirement for the Degree of

MASTER OF SCIENCE

CHEMICAL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR,

PERAK

AUGUST 2011

DECLARATION OF THESIS

| Title of thesis | AT-RISK BEHAVIOUR ANALYSIS AND IMPROVEMENT STUDY IN CHEMICAL ENGINEERING LABORATORIES AT UNIVERSITI TEKNOLOGI PETRONAS |
|---|---|

I <u>NORAFNEEZA BINTI NORAZAHAR</u>

hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

Witnessed by

| | |
|---|---|
| ______________________________ | _________________________ |
| Signature of Author | Signature of Supervisor |
| Permanent address:<br>No.18, Lorong SMP 15,<br>Taman Tunas Mahkota,<br>26070 Kuantan, Pahang. | Name of Supervisor<br>AP Dr. Azmi Mohd Shariff |
| Date : ____________________ | Date : __________________ |

# ACKNOWLEDGEMENTS

I owe my deepest gratitude to many people who have been very helpful, and deserve a word of thanks, not only for the role they played in the completion of this research, but also for their continuous help and support throughout my advanced degree studies. In particular, I would like to thank the following people:

To AP Dr. Azmi Mohd Shariff. I am extremely grateful to him for his help. He guided and supported me throughout the entire research project. His input and constructive comments into this particular project has been invaluable. More importantly, he provided me with an environment in which I was able to grow not only as a researcher, but also as an individual.

To Process Safety & Loss Prevention (PSLP) and Chemistry lecturers, specifically Dr. Mohanad M.A.A El-Harbawi, Dr. Risza Rusli, and Dr. Chandra Mohan. They warmly welcomed Lab-ARBAIS implementation as a program to enhance safety in the laboratory.

To the lab technicians. I was fortunate to perform Lab-ARBAIS in the PSLP and Chemistry labs with their assistance. I thank them for their willingness to assist me in this research.

To my parents. Last but certainly not least, my parents have provided me with advice, encouragement, patience and support throughout the years. They gave me the resources I needed to complete this journey, and I will always be grateful for that.

Finally, I would like to thank all my family and friends. Without their support, I certainly would never able to undertake this endeavour.

ABSTRACT

Students in chemical engineering laboratories could be exposed to not only physical hazards but also chemical hazards. Thus, procedures and guidelines dealing with hazardous chemicals are set as a foundation for laboratory safety. Occasionally, these procedures and guidelines are seen as applying only to some situations and not easily followed in all operations. As a result, sometimes injuries, accidents or even fatalities happen due to students violating laboratory safety rules. Violation of laboratory safety rules is students' behavioural issue. In industries, organisation tackles the behavioural issues by implementing Behaviour Based Safety (BBS) technique to identify and control at-risk behaviours. The technique is proved successful in reducing the injury rate of workers in many organisations. Nevertheless, some organisations cannot sustain the comprehensive participation required in BBS related activities. Alternatively, Online At-Risk Behaviour and Improvement System (e-ARBAIS) was introduced to overcome some of the BBS limitations. A modified e-ARBAIS methodology for the chemical engineering laboratory setting is introduced as a technique to identify, monitor and improve at-risk behaviours of undergraduate students known as Lab-ARBAIS. The Lab-ARBAIS maintains the original e-ARBAIS concept by using computer technology for data acquisition and analysis of at-risk behaviours observed. The analyzed observation feedback is posted in students' e-Learning portal to allow the students to view and judge their safety practices in the laboratory. The Lab-ARBAIS program is implemented in chemical engineering laboratories at Universiti Teknologi PETRONAS for undergraduate class as a case study. The Lab-ARBAIS program receives positive students' participation and gives significant improvements on frequent violated safety practices by students.

# ABSTRAK

Pelajar-pelajar di makmal akademik kejuruteraan kimia boleh terdedah kepada bahaya fizikal dan bahaya kimia. Oleh itu, prosedur dan garis panduan untuk mengendali bahan kimia berbahaya dibentuk sebagai asas keselamatan makmal. Sekali-sekala, prosedur dan garis panduan hanya diguna untuk beberapa situasi dan sukar diikuti dalam semua operasi. Akibatnya, banyak luka, kemalangan dan kematian berlaku kerana pelajar gagal mematuhi peraturan. Pelanggaran peraturan keselamatan adalah disebabkan masalah perilaku pelajar. Organisasi industri menangani masalah perilaku dengan menerapkan teknik Keselamatan Berasaskan Perilaku (BBS) untuk mengenalpasti dan mengendalikan perilaku berisiko. Teknik ini berjaya mengurangkan tahap kecederaan pekerja dalam organisasi. Namun, beberapa organisasi tidak berupaya mengekalkan penyertaan menyeluruh dalam kegiatan BBS berkaitan. Sebagai gantinya, Sistem Perilaku Berisiko dan Penambahbaikan dalam Talian (e-ARBAIS) diperkenalkan bagi mengatasi beberapa kelemahan BBS. Metodologi e-ARBAIS disesuaikan dengan prosedur makmal akademik sebagai teknik untuk mengenalpasti, memantau dan memperbaiki perilaku berisiko pelajar lantas dikenali Lab-ARBAIS. Lab-ARBAIS mengekalkan konsep e-ARBAIS dengan menggunakan teknologi komputer untuk pengambilalihan data dan analisis perilaku berisiko. Maklum balas analisis cerapan ditunjukkan di portal e-Pembelajaran pelajar untuk membolehkan para pelajar melihat dan menilai amalan-amalan keselamatan mereka di makmal. Program Lab-ARBAIS dilaksanakan di makmal kejuruteraan kimia Universiti Teknologi PETRONAS untuk pelajar sarjana sebagai kajian kes. Program Lab-ARBAIS disertai pelajar secara positif dan amalan-amalan keselamatan yang sering dilanggar oleh pelajar dapat diperbaiki secara signifikan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Each chemical engineering student will undergo a learning process that transforms their knowledge to a higher level. The learning process basically involves theoretical and experimental modules. To understand and verify scientific theories, it is compulsory for the students to practise experiments in laboratories or usually referred to as labs. The labs are mainly designed to provide good approaches to training and applications of principles and theories to improve students' practical skills and attitudes (Abu-Khalaf, 2001). The labs, as real test rooms, contain hazardous chemicals that may pose threats to students. Generally, the hazardous chemicals are acids, bases, other corrosive, flammable and combustible liquids, oxidizers, water-reactive, explosive, compressed gasses, asphyxiants, toxics, and unstable chemicals. Due to the existence of chemical hazards in the lab, it illustrates that the lab is a serious place of work and study.

Status of academic labs was highlighted by Neal Langerman (2009), who is a regular columnist for the *Journal of Chemical Health and Safety*. He had reviewed some of the 94 lab incidents identified by the Chemical Safety and Hazard Investigation Board (CSB) and other incidents published in various media and thus, he concluded that most academic labs are unsafe venues for work and study. This conclusion is similar to a statement made by Michael J. Halligan, who was an associate director for Environmental Health and Safety at the University of Utah. He said that more accidents happen in academic labs than industrial labs. But the accidents were in a smaller scale because academic labs are seldom worked with the quantity of materials or scale of processes that are common in industries (Schulz, 2005). It is obvious that activities in the academic labs are distinguished from those in the industrial labs by their small scale. The smaller quantities of chemical in the academic labs can reduce the overall consequence of an incident. In addition, heat losses are relatively greater at the lab scale and thus, certainly reduce the hazards. As hazards are minimal in the lab, the lab safety is not given a top priority due to the perception that small quantity of materials would not give a significant hazardous impact to people and environment. If the small scale of the hazard leads to poor practice, the risk is augmented. It is, therefore, not surprising to know that rate opportunities of lab accident in schools and colleges is 100 to 1000 times greater than at Dow or DuPont as estimated by James Kaufman (Benderly, 2009a).

An accident in the chemical engineering lab can give rise to considerable personal injury, loss of life and direct damage loss. To prevent accidents in the lab, a common practice in academic institutions expects students to have a business-like attitude all the time in the lab by depending on lab safety rules. The lab safety rules are about specification, communication and control of students' safe behaviour in the labs. A typical lab safety rules and regulations is given in Appendix A which covers the elements such as conduct of behaviour, general work procedures, students' apparel, hygiene practice, chemical handling, and housekeeping in the lab. More importantly, personal protective equipment (PPE) is required for operation in any lab. This equipment basically consists of a lab coat, safety glasses and gloves. As a matter of fact, rules are provided to govern the behaviour of the students while working in the labs. However, the rules are often seen as applying only to some situations and not possible to follow in all operations in the lab. Another factor of breaching the rules is students have the tendency to pride themselves on their inventiveness and curiosity while running experiments in the lab. Then, the rules will always be difficult to be fully imposed and relied upon (Hale, 1990). Students' behaviour in the labs had been studied by Wu et al. (2007) who identified that lab accidents are intrinsically link to lab safety rules violation and students' at-risk behaviours.

Recently, a few cases of lab accidents which resulted to injuries due to students' at-risk behaviours were reported. On 13 April 2011, Michele Dufault's hair was caught in a lathe in a chemistry lab's machine shop at the Yale University. The quick-spinning machinery pulled her in and it had choked her. The medical examiner determined that she died from accidental asphyxia by neck compression (Irons, 2011; Quinn, 2011). On 7 January 2010, Preston Brown, 29, was seriously injured on his face and hands when a mixture of nickel hydrazine perchlorate exploded in a chemistry department laboratory at Texas Tech University (Johnson, 2010a). Another case occurred in an organic chemistry laboratory at the University of California, Los Angeles (UCLA) on 29 December 2008. A research assistant did not wear a lab coat while working with a pyrophoric chemical. She died due to third-degree burns (43% of her body) and complications (Benderly, 2009b; Kemsley, 2009a; Trager, 2009a). The accident prompted California Division of Occupational Safety and Health (Cal/OSHA) to conduct further investigations. They found that the lack of wearing protective coats was the main factor of the accident. This factor has triggered Cal/OSHA of an unreported accident at UCLA too (Christensen, 2010). The accident had caused a graduate student suffered first- and second-degree burns on his hands and chest when ethanol he was handling splashed onto his clothing and hands and was ignited by a Bunsen burner in November 2007 (Kemsley, 2009b).

The highlighted accidents and many more that may not be reported, due to unsafe practices have caused a wake-up call to everybody. John Bresland, U.S. Chemical Safety Board (CSB) Chairman, has announced that it is time to begin examining these accidents to see if they can be prevented through rigorous safety management systems that industrial people have advocated in industrial settings (CSB, 2010). However, the industrial practices may not be the perfect method for direct implementation because academician and students are often unwilling to follow rigorous safety protocols established by industries because academic experiment work normally uses small quantities of chemicals. Yet, this difficult situation can be changed and accidents and injuries can be prevented with greater awareness of lab safety issues and knowledge of simple yet effective procedures (Schulz, 2005). For Russell W. Phifer, safety consultant and past chair of American Chemical Society's Division of Chemical

Health and Safety, lab accidents investigations had revealed that academic institutions are not seriously paying attention when handling hazardous materials and equipment in labs. Thus, he added that there is a need to improve safety practices and culture at many university labs (Johnson, 2010b; Trager, 2009b).

Safety practice is a desire of an individual to protect himself and his associates and a need to follow a set of rules (ACS, 1973). The challenge of creating safety practices as a valued and inseparable part of all lab activities is to nurture basic safe behaviours and habits naturally to the students. Ideally, the lab is the arena for students to recognise hazardous chemicals and thus, the students spontaneously know the importance of safety and they begin to adopt safe behaviours. In this way, safety values become an internalized attitude and it is not just an external factor driven by the lab safety rules. Hence, the students are expected to have a stronger safety practices. These practises and behaviours can be considered as a safety preparation for students to be hired by industry for professional work, which has a serious responsibility in terms of safety.

## 1.2 Problem Statement

There is always emphasis on safety rules, safety practices, and safe behaviour in the chemical engineering school. To ensure everyone is working safely in the lab, every course of chemical engineering school stresses the importance of safety. It is compulsory for the students to attend safety briefing for every lab experiment (Peñas et al., 2006). However, the students do not seriously practise laboratory safety rules throughout the years of chemical engineering school. Moreover, there are some students who keep breaching the rules even though the academic institutions have executed disciplinary actions.

Academic institutions have carefully implemented and enforced lab safety rules and regulations in every lab. But, it is still lacking of knowledge and skill in controlling and handling human behaviour because the lab accidents due to students' at-risk behaviour are being reported persistently. It is necessary to reduce human error by ways of changing behaviours (Foord and Gulland, 2006) in order to improve safety in the lab.

The frequent accidents due to at-risk behaviours reported in the media or literature signified that some students literally do not value safety in the labs. It is because they might not have a real picture of how at-risk behaviour affected safety management in the lab. Process Safety Management is one of the chemical engineering courses, which can be a medium to enhance human behaviour that lead to safety in the designated working area. Human factor in the process safety management is necessary to be broaden and to also include student's at-risk behaviour while working in the lab.

Despite the growing awareness on lab accidents, there is still no structured technique or implemented system that could be adopted to minimise the accidents due to students' at-risk behaviours. Hence, there is a need to have a system that systematically controls and monitors the students' behaviours which could then reduce frequency of the accidents and injuries.

## 1.3 Objectives

The goal of this research is to introduce and implement a system that would influence students to comply with safe working behaviours and lab safety rules in chemical engineering laboratories at Universiti Teknologi PETRONAS.

The objectives of the research are:

a) To introduce a framework to assess students' at-risk behaviour in chemical engineering labs at Universiti Teknologi PETRONAS.

b) To introduce an improvement system according to the chemical engineering lab setting.

c) To transform the framework as an assessment tool in order to prove the concept.

## 1.4 Scope of Research

This study involves identifying students' at-risk behaviours and frequent violated safety rules in the labs. Therefore, the students' at-risk behaviour in the laboratory were identified and assessed by using the developed assessment tool in two (2) case studies. For each case study, the area of research is limited to academic chemical engineering laboratories at Universiti Teknologi PETRONAS. And, the subjects were students in chemical engineering school.

The effectiveness of the assessment tool in improving students' at-risk behaviour was evaluated in both case studies. After identifying frequent and unimproved at-risk behaviours, a cognitive psychological effect and action by HSE committee, lecturers and lab demonstrators are applied to support the tool in order to change and improve students' at-risk behaviours.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 What Is An At-risk Behaviour?

Russell (1999) defined behaviour as an observable action that the person chooses to do. He also specifically defined at-risk behaviour as an observable action that put someone in a position of exposure to injury.

For Gupta (2007), at-risk behaviour is defined as the result of lack of knowledge or skill on the part of employee, certain bodily defects and wrong attitudes.

And, EPSC (1996) has identified that multitude of factors influence people's behaviours. These factors include:

a) they may not know the correct way to behave

b) they may not have the correct equipment/tools to perform the task

c) they may be subject to other pressures – for example, from supervisor or peer groups

d) they may not understand the consequence of their action

e) they may not have been trained

There are also many reasons why employees engage in at-risk behaviour at work. IOSH (2006) described the reasons as below:

a) To save time: Employees often decide not to use personal protective equipment (PPE) because a task may only take seconds to complete. In this example, the at-risk behaviour has the benefit of saving time.

b) Accepted practice: The job may have always been done in that way.

c) Reinforcement of at-risk behaviour by the actions of supervisors: This may also undermine employees' confidence in the management's commitment to manage concerns such as safety.

d) Misunderstanding of at-risk behaviour: Employees may be unaware, or have a low perception, of the risks associated with a particular task or activity. This could be due to insufficient information or training.

e) Instinctive risk-taking behaviour: Some people are more naturally inclined than others to take risks.

**2.2 Consequences of At-risk Behaviour**

Russell (1999) stated that, most of the task-related behaviours that put people at risk of injury are not obvious or blatant. Instead, they are small momentary actions that the entire workforce may take for granted because they perform them thousands (or even tens of thousands) of times before the incident happens.

Reason (1989) addressed that there are often violations where the consequences are not intended and often not contemplated. The conflict of interests may arise within one person, either short term goals (i.e. complete the task given) or long term safety and health effect. For example, one person decides to use uncomfortable protective equipment against long term cancer risks.

McSween (2003) discussed a safety triangle, as described in Fig. 2.1, to illustrate the consequences of at-risk behaviour. Based on the safety triangle, he described as severity of accident decreases, frequency of personnel's at-risk behaviour increases. For instance, there are 30,000 cases of personnel's at-risk behaviours that could cause up to 3,000 cases of near-miss and first aid. In some of the near-miss and first aid cases, there are individuals who have minor or major injuries. Thus, the injuries are reported as recordable injuries to management. This circumstance could lead up to 300 recordable injury cases and 30 cases of lost-workday injuries. There are chances of fatality depending on seriousness of the injury.

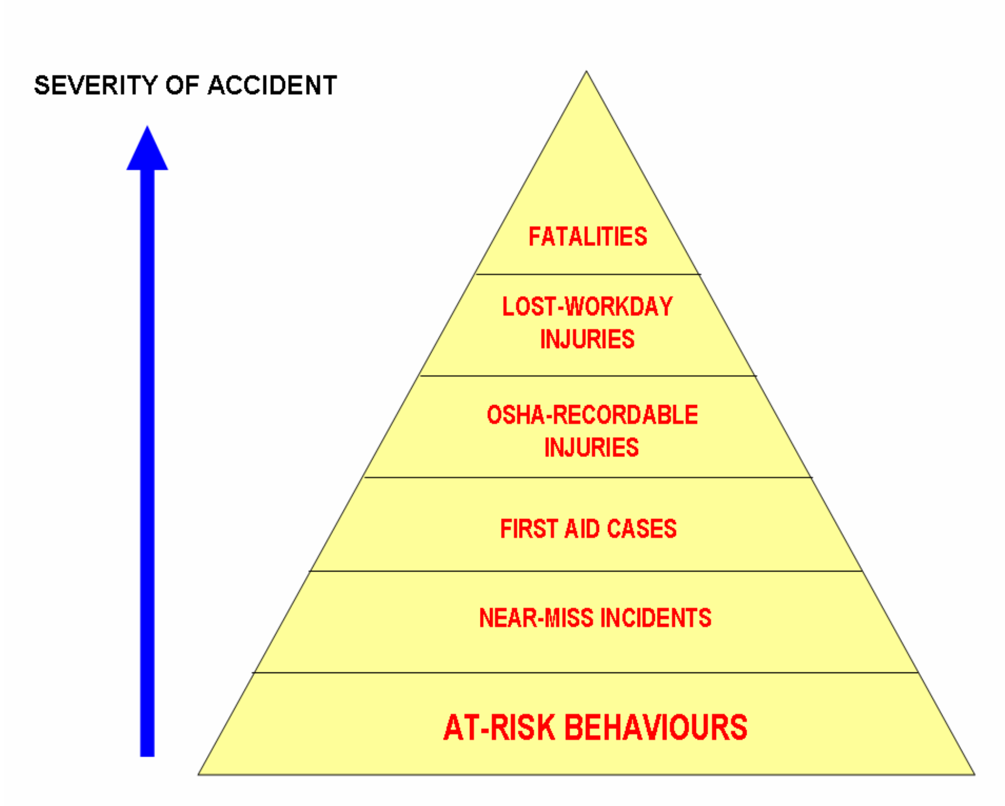


Fig. 2.1. A safety triangle.

Geller (1988) discussed the implication of the safety triangle that is much at-risk behaviour occurs before an injury takes place. The at-risk behaviours had the potential to create a bigger damage even after a minor accident. In other words, at-risk behaviour is an early warning system for accidents. But, the at-risk behaviours at the base of the triangles offer preventative opportunities. If actions can be taken at this level, the chances of more serious injuries occurring will be greatly reduced and avoided.

The bottom line is anyone doing a task in an at-risk way is subjected to possible injury. Goetsch (2002) cited Heinrich who had summarised industrial accidents in ten statements which he called Axioms of Industrial Safety. Details of these axioms are paraphrased below:

a) Injuries resulted from a completed series of factors, one of which is the accident itself.

b) An accident can occur only from an unsafe act by a person and/or a physical or mechanical hazard.

c) Most accidents are the result of unsafe behaviour by people.

d) An unsafe act by a person or an unsafe condition does not always immediately result in an accident/injury.

e) The reasons why people commit unsafe acts can serve as helpful guides in selecting corrective actions.

f) The severity of an accident is largely fortuitous, and the accident that caused it, is largely preventable.

g) The best accident prevention techniques are analogous with the best quality and productivity techniques.

h) Management should assume responsibility for safety since it is in the best position to get results.

i) The supervisor is the key person in the prevention of industrial accidents.

j) In addition to the direct costs of an accident (i.e., compensation, liability claims, medical costs, and hospital expenses), there are also hidden or indirect costs.

## 2.3 Mechanism of At-risk Behaviour in the Context of ABC Principle

Addressing human at-risk behaviours and the consequences are important ingredients in controlling accidents and injuries. For intentional behaviour, it is important to apply ABC model to analyse the behaviour.

ABC model is Antecedents (A) Behaviour (B) and Consequences (C). The ABC model specifies that behaviour is triggered by a set of antecedents (something which precedes behaviour and is causally linked to the behaviour) and followed by consequences (outcome of the behaviour for the individual) that increase or decrease the likelihood that the behaviour will be repeated. The antecedents are necessary but not sufficient for the behaviour to occur. The consequences explain why people adopt a particular behaviour.

Hammer and Price (2001) described antecedents as events or conditions which tell a person what to do or when to do it. Then, they added behaviour is an observable action that follows an antecedent. Finally, it followed with consequences, which are the resulting events of the activated behaviour.

The relationship between these behavioural events is a contingency relationship. It means that if antecedent conditions are present, then the behaviour will occur. If the behaviour occurs, it will be followed by consequence. This relationship is represented in Table 2.1.

It should be noted that both the antecedent and the consequences are controlling the occurrence of the behaviour. Firstly, it demonstrates the role of antecedents because if the individual did not hear the telephone rang, they would not pick up the telephone receiver. Secondly, it highlights the fact that it is the consequences for the individual that drives their behaviour, because in both instances, the individuals heard the telephone rang but, the person did not lift the receiver because working uninterrupted was, for them, a more positive consequence than conversing with a friend.

Table 2.1. Relationship between antecedent, behaviour, and consequence (McSween, 2003).

| **Antecedents** (Causal event, which is triggered, preceding the behaviour) | **Behaviours** (Observable thing that someone does or doesn't do) | **Consequences** (Outcome of the behaviour for the individual that influences the likelihood that the behaviour will be repeated) |
|---|---|---|
| Hear telephone ringing | Lift telephone receiver | Have an interesting conversation with a friend |
| Hear telephone ringing | Do not lift receiver, let the answering machine picks up message | Continue working |

Antecedents come before the behaviour, and help to trigger the behaviour. Examples of antecedents include rules and procedures, suitable tools and equipment, information, signs, skills and knowledge, training and knowledge of other people's expectations, etc. Whilst antecedents are necessary to help trigger behaviour, their presence does not guarantee behaviour to occur. For example, the existence of safety rules and procedures does not ensure safe behaviour to occur.

## 2.4 Behaviour-Based Safety as a Controlling Approach

Having fully described the problematic behaviour, Lardner and Scaife (2006) suggested further behaviour analysis. Steps of the analysis are included to define a safe alternative to the behaviour, to identify which antecedent will help to ensure that the behaviour is triggered, and to recognise the type of consequences that will help to reinforce the behaviour. The results of the analysis can then be turned into practical recommendations to reduce at-risk behaviours and introduce new and safe alternatives to replace at-risk behaviours.

To reduce the chances for accidents to occur, Cooper and Philips (2004) recommended reductions in the frequency of at-risk behaviours and their antecedents (i.e., unsafe conditions or situations). Moreover, Goetsch (2002) emphasized an approach which is able to identify at-risk behaviours and to reduce the injury rate due to at-risk behaviours of workers in the industry.

Behavioural safety, also known as Behaviour Based Safety (BBS), is one of the successful techniques to improve unsafe acts in industrial setting. It was introduced and implemented successfully in various industrial settings since 1970s (Krause et al., 1999; Quintana, 1999; Williams and Geller, 2000).

BBS concepts are in line with basic principles for the practice of safety. BBS must identify at-risk behaviours and then observe them with the aim of encouraging safe behaviours and removing unsafe behaviours.

BBS typically includes assessment and identification of behaviours, development and implementation of a behavioural observation process; evaluation of observation data; and execution of a behavioural feedback process. The observation process involves training employees to conduct safety observations using a behavioural checklist. When conducting observations, observers (i.e., trained employees) approach other employees, observe, and score their performance using the checklist (Alvero et al., 2008).

## 2.5 Benefits of BBS

IOSH (2004) reported a case study in a pallet manufacturing company which had initiated BBS in 1997 as a way to improve its health and safety profile. The company reported positive changes in the attitude of shop floor staff and the safety culture. There were other benefits of BBS reported as follows:

a) Greater involvement and ownership from shop floor staff in respect of health and safety issues and the generation of solutions

b) A reduction in the number of loss-time injuries. Frequency rates steadily decreased from approximately 44 (per 1,000,000 hours worked) in 1999, to 11.8 in 2003

c) An increased understanding and awareness of behaviour and its influence on personal safety

d) Increased productivity – the number of lost eight-hour working days fell from 550 in 1999 to 301 in 2003

e) An estimated cost saving of £285,000 per year

BBS approach can be successful in reducing unsafe behaviors in the workplace. Due to the nature of the approach, there are other less tangible benefits as described by Anderson (2005). The benefits are:

a) Management may demonstrate their commitment to improve safety;

b) The workforce and management communicate with each other about safety;

c) It increased profile of health and safety;

d) It increased visibility of management in the workplace;

e) Employee engagement in safety;

f) Managers/supervisors learn to act promptly on at-risk behaviours (and have a legitimate mechanism for doing so);

g) Managers/supervisors may improve their safety leadership

h) Managers/supervisors learn to think about human factors

Similarly, OHSREP (2008) had also proved the benefits of BBS. Many employers, in Australian workplaces, like the approach of BBS because it takes the focus off what they were doing and onto watching workers. The BBS approach often:

a) Focus attention to the individual's behaviour.

b) Make workers engage with responsibility. The focus shifts from what the employer should do to what workers can and should do for themselves.

c) Produce a more democratic workplace by involving empowering workers.

d) Provide a mechanism for workers to develop a way of disciplining fellow workers.

## 2.6 Perspective of BBS in Engineering and Process Safety

The technique of BBS is used to improve the extent to which people follow procedures and accepted good practice. BBS brings about substantial improvement in the everyday accident that makes up most of the lost-time and minor accidents rate.

More importantly, BBS has an effect on process safety. The success or failure of any process safety in chemical plants depends mainly on human behaviour. It is because, as Foord and Gulland (2006) pointed out, engineering solutions have to be supported by procedures to ensure that designs, construction and maintenance are carried out correctly. In practice, automatic equipment does not eliminate the human element entirely. It will be necessary to focus on behaviour and methods of working during all phases of the lifecycle so as to remove or reduce opportunities for human error.

All incidents resulting from the exposure to hazards and reducing that exposure are the primary mechanisms of safety improvement. Manuele (2006) emphasised if incident still occurs, BBS practitioners should recognize the validity of extending BBS work to influence safety management systems and the design of the workplace. If the incident happened due to behaviour, then behavioural methods to attain solutions should be applied. Design, engineering, safety and operations personnel should recognize that the need may rise to engage skilled people in occupational psychology and organizational psychology when designing and engineering measures failed. In this matter, it happened because of psychosocial work situations.

The suggestion to include experts in engineering and technical was also being discussed by Lardner and Scaife (2006). They commented that it is possible to train engineers to successfully use BBS to analyse errors and violations, thus implement corrective actions which are designed to influence safe behaviour in the future. They said so because majority of process industry organizations are incompetent in coping with human behaviour and developing recommendations which would maximize influence on future behaviour. The organizations are applying a typical set of existing recommendations to address behaviour by giving briefing to personnel, rewriting a procedure, and providing further training.

For Abu-Khader (2004), attitude changes have an important role in accident prevention. Important challenges are to develop interventions that influence social norms and safety-related aspects of culture and to identify optimal combinations of preventive measures. The major safety issue in the development of technological societies is the consideration of the human element as the source of, and a contributor to accidents and that all accidents in artificial systems are directly or indirectly caused by human behaviour.

## 2.7 BBS Limitations

BBS is a popular approach to safety used in companies around the world. Agraz-Boeneker et al. (2007) found that BBS have often been presented and explained by safety professionals, quality experts and psychologists, but have not been systematically evaluated to examine relationships between incident occurrence and the implementation of BBS. Evaluating the impact of BBS on incidence rate alone is often complicated by confounding factors and/or pre-existing trends. BBS studies often present cases of injury rate reduction that started before a BBS implementation making it difficult to determine a cause-effect relationship.

Although BBS approach is consistently effective at reducing the frequency of at-risk behaviours, it can only work optimally if used throughout an organization. Usually, employees do not participate actively in observation and feedback sessions that help to implement BBS intervention procedures (DePasquale and Geller, 1999).

Furthermore, BBS process could be very labour intensive (Keng, 2008). It requires many observers to make the process effective. Much effort is required to train the employees to become the observers. Many organizations that attempted to obtain the benefits of BBS did not sustain comprehensive participation that is required in BBS-related activities.

## 2.8 e-ARBAIS As An Alternative to BBS

Shariff and Keng (2008) established an alternative to the BBS, which was termed Online At-Risk Behaviour Analysis and Improvement System (e-ARBAIS). The e-ARBAIS utilizes computer technology in making the routine observation process to be more sustainable and hence instilling the habitual awareness through the cognitive psychology effect. Through this process, the tedious observations by trained observers as required in BBS were done naturally by all the e-ARBAIS respondents. It saved time and money compared to the BBS technique. e-ARBAIS concept was implemented in Company X to identify at-risk behaviours that needed improvement. The employees gave good support and response to the e-ARBAIS program.

Apparently, both BBS and e-ARBAIS are reported successful in collecting workers' at-risk behaviours in industrial application. But, none of them is applied in educational application, particularly in academic laboratory setting, in order to reduce frequency of accidents happened due to at-risk behaviours of students.

## 2.9 Safety in the Chemical Engineering Laboratory

Simmons et al. (2009) had reviewed the results of previous analysis of the causes of chemical accidents. He found laboratory knowledge and experience are crucial because they provide hands-on knowledge of chemical behaviour, limitations of laboratory or chemical process equipment, and potential alternatives that would make the work safe. He also added that there are very few people with sufficient educational background and experience to recognize near misses and precursors to an accident.

Safety in education or university level is considerably basic to the broad safety area. Kletz (2002) revealed safety learning should include discussion of accidents happened because they illustrate important safety principles such as the need for inherently safer design, the identification and assessment of hazards, the science of fires and explosions and the need to look below the immediate technical causes for ways of avoiding the hazard and for the weaknesses in the management system.

The summary of the lack of knowledge in safety can be related to a study by Blair et al. (2004). He performed the study with the aim to measure the magnitude of the relationship between safety beliefs and safe behaviour of Midwestern college students. The students were found less safety-conscious in terms of self-reported safety beliefs and safe behaviours. The finding indicates that safety education of adolescents and young adults in the United States has not been effective. Based on results of the study, he suggested safety education should focus more on changing safety beliefs. He added personal responsibility should be greatly emphasized in every aspect of education and training as a way of preventing unintentional injuries.

To change safety in education and university level, Hill Jr. (2004) encouraged academicians to apply a plan of action that will engage, enlighten, and encourage the needed change.

a) Engage – Get America Chemical Safety (ACS) leadership to accept the need and support the effort.

b) Enlighten – Explain the importance of a strong safety ethic and the need for a strong education in chemical safety principles.

c) Encourage – Establish a network of experienced people who can provide assistance and consultation to those implementing safety programmes.

To begin safety programme, Peñas et al. (2006) suggested applying industrial health and safety criteria to the design and start-up of a laboratory for chemical engineering teaching. Safety aspects for designing and setting up chemical engineering teaching laboratories are safety rules and regulations, safety facilities in the laboratory (i.e. the lab equipped with fire extinguishers, a safety shower, a fire blanket, an eyewash station, a first-aid kit with the basic medical products, smoke and gas detectors and two emergency doors) and specific training on the safety issue to the students that are involved in laboratory experimentation. They concluded that by promoting laboratory safety at the university level, there will be a positive impact on all the people who will share the professional environment of chemical engineers in the future.

Safety management could enhance the safety programme in the education and university level, as performed by Zakzeski in 2009. He conducted a study of a framework for Total Quality Management (TQM) to improve laboratory safety. A chemical engineering laboratory at the University of California, Berkeley was selected for the study. The framework has included proactive elements (i.e. Safety Audits and HAZOP analysis), reactive elements (i.e. Accident and Near-miss reports, In-service Inspection reports), and interactive elements (i.e. Crisis Management). Based on his study, he had been informed of the importance of implementing this framework, especially with the constant influx of new students, the potential for communication break-down between shared equipment, and the large number of potential hazards inherent in a chemical engineering laboratory.

Hazard recognition in laboratories and pilot plants is generally managed under the US Occupational Safety and Health Administration (OSHA) Laboratory Standard. Langerman (2009) examined application and benefits of the OSHA

Process Safety Management (PSM) to further reduce risks associated with the operations in the labs. He suggested training, one of PSM major elements. Training is not adequate to meet reasonably foreseeable process occurrences. There is a prevalent attitude that students do not need training related to the health, safety and emergency aspects of their processes. The faculty, staff and students of each laboratory should have an annual training session to review their general and specific process safety hazards. The training must address incidents which have occurred and the practices implemented to prevent a recurrence. All training must be fully documented.

Perrin and Laurent (2008) reported the education of chemical engineers in the principles of safety has been a priority in France for 15 years. The academicians familiarize the chemical engineering students with the occupational safety concerns. They have to be familiar with the principles because engineers are often responsible for the design and construction of industrial facilities and the protocols relating to their operation. Thus, the engineers must involve more with worker-related issues, and new materials or new or improved processes, or both, that are constantly being introduced to industry which require greater awareness of their safety effects at the design stage, and engineers should not relegate safety considerations to retrofitting practices.

## 2.10 New Approach to Students' At-Risk Behaviours

Based on the literature review, there is no structured technique to address and improve at-risk behaviours for lab environment. There is certainly an advantage to develop a systematic technique for assessing and improving students' at-risk behaviours. In this research, the approach of addressing and improving students' at-risk behaviour in the lab would be based on Online At-risk Behaviour and Improvement System (e-ARBAIS) concept with some modifications to suit the lab environment.

# CHAPTER 3

# METHODOLOGY

The Online At-risk Behaviour and Improvement System (e-ARBAIS) concept is using a computer technology to create a cognitive psychology effect, to inculcate safety culture, and to take an action for any safety violation. However, the e-ARBAIS concept is modified in order to suit with the students and academic lab setting and later it is termed as Laboratory At-Risk Behaviour Analysis and Improvement System (Lab-ARBAIS).

## 3.1 Lab-ARBAIS Concept

The Lab-ARBAIS concept is schematically shown in Fig. 3.1 and its explanations are given step by step below.

### 3.1.1 Computer Technology as a Medium of Communication

By using a computer technology, the Lab-ARBAIS is a medium between students and lecturers to communicate about safety in the lab. It is because the Lab-ARBAIS is appropriate to be used as a communication channel to approach students who violated lab safety rules and to improve safety practice. The communication is regularly focused on observation of safety practices, feedback based on observation, analysis of feedback and lastly, review analysis.

### 3.1.2 Create a Cognitive Psychological Effect through Repetitive Observation

The Lab-ARBAIS observation items are based on safety practices as in lab safety rules. An observation is conducted when there are students working in the lab. In the beginning of every experiment session, lecturers or lab demonstrators ask students to notice and observe any lab safety rules violation around them and thus, give the observation feedback in the Lab-ARBAIS observation list. This practice is intended to instil a cognitive psychological effect where the students are reminded on lab safety rules. An advantage of training peer observers, as claimed by McSween (2003), is the act of observing the safety performance of others promotes the observer's own safety behaviour. As the students perform observations on the practices of their friends, they come to recognize any discrepancies between their own behaviour and what is considered safe and thus, they begin to adopt safe practices more consistently.

### 3.1.3 Create Environment to Inculcate Safe Behaviour and Safety Culture

It is important to repeat performing observation and giving observation feedback. Repetition of observing lab safety rules practices or violations would enhance long-term memory of lab safety rules to the students. As the students memorize the observed lab safety rules practices, they begin to follow and practise the lab safety rules. Routine observation does not only encourage students to work safely, but it also nurtures students to embrace safe working behaviours. The safe working behaviour is basically proportional to safety culture. If many students embrace safe working behaviours, it has induced a safe working environment. So, a safety culture has been developed in the lab. As Attwood et al. (2006) pointed out; safety culture is often developed by enforcing day-to-day safety rules.

### 3.1.4 Implement Alternative Solution for Unimproved At-Risk Behaviour

The Lab-ARBAIS provides analysis of the results of lab safety rules practices and violations not only to the students but also to HSE committee, lecturers and lab demonstrators. They could analyse and determine whether the implemented Lab-ARBAIS successfully improved the considered at-risk behaviours. If the Lab-ARBAIS failed to improve the at-risk behaviours, HSE committee, lecturers, and lab demonstrators could provide some recommendations to mitigate the issues. To stop lab safety rules violation, they can apply ABC model in considering actions to be taken. Then, the students should be instructed and encouraged to perform the tasks correctly and safely.

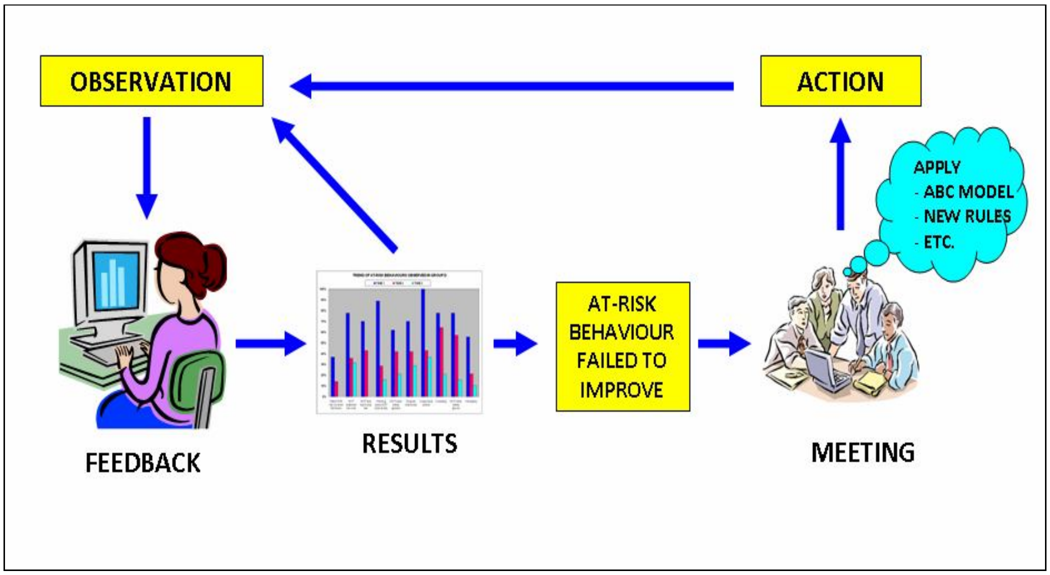


Fig. 3.1. Concept of Lab-ARBAIS

### 3.2 Lab-ARBAIS Framework

The overall procedure of the Lab-ARBAIS program was designed as illustrated in Fig. 3.2. Description of the framework is given below.

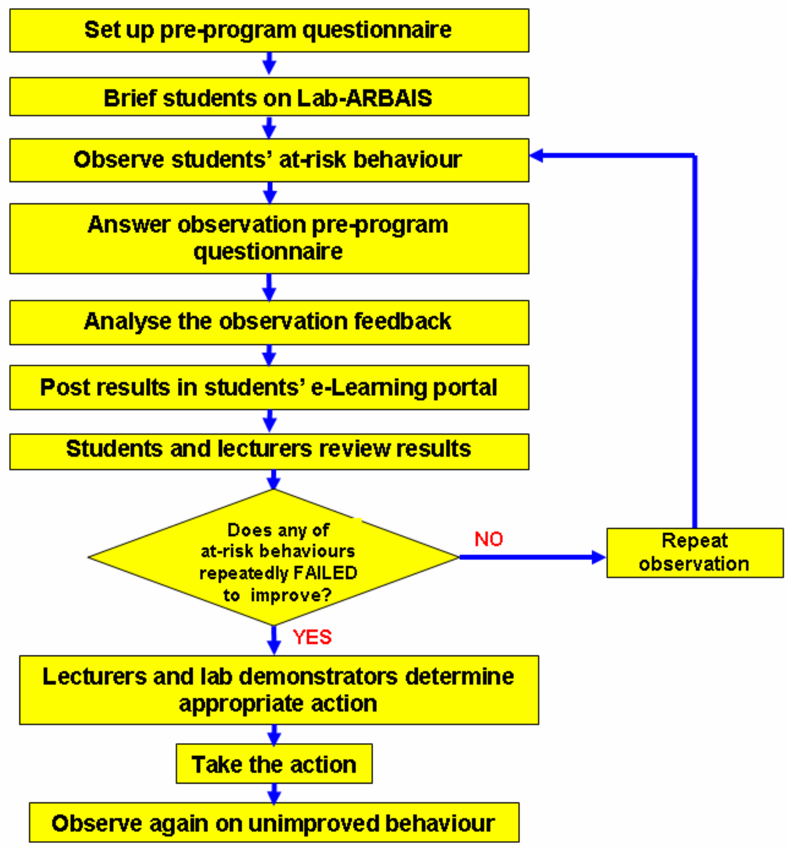


Fig. 3.2. Framework of Lab-ARBAIS.

### 3.2.1 Set Up Pre-program Questionnaire

The program starts by setting up pre-program questionnaires in a database. Critical at-risk behaviours of students are identified based on laboratory accident track records and the result of frequently observed at-risk behaviours. The identified critical at-risk behaviours are prioritised and transformed into questionnaires form in MS Excel.

### 3.2.2 Lab-ARBAIS Briefing

The Lab-ARBAIS is introduced and briefed to the students in their first session of the laboratory class in the beginning of the semester. Introduction and briefing help the students to understand and familiarize with observation and the Lab-ARBAIS.

### 3.2.3 Peer Observation

A characteristic feature of Lab-ARBAIS is its reliance on direct peer observation of safety practices. In the Lab-ARBAIS briefing, students are required to observe and recognise their friends who break any lab safety rules while they are working in the laboratory. To be precise, the students are the observers for their friends. As a safety precaution, the students are encouraged to directly advise their friends if they break the rules. Another method is to report what they have observed to the Lab-ARBAIS by answering the questionnaire.

### 3.2.4 Observation Feedback

Observational recording method is aided by the Lab-ARBAIS in MS Excel to record occurrences or non-occurrences of the targeted behaviours. Answers from the data input are entered into a database after each observation. It is automatically saved in the MS Excel program.

### 3.2.5 Feedback Analysis

The observation feedbacks are calculated according to the formula as discussed in Section 3.4. Based on the calculation, the Lab-ARBAIS constructs a graphic feedback to show measures of safety performance over time. This graphic, in computer generated, is the mode of feedback delivered in order to influence the Lab-ARBAIS effectiveness to the students. To influence students, the graphic shows percentage of safe behaviours and percentage of at-risk behaviours observed.

### 3.2.6 Display Results

The graphic feedbacks are publicly displayed in the students' e-Learning portal with the aim to be readily and continuously available to the entire chemical engineering school. Through these graphic feedbacks, the students are indirectly reminded that their behaviours are being observed and reported by their colleagues. In their minds, they should think that someone is watching their behaviour and they must behave and follow all the safety rules and regulations.

HSE committee, lecturers and lab demonstrators should also review the results as well. From that review, they have an opportunity to select a high-risk behaviour for problem solving.

### 3.2.7 Review Results by HSE Committee

Should the results show insignificant improvement of the at-risk behaviour, the lecturers and demonstrators could take appropriate action as necessary. Action taken depends on the type of at-risk behaviour observed. For example, the lecturers and demonstrators give a penalty to the identified students who practised at-risk behaviour repeatedly in the lab. Further, it is appropriate if the lab coordinator or management repeats the behaviour observation in order to re-evaluate students practising the behaviour.

## 3.3 Lab-ARBAIS Case Studies

To illustrate ways to effectively implement Lab-ARBAIS concept in the academic lab with an emphasis on managing student behaviour, a chemical engineering lab of Universiti Teknologi PETRONAS (UTP) was selected as a case study. The case study was then divided into two lab cases, which were Process Safety and Loss Prevention (PSLP) and Chemistry labs. These two labs were used to examine and to compare Lab-ARBAIS effectiveness for students at different age; which were PSLP students of usually 20 years old and 18 years old of Chemistry students.

To start the Lab-ARBAIS in both lab cases, a survey was conducted to identify critical students' at-risk behaviour. Chemical Engineering lab safety rules and regulations, as in Appendix B, were referred to create questions for the survey. The focus of the case study was to identify, monitor and improve students' at-risk behaviours. Thus, the survey questions (Appendix C) were particularly concerned behaviours of the students in the labs, i.e. usage of personal protective equipment (PPE), housekeeping habit, and safe practices. The survey questions, in a hardcopy form, were distributed to a group of people who were authorised to control and monitor PSLP and Chemistry labs, such as lecturers, lab demonstrators, and technicians. The information from the survey has prioritised ten (10) at-risk behaviours practised as listed in Table 3.1.

Table 3.1. List of at-risk behaviours practised and consequences.

| NO. | AT-RISK BEHAVIOURS PRACTICE | CONSEQUENCES |
|---|---|---|
| 1 | Untying long hair | - Long hair will be easily caught by flames or rotating equipment. |
| 2 | Not wearing full-covered flat shoes | - Exposed foot does not have protection against falling object or stray chemical spill. |
| 3 | Not cleaning working area | - Untidy working area is not safe to work with because it is not clear of chemical spills, books, papers or anything that are not being used. |
| 4 | Unbuttoning lab coat | - Unbuttoned lab coat is an invitation for stray chemical spills/splash that would result in skin corrosion/burns. |
| 5 | Not wearing safety glasses when handling chemicals | - Unprotected eyes will not have protection of chemical splashing. |
| 6 | Pouring waste chemical into the sink | - Stagnant chemical in the sink can react when student pours chemical into the sink.<br>- Sink is used to drain water only. If students pour chemical into the sink, chemical in sanitary sewer system can cause damage to eco-systems and water pollution as well. |
| 7 | Not wearing gloves when handling chemicals | - Touching chemicals with bare hands can cause corrosion. |
| 8 | Engaging in horseplay in the lab | - Students messing around doing something that they have already been told not to do. Thus, the students distract or startle other students to work safely. |
| 9 | Using handphone in the laboratory | - Handphone battery is a source of ignition. The battery emits electromagnetic radiation which could cause localized heating.<br>- Handphone battery could ignite flammable chemical in the lab. |
| 10 | Students crowding the designated working area | - Students interfere with the experiments of other students. Thus, the unwelcome students distract other students to work safely. |

In this study, safe mode and unsafe mode questionnaires were introduced with the aim to reinforce safe behaviours and to reduce at-risk behaviours, respectively. The safe behaviour questionnaires are listed in Table 3.2 and the unsafe behaviour questionnaires are given in Table 3.3.

These two modes were developed because Alvero et al. (2008) reported that the observation accuracy data collected in the research indicates that some behaviours observers were unable to correctly identify differences between safe and unsafe performance. They also added that it is not clear if observers lacked the skills to discriminate between safe and unsafe behaviour or if they lacked the motivation to do so. Thus, this study intended to ease observer's understanding in observing either safe behaviour or unsafe behaviour.

Table 3.2. Observation questions for safe mode group.

| **No.** | **Questions for Safe Mode Group** |
|---|---|
| 1 | Have you seen your friend wearing full-covered flat shoes? |
| 2 | Have you seen your friend buttoning his or her lab coat? |
| 3 | Have you seen your friend tying his or her long hair? |
| 4 | Have you seen your friend cleaning his or her working area after use? |
| 5 | Have you seen your friend wearing safety glasses in the lab? |
| 6 | Have you seen your friend NOT disposing chemical into the sink? |
| 7 | Have you seen your friend NOT using hand phone in the lab? |
| 8 | Have you seen your friend NOT crowding working area while conducting experiments? |
| 9 | Have you seen your friend wearing safety gloves in the lab? |
| 10 | Have you seen your friend NOT engaging in horseplay in the lab? |

Table 3.3. Observation questions for unsafe mode group.

| **No.** | **Questions for Unsafe Mode Group** |
|---|---|
| 1 | Have you seen your friend wearing NON full-covered flat shoes? |
| 2 | Have you seen your friend NOT buttoning his or her lab coat? |
| 3 | Have you seen your friend NOT tying his or her long hair? |
| 4 | Have you seen your friend NOT cleaning his or her working areas after use? |
| 5 | Have you seen your friend NOT wearing safety glasses in the lab? |
| 6 | Have you seen your friend disposing chemical into the sink? |
| 7 | Have you seen your friend using hand phone in the lab? |
| 8 | Have you seen your friend crowding working area while conducting experiments? |
| 9 | Have you seen your friend NOT wearing safety gloves in the lab? |
| 10 | Have you seen your friend engaging in horseplay in the lab? |

All the procedures for the case study were prepared to implement PSLP lab and Chemistry lab case studies. The details of both case studies are stated accordingly.

### 3.3.1 Case Study in PSLP Lab

PSLP course was selected as a lab case because PSLP is a course that focuses on process safety and it certainly enhances safety and loss prevention issues. The Lab-ARBAIS case study in PSLP was continued to the following semester, i.e. semester 1 and 2, with the aim to examine safety practice habit of the students when they are exposed to a different lab course.

Students are eligible to take PSLP course during the second semester of their second year chemical engineering school. This requirement is fundamental to measure students' maturity in safety belief and perception as they have experienced two (2) years doing experimental works in the labs. Thus, it is necessary to conduct a survey before Lab-ARBAIS is launched to the students. This survey is called Safety Survey Before Lab-ARBAIS.

In this survey, students were assessed based on safety aspects and requirements that had been implemented by university. The approach to the survey involved developing questionnaire-based survey with reference to questions as developed by DePasquale and Geller (1999), Laurence (2005), Shariff and Keng (2008), and Mohamed et al. (2009). The survey questionnaire was delivered to the students. The survey is shown in Appendix D. The survey questions were distributed to all of PSLP students. After the students returned the survey form, participation and responses were calculated by using the following equation.

The participation was calculated based on the survey form returned and total number of students and it was formulated as below;

Total participation in percentage

$$= \frac{\text{Total survey form returned}}{\text{Total number of students enrolled in course}} \times 100\% \qquad \text{... Equation 3.1}$$

Each question of the survey requires students to answer ‘yes’ or ‘no’ only. To calculate ‘yes’ and ‘no’ responses for each question, it was measured by using the formula in Equation 3.2.

$$\text{Total 'yes' answers in percentage} = \frac{\text{Total of students answer 'yes'}}{\text{Total survey form returned}} \times 100\% \quad \text{… Equation 3.2}$$

Total ‘no’ answers in percentage were calculated by using Equation 3.2, but the calculation focused to the ‘no’ answer only.

The Lab-ARBAIS was then launched during PSLP course briefing. A total of 142 students (PSLP January-2009 semester) participated and were divided into groups of designated safe and unsafe mode. Each mode was applied to two different groups of students i.e. Group A and Group B for safe mode, whereas Group C and Group D for unsafe mode.

As the PSLP lab case study had two semesters, semester one was named as Phase 1 and semester two was Phase 2. For each semester, it had different number of observations depending on the number of experiments required by syllabus. Semester one had three (3) experiment sessions and semester two had four (4) experiment sessions. It meant that, there were three (3) observations during phase 1 and four (4) observations when the students were in their phase 2.

The students were required to do observation each time they were working in the labs. They should give observation responses by answering a set of questionnaires in the Lab-ARBAIS tool once they had completed their work. The answering process took about two to five minutes. The same set of questionnaire was used and repeated in each experiment session. The purpose of repeating the same questionnaire of observation is to study trends of the observed students’ safe and unsafe behaviours continuously.

During the last observation, which was the fourth experiment session in phase 2, another survey was conducted to re-evaluate students' safety perception and practices after they had participated in the Lab-ARBAIS program. This survey was known as Safety Survey After Lab-ARBAIS and it was delivered to the students. Questionnaire by Keng (2007) was used as reference in developing the survey questionnaire. The questions of the Safety Survey After Lab-ARBAIS are shown in Appendix E. To calculate responses for the survey, it was done by using the formula as in the Safety Survey Before Lab-ARBAIS, i.e. formula in Equation 3.1 and Equation 3.2.

Fig. 3.3 illustrates a summary of PSLP case study. And, Fig. 3.4 shows a flowchart of the Lab-ARBAIS tool.

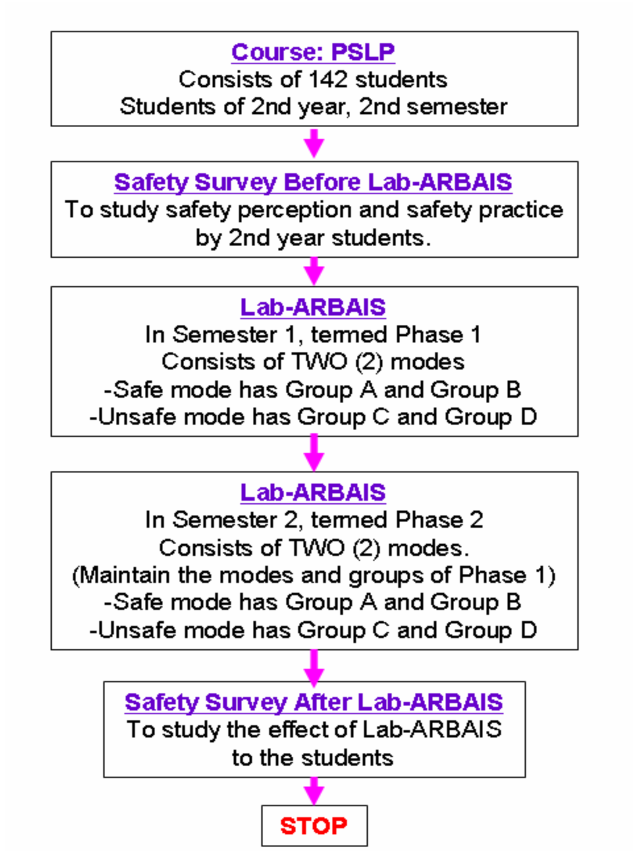


Fig. 3.3. Summary of case study in PSLP lab

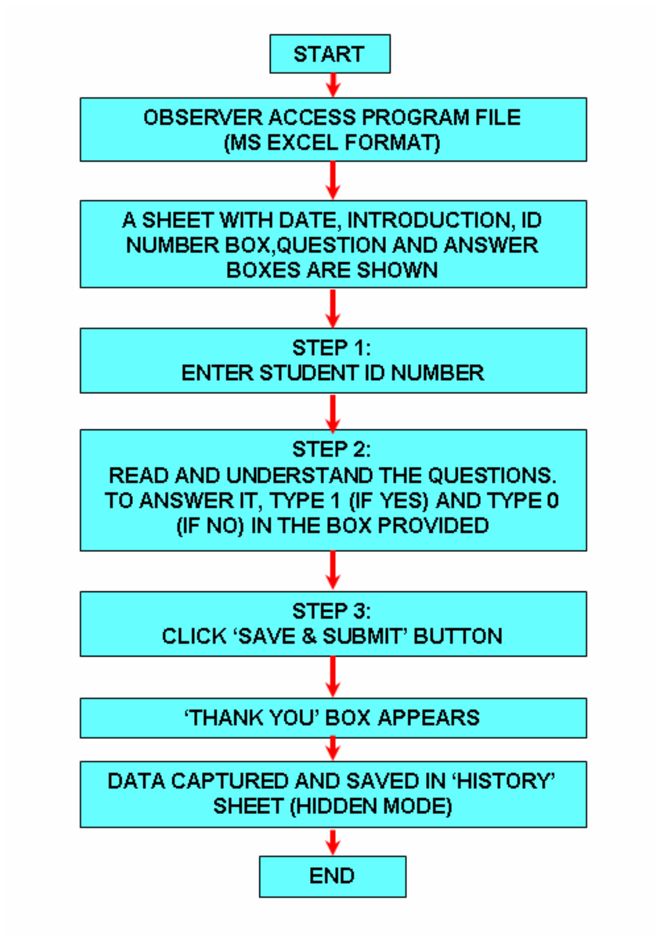


Fig. 3.4. A flowchart for Lab-ARBAIS tool in PSLP lab.

A student or user accessed the file Lab-ARBAIS in a folder which was labelled as PSLP lab case study. When the file was opened, the main page of the Lab-ARBAIS was appeared as shown in Fig. 3.5. The main page contained all the questionnaire of the observation that the student or user should answer. The first step was the student must identify himself or herself by giving student ID number. The next step was to read and understand the observation questions so that the student could answer them. The student or user must key in 'One' (1) that were referred to 'Yes' and 'Zero' (0) as the answer to 'No'. After the student or user had completed answering the questions, he or she had to click 'Save and Submit' button to complete the process. Through that button, Lab-ARBAIS popped out 'Thank You' box as a sign that the data input had been captured and saved.

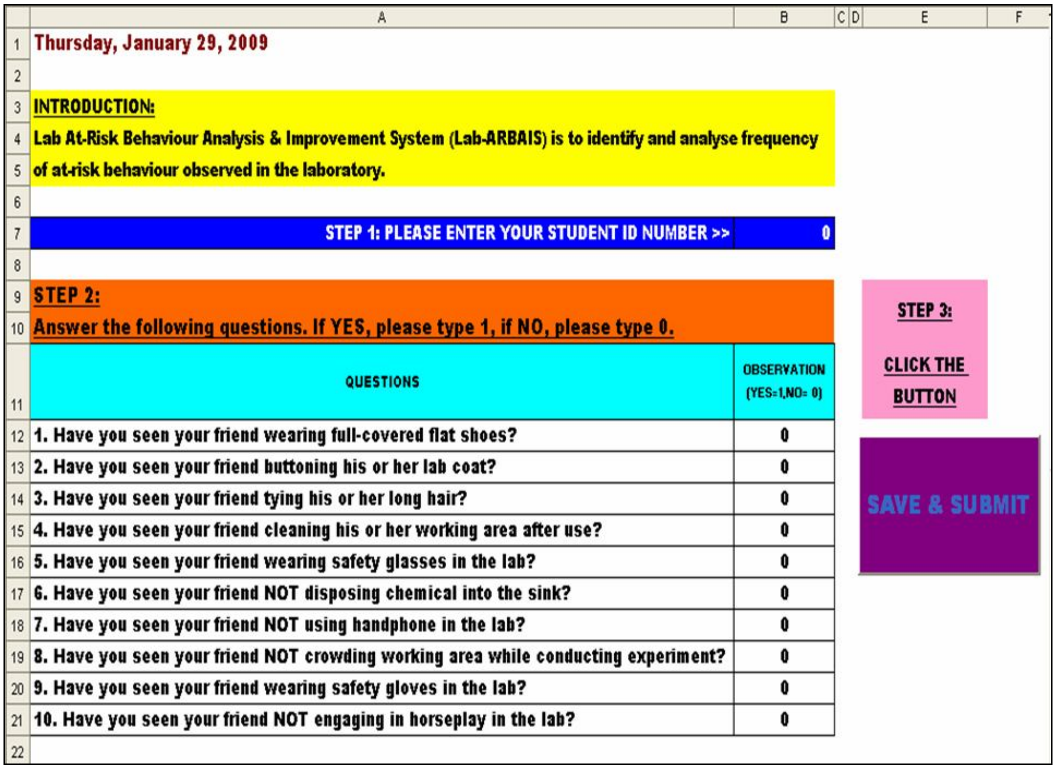


Fig. 3.5. Main page of Lab-ARBAIS tool for students in PSLP lab

### 3.3.2 Case Study in Chemistry Lab

Chemistry is a foundation course of chemical engineering school. Thus, it is necessary to introduce the Lab-ARBAIS concept to new students with the aim to foster habitual safety practices at the beginning of their studies in chemical engineering school. To start Lab-ARBAIS, 105 students of January-2009 semester were divided into groups of unsafe and safe mode. Each mode held two groups of student i.e. unsafe mode had Group A and Group B, whereas safe mode had Group C and Group D. Each group was actually using the same lab room. The lecturer set Group A alternated with Group B.

Lecturers of Chemistry were normally put a disciplinary action to the students who disobeyed the lab safety rules and instructions. In this case study, the Lab-ARBAIS remained the disciplinary action idea as a strategy for students to adopt self-protective behaviours by following the lab safety rules. Before the Lab-ARBAIS was introduced to the Chemistry students, a survey for identifying students' preference action was conducted in the class. The survey named as Survey on Preferred Action and it was to find types of action that students believed psychologically influence their safety practices and behaviours in the lab. Questions were created based on actions which were previously applied by the lecturers. The survey questions were distributed to the students according to their unsafe and safe mode groups during Chemistry briefing course. The questions are shown in Appendix F. Participation and responses of the survey were calculated using Equation 3.1 and Equation 3.2. Results of the calculation are discussed in Chapter 4.

Next, the Lab-ARBAIS was launched in Chemistry lab during the first experiment session. In the Lab-ARBAIS briefing, the students were trained to notice their friends who broke the lab safety rules. Then, the students were required to respond to the observation questions in the Lab-ARBAIS tool after they completed their experimental works. This process took about two to five minutes per student. Through observation responses and analysis results, a student who had been identified not following the rules was penalized according to the suggested action.

The process of observe, respond, and action taking were repeated for the next experiment session. There were three (3) experiments session for Chemistry, thus it meant three (3) times of observation. The students had to answer the same set of observation questionnaires for each observation. It was actually to observe and to study trends of safe and unsafe behaviours observed in the designated groups.

To ease understanding of the Chemistry case study, a summary of the study is shown in Fig. 3.6.

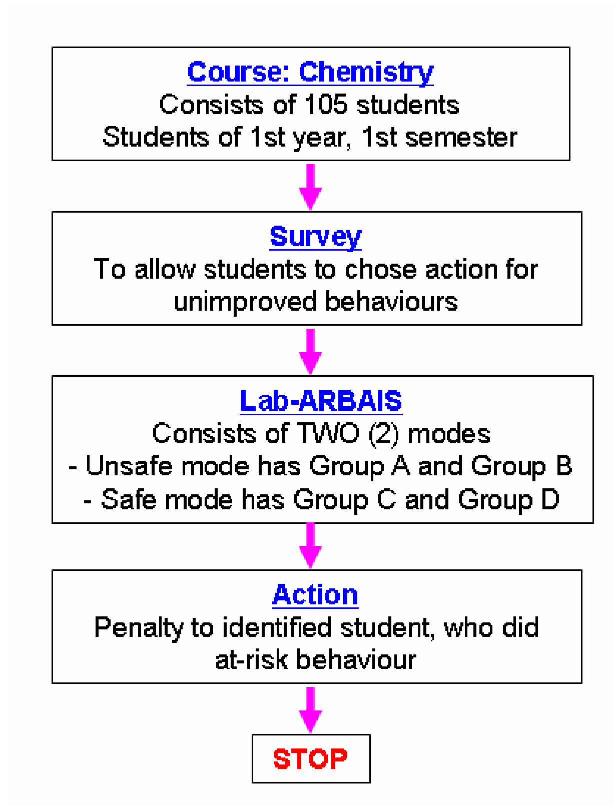


Fig. 3.6. Summary of case study in Chemistry lab.

When a student or user approached the Lab-ARBAIS, he or she had to access the file Lab-ARBAIS in a folder which was labelled as Chemistry lab case study. Once the file was opened, main page of the Lab-ARBAIS was appeared the same as Lab-ARBAIS in PSLP lab. But, it had additional step in giving the observation feedback. Fig. 3.7 shows a third step that was optional to the student or user. If the student or user thought it was necessary to put table's number of the student who did unsafe behaviours, he or she can do so in Step 3. After that, the student or user had to click 'Save and Submit' button to complete the process, which was similar to the Lab-ARBAIS in PSLP lab.

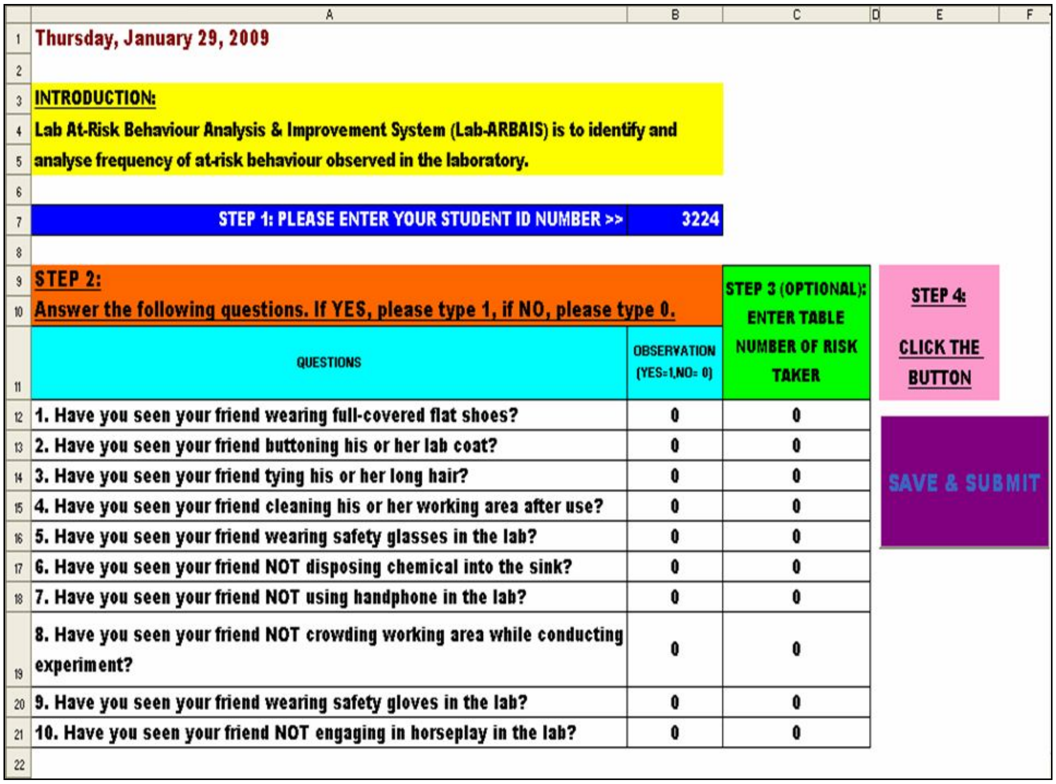


Fig. 3.7. Lab-ARBAIS tool with optional to enter table number of violator.

### 3.4 Lab-ARBAIS Data Analysis

Students' behaviour while working in the lab was the main focus to the Lab-ARBAIS. It was because these behaviours can be calculated. Cooper (2000) stated that an individual's behaviour can be measured by safe behaviours percentage. Choudhry et al. (2007) also highlighted the identified safe behaviours placed on observational checklists and then it should be translated into 'percentage of safe scores' to provide feedback to those being observed. This recommendation was similar to Cooper et al. (1994). He stressed that the observation results were used to compute a safe score percentage, which was primarily intended to provide ongoing feedback so that people can adjust their performance accordingly. The formula for calculating the percentage of safe behaviour was based upon individual's total of both safe and unsafe behaviours, and dividing the sum of these totals into the amount of safe behaviours recorded and multiplying by 100 percent, i.e. total safe behaviour / (total safe behaviour + total unsafe behaviour) x 100%. The observed safe score percentage was thought to be one of the most useful indicators of safety performance to organizations (Reber et al., 1989).

Thus, the Lab-ARBAIS collected the observation responses according to safe and unsafe behaviours. Example of data saved is shown in Appendix G. All data were analysed in the pre-program calculation in MS Excel based on numerical formula for safe and unsafe behaviours. The analysis formulas for safe and unsafe behaviours are discussed below.

### 3.4.1 Calculation for Percentage of Safe Behaviour

To focus on safe behaviours of students, it was done by concentrating to the safe mode group. In this group, the scale used to rate the students' behaviours consists of two options of answers, for each question, which were 'Yes' and 'No'. Yes was to represent students behaving safely and it was scored safe by typing One (1). For students behaving unsafely, it was scored unsafe by typing Zero (0).

To formulate the calculation, it began with the total numbers of observers participated giving observation response, as in Equation 3.3.

Total participation of students in safe mode group
= observer 1 + observer 2 + observer 3 + … + observer n … Equation 3.3

After that, total number of 'yes' responses for each question was calculated using Equation 3.4.

Total answers of 'yes' given by observers
= Response from observer 1 + Response from observer 2 +
Response from observer 3 + … + Response from observer n … Equation 3.4

For each question, total number of 'yes' answers, named as Total safe behaviour observed, was used to find a safe behaviour percentage.

Safe Behaviour Percentage

$$= \frac{\text{Total safe behaviour observed}}{\text{Total participation of students}} \times 100\% \qquad \text{... Equation 3.5}$$

By using Equation 3.5, the result of safe behaviour percentage was weighted heavily towards safe behaviour practised and observed. The percentage was used to detect the slightest improvement in the frequency of safe behaviours. Therefore, any improvements in safety behaviour that were detected were real improvements that correspond with students who were working in the lab.

### 3.4.2 Calculation for Percentage of Unsafe Behaviour

In the unsafe mode group, the students observed their friends violated lab safety rules. The questionnaires in this mode emphasized on at-risk behaviours practice. Scales used to rate these students' behaviours consists of two options of answers in each question, which were 'Yes' and 'No'. The answer of yes meant student practicing at-risk behaviours and it was scored as One (1). For student who did not practise at-risk behaviour, the answer was no and it was represented by typing Zero (0).

The number of students who gave feedback in unsafe behaviour observation were calculated using formula in Equation 3.3. Then, the calculation continued with counting total number of 'yes' responses for each question as given in Equation 3.4. This total of 'yes' answer was then named as total at-risk behaviour. Equation 3.5 was used to find at-risk behaviour percentage.

The result of at-risk behaviour percentage was weighted heavily towards unsafe behaviour practised and observed. If there was a reduction in the percentage for the following observation, it meant that a frequency of students practising at-risk behaviours become lesser. Therefore, any reductions detected in percent at-risk behaviour were real reductions that correspond with students who were working in the lab.

Appendix H shows an example of calculation for safe behaviour and at-risk behaviour percentage.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

The Lab-ARBAIS was launched to the PSLP students on 29 January 2009 until 8 November 2009 whereby for chemistry course, it was launched on 27 January 2009 until 6 April 2009. Analysis of results for PSLP and Chemistry lab case studies are discussed in this chapter.

## 4.1 Results of Case Study in PSLP Lab

For case study in the PSLP lab, there are four (4) results analysis and discussion sections. Each section is discussed below.

### 4.1.1 Analysis of Safety Survey Before Lab-ARBAIS

Participation achieved 100 percent because all students had responded to the survey questions. The result of each question is described in the following section.

#### *4.1.1.1 To Assess Number of Students Who Read Safety Rules and Experimental Procedures*

All the lab safety rules of chemical engineering school had been carefully written and enforced by the academic institution. Lab safety rules were safety guidelines for each student to behave while studying and working safely in the lab. Experiment procedures manual was to guide students in handling experiments and equipment

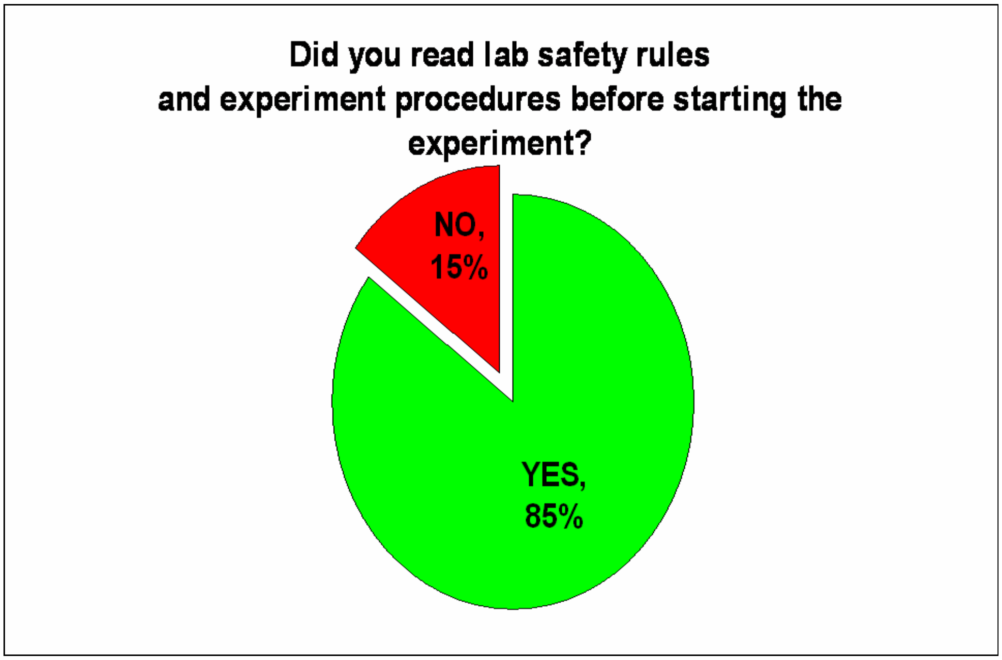


Fig. 4.1. Students reading safety rules and experiment procedures.

safely. Hence, academic institutions required student to carefully read lab safety rules and experiment procedures before they can start to do any experiments.

The first question was regarding lab safety rules and experiment procedures manual, as shown in Fig. 4.1. It was to check reactions of the students to the working procedures as ruled by academic institution. Based on the survey responses, 85 percent of the students informed they read lab safety rules and experiment procedures as instructed by lab coordinators. However, 15 percent of the students failed to read the manual. This 15-percent case was found to have a similarity to one survey conducted by DuPont™ (2003), whereby 93 percent of teachers stated that the biggest reason for accidents in lab was due to students' failure to carefully read and understand laboratory activity instructions.

*4.1.1.2 To Assess Number of Students Attending Safety Briefing*

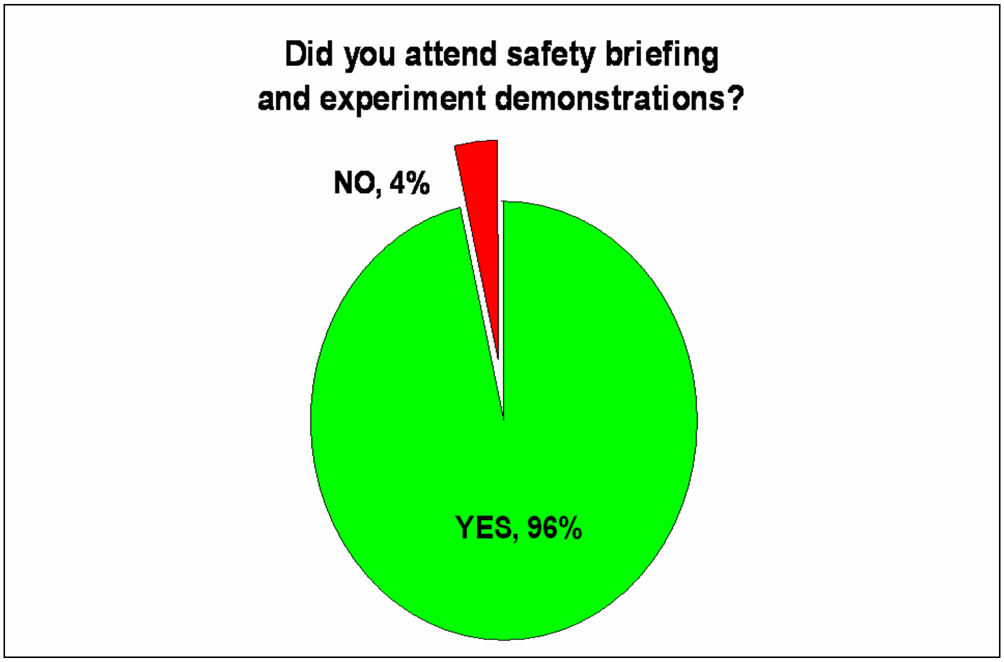


Fig. 4.2. Students attending safety briefing.

In the labs, lecturers and lab demonstrators played a crucial role in the proper development of the safety practices. They were the ones who must carefully enforce the safety rules in the labs. Before students can conduct the experiments, they should attend safety briefing and demonstrations by lecturers and demonstrators. The briefing was based on the lab safety rules and experiment instruction manuals. And, it was to remind students and to answer any questions regarding safety rules and instruction. The academic institution required each student was compulsory to attend safety briefing and demonstration.

Fig. 4.2 shows the results of students attended safety briefing and demonstrations. The survey revealed that 96 percent of the students attended the briefing whereas 4 percent of the students failed to do so. Based on the results, some students failed to follow the instruction even though the experiments had not started yet.

*4.1.1.3 To Assess Number of Students Concern about Their Safety*

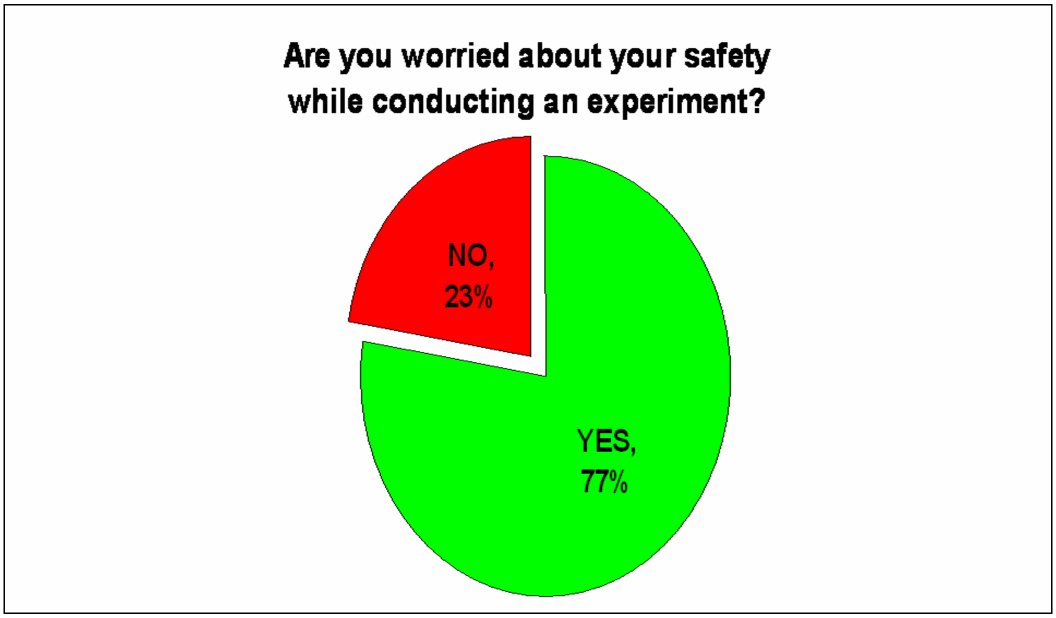


Fig. 4.3. Students worried about safety.

The students had two years experience in conducting experiment works and had attended many lab safety briefings. Thus, it was necessary to know whether students concerned about their safety while conducting experiments or not. 77 percent of the students stated they were worried about their safety. This response had similarity in one study conducted in the industry in terms of awareness of risk associated with works and assignments. In that study, a majority of operatives were aware of the risk involved in their work that they could be injured, become disabled or experience the possibility of death (Choudhry & Fang, 2008).

In another study by Mullen (2004), she found that majority of the interviewees were aware and informed about the risks involved in their work. Individuals were well aware that they could be badly injured, experienced long-term health effects, as well as the possibility of death. In another case of similar study, the perceived risk was low and perhaps underestimated by the individual, thus justifying a behaviour that was unsafe. The individual assumed his risk level was much lower than it actually was and the behaviour he engaged in could have seriously injured the individual, or possibly had resulted in his death. Thus, underestimating one's risk may explain why individuals continue to engage in unsafe behaviour. This perception could also happen to the students whereby 23 percent of the students reported they were not worried about their safety.

*4.1.1.4 To Assess Number of Students Allowing Someone to Observe Safety Practices*


Fig. 4.4. Students allow observers in the lab.

Observation was basic in the Lab-ABAIS and it was introduced to students who had no experience in observation. So, it was necessary to ask students' opinion regarding safety practices and behaviours observations in the labs. Responses resulted 50 percent of the students agreed and 50 percent of the students disagreed. Those students who disagreed show similar results to one report done by Cox and Jones (2006). They had discussed that employees reported some of the pitfalls within the behavioural safety approach. The employees explained that they were concerned their managers could have used observations, in the behavioural safety approach, negatively as a weapon against individuals. Thus, there was a reluctance to be observed as reported by the employees.

*4.1.1.5 To Assess Number of Students Being Informed about Breaking Safety Rules*

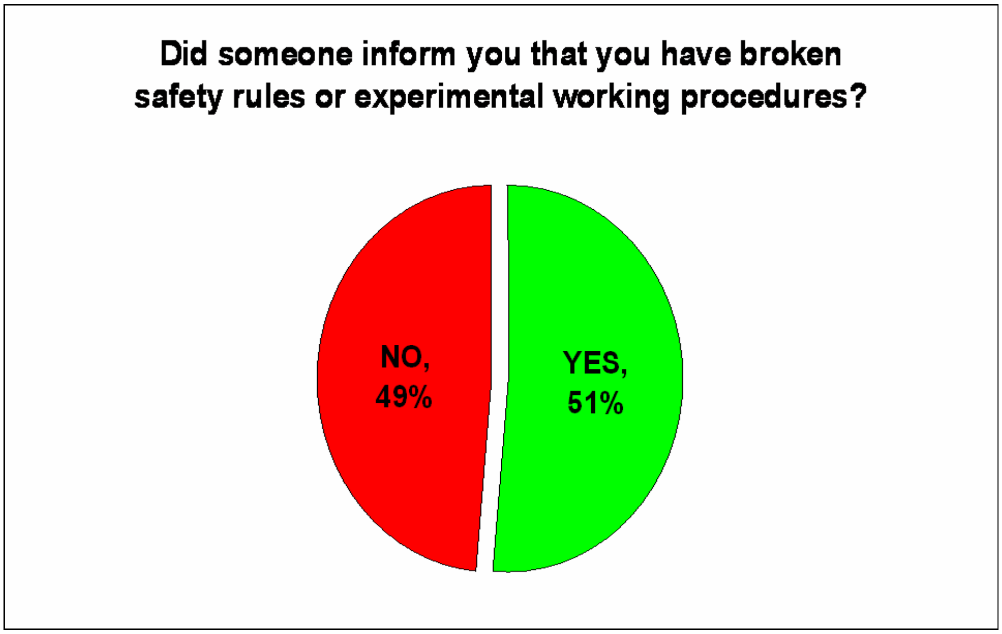


Fig. 4.5. Students being informed about break safety rules.

The aim of this question was to identify experience of students breaking safety rules or experimental work procedures in the labs. As a rule in the university, anybody breaks the rules should be informed and advised so that he or she realized his or her unsafe behaviours. Individuals to inform or advise can be lecturers, lab demonstrators, lab technicians, or friends. Along two years of taking chemical engineering course, 51 percent of the students had experienced being informed that they broke the rules and 49 percent of the students reported they had not been informed or advised when they were breaching the rules.

*4.1.1.6 To Assess Number of Students Notice Friends Break Safety Rules*

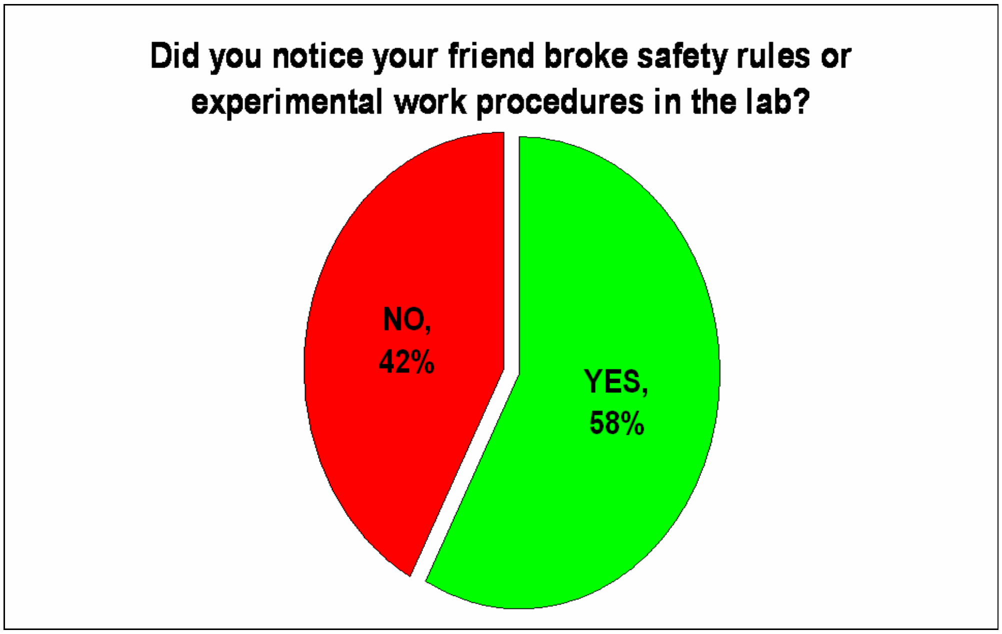


Fig. 4.6. Students noticed their friends broke safety rules.

Chemical engineering school of UTP assigns each student to work in a designated group. It is to ease student to complete the assignment and experimental works in the time given. While they are working together, they will certainly notice their friends' behaviours.

In this survey, the question was to assess students who had noticed their friends broke safety rules. If the student could notice their friends' behaviours, they were actually able to do surveillance. According to responses received, 58 percent of the students stated they had noticed their friends broke safety rules. This majority of students were categorized as sociable people. It was because John et al. (1991) had reported that sociable people were more attuned to safety situations and had more positive attitudes toward safety because they had many social ties and may feel more personally responsible for the well-being of others. There was 42 percent who failed to realize that their friends broke safety rules.

*4.1.1.7 To Assess Number of Students Advise Friends Who Have Violated Safety Rules*

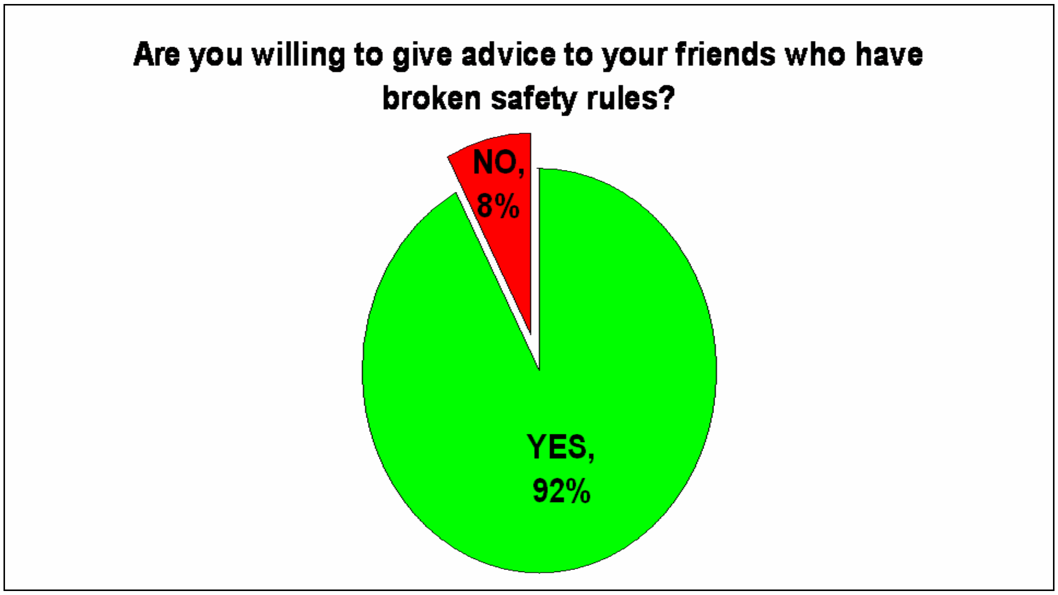


Fig. 4.7. Students gave advice to friends who broke safety rules.

A culture called informed culture was already applied in the industries or organizations. An informed culture was defined as a culture in which the members of the organisation understand and respect the hazards of their operations. And, the members were alert to the many ways in which the system's defences were breached or bypassed (Reason, 1998).

The informed culture was not common to students in the labs. So, it was appropriate to measure willingness of students to accept the informed culture in the labs. It was done by asking the students' opinion and willingness in this survey. The result showed that 92 percent of the students were willing to inform or gave advice to their friends who had broken safety rules. However, 8 percent of the students chose to keep silent rather than informing or advising those who had broken safety rules.

*4.1.1.8 To Assess Number of Students Report on Safety Rules Violation to Lecturers/Lab Demonstrators*

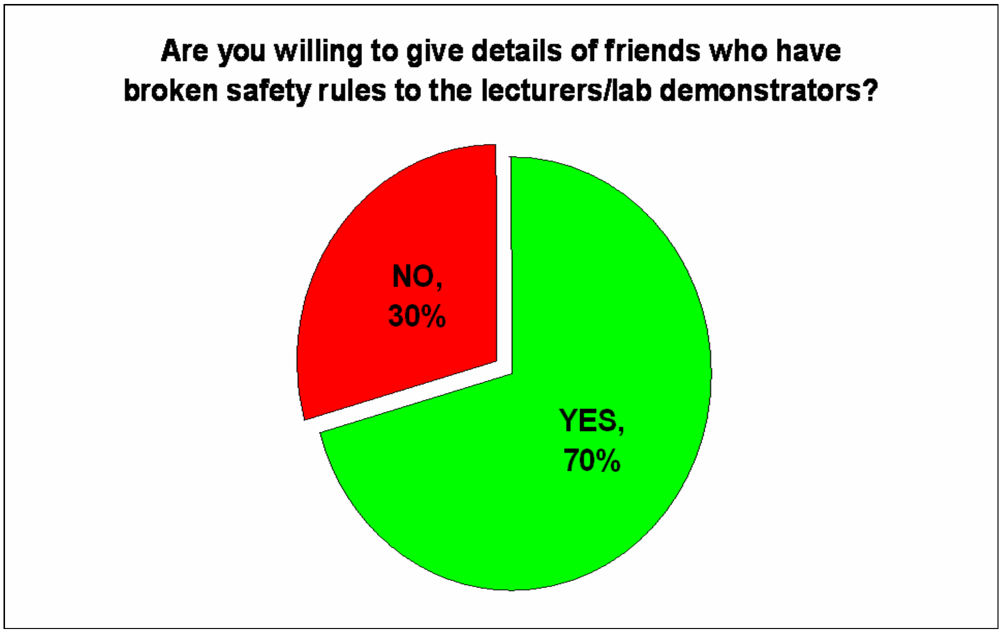


Fig. 4.8. Students report details of friends broke safety rules.

Many organisations in the industries had such low levels of reported injury or ill health that it was difficult to base improvement plans on safety. Improvement required knowledge of all incidents, near misses and concerns. The first requirement was to create a reporting culture and along with this a culture of fair blame in which standards were clear, thus most reckless safety failures were reported without fear of retribution. It was by no means easy to engineer a fair blame culture, but it linked directly to an organisation's understanding of the risks that it needed to manage; an informed culture was better placed to appreciate the distinction between unsafe acts arising from lapses of concentration, for example, and those that were simply wilful. Clearly, it is important that the organisation did not undermine the reporting culture (Reason, 1998).

Therefore, the survey included a question on reporting details of friends, who had broken safety rules, to lecturers or lab demonstrators. As a result, 70 percent of the students were willing to report details of friends' behaviour and 30 percent of the students chose not to do so.

*4.1.1.9 To Assess Students' Opinion on Safety Improvement*


Fig. 4.9. Students agree to improve safety by reporting method.

In achieving a positive safety culture, the organisation or management should establish open reporting of unsafe behaviours, incidents, near misses and concerns. The survey looked at students' opinion in improving safety and safe work behaviours by reporting friends' behaviours to the lecturers or lab demonstrators. 96 percent of the students were positive in giving opinion to report other students who had broken or violated lab safety rules. It was a remarkable point to improve existing safety and safe working behaviours using the reporting technique even though 4 percent of the students disagreed with the practices of reporting.

*4.1.1.10 To Assess Number of Students Welcoming Safety Program*

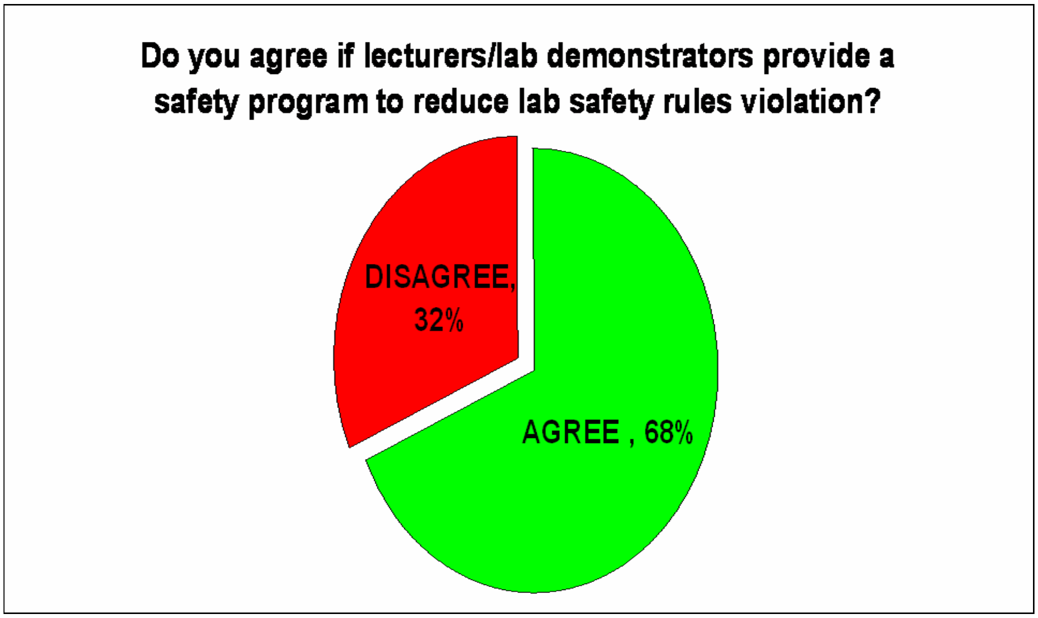


Fig. 4.10. Students agree on safety program in the lab.

Lecturers and lab demonstrators were responsible for students' safety and discipline. So, the lecturers and lab demonstrators should be responsible to take or implement correction action to the students. To the question whether the lecturers and lab demonstrators should provide a safety program in order to reduce frequency of lab safety rules violation, 68 percent of the students agreed and 32 percent disagreed.

In one study conducted by DeJoy et al. (2004), he found the importance of organizational support and communication fit nicely with the idea that a positive safety climate was more likely to exist in an environment that generally supports and values its employees and where there was open and effective exchange of information. Employee safety climate perceptions provided important information pertinent to safety. It also appeared that taking action to strengthen overall social support and communication within the organization enhanced safety climate.

As a conclusion of the survey analysis, the minimum requirement to proceed with the implementation of Lab-ARBAIS are 68 percent of the students agreed on safety program and 96 percent of the students agreed on reporting lab safety rules violations.

### 4.1.2 Analysis of Lab-ARBAIS in PSLP Lab

In this case study, the task of responding to pre-program questionnaire was a simple and quick process. Furthermore, the process was completed within approximately two until five minutes. After that, feedbacks of questionnaire were collected in a database. An analysis was discussed according to safe and unsafe mode group.

*4.1.2.1 Safe Mode Group*

Safe behaviours observed in the Group A and Group B are discussed as below.

*Group A in semester 1*

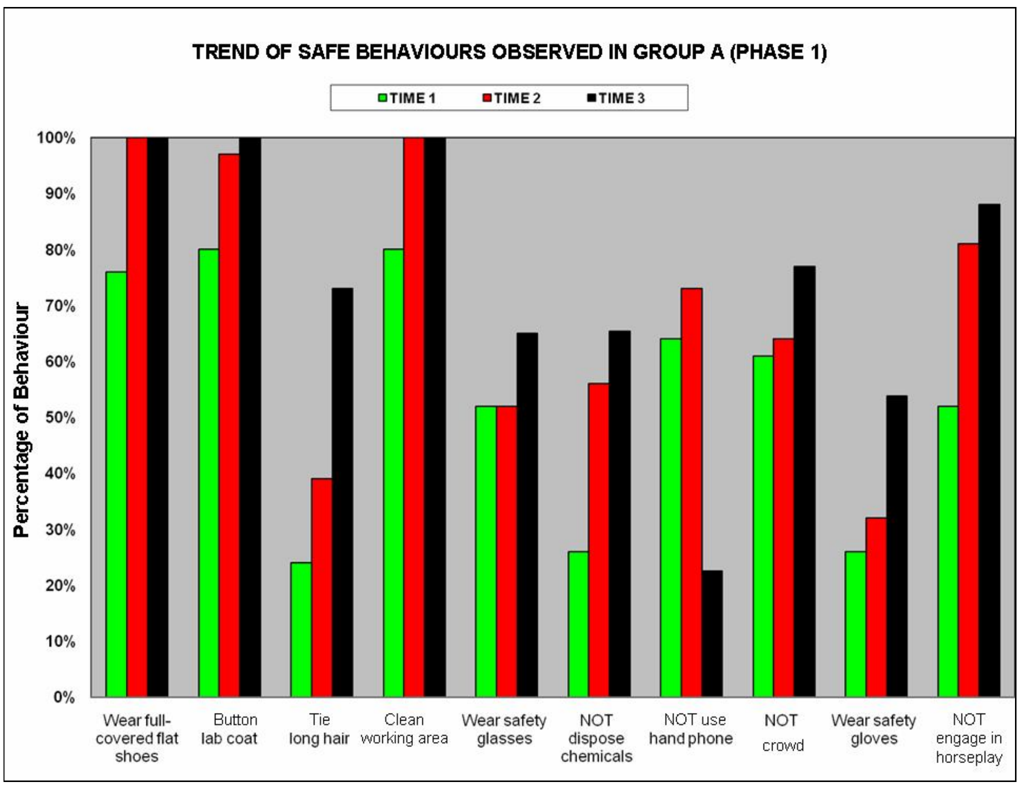


Fig. 4.11. Safe behaviours observed within Group A in semester 1 (Phase 1).

Group A had two parts, which were percentage of safe behaviours observed in Semester 1 and Semester 2.

Fig. 4.11 shows the trend of safe behaviour observed in the lab for Group A in semester 1. Time 1, Time 2 and Time 3 indicate students did observation in the first experiment session, second experiment session, and third experiment session, respectively. Each experiment session took four (4) hours per day.

Observation in Time 1 resulted behaviour of buttoned lab coat and cleaned the working area achieved 80 percent. The lowest percentage of safe behaviour was 20 percent for behaviour of tied long hair, not disposed chemical into the sink, and wore safety gloves.

The observation continued to observation in Time 2. At this time, behaviour of buttoned lab coat and cleaned the working area were increasing until 95 and 100 percent, respectively. Students wore full-covered flat shoes also increased to 100 percent compared to 75 percent in Time 1. The observation influenced the students to practise more on tying long hair, not disposing chemical into the sink, and wearing safety gloves. These three behaviours had shown a little improvement because it achieved 30 until 50 percent.

Lab-ARBAIS observation repeated in Time 3 and a percentage of 100 percent was obtained pertaining to students buttoned lab coat, cleaned the working area, and wore full-covered flat shoes. The students tried to enhance practising tie long hair, not disposing chemical into the sink, and wearing safety gloves. Their effort had made those behaviours improved to 50 until 70 percent.

Similar progresses were also observed for other three safe behaviours, which were students wore safety glasses, did not crowd working area, and did not engage in horseplay, from Time 1 until Time 3.

But, there was a sudden decrease in safe percentage for students not allowed to use handphone in the lab. This behaviour was observed at 60 percent in Time 1, 70 percent in Time 2 and it became worse during Time 3 with only 20 percent of students not using handphone in the lab.

*Group A in semester 2*

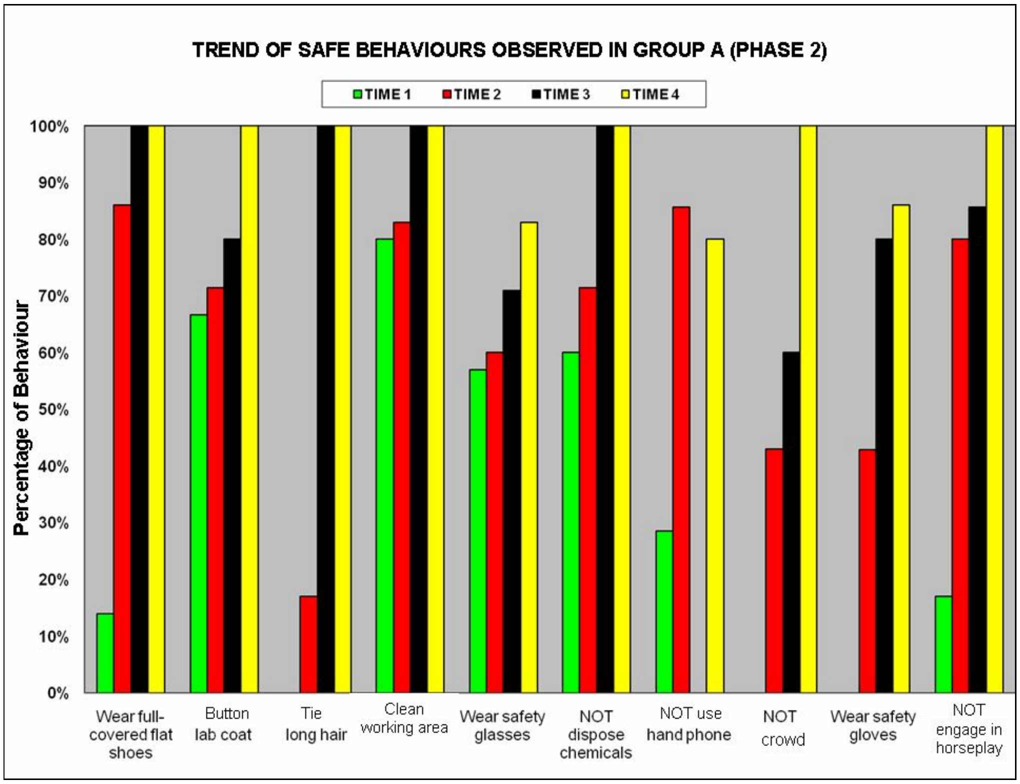


Fig. 4.12. Safe behaviours observed within Group A in semester 2 (Phase 2).

The observation of safe behaviour in semester 1 continued to semester 2. The results of the observation are shown in Fig. 4.12. Time 1, Time 2, Time 3, and Time 4 refer to observation during experiment in session 1, session 2, session 3, and session 4, respectively. Each experiment session in semester 2 took four (4) hours per day.

The results of observation in Time 1 showed that the students who were observed did not seriously practise safe behaviours. Obviously, the students did not tie long hair, crowded working area, and did not wear safety gloves. These behaviours indicated nil percentage. Other seven behaviours showed a low percentage ranging from 15 to 80 percent. The nil and low percentage happened because there might be time gap between semester 1 and semester 2, approximately two months. It was assumed that the students might forget the safety habit that they had in semester 1.

During observation in Time 2, the three critical behaviours, i.e. did not tie long hair, crowded working area, and did not wear safety gloves, showed improvement ranging from 20 until 40 percent. The same improvement was observed for other seven behaviours, i.e. wore full-covered flat shoes, buttoned lab coat, cleaned the working area, wore safety glasses, did not dispose chemical into the sink, did not use handphone, and did not engage in horseplay, ranging from 60 until 85 percent.

As the observation progressed, the students were practising more safe behaviours. While the student were working experiment in Time 3, safe behaviours of wore full-covered flat shoes, tied back long hair, cleaned working area, and did not dispose chemical into the sink had achieved 100 percent. These behaviours remained safe until the fourth experiment session. In other words, the students were seriously upholding safe behaviours of buttoned lab coat, did not dispose chemical into the sink, did not crowd, and did not engage in horseplay because these behaviours maintained 100 percent safe.

However, there was a serious violation of lab safety rules particularly the ban of handphone usage in the lab. The violation had been observed and reported in Time 3 with zero percent. The same behaviour observed again in Time 4. The same observation indicated a sudden increment to 70 percent. It proved that the students were aware that their safe working behaviours had been extensively observed and reported by their friends.

*Group B in semester 1*

Similar to Group A, Group B had the same observation occasions for ten safe behaviours. Group A and Group B were set for comparison and similarity to each other in terms of safe behaviour observed. Both groups were taking turn to use the lab room according to the schedule given by the lecturers and lab demonstrators. Group A was the first group to use the lab room. Then, Group B was the second group to use it.

In Time 1, all ten safe behaviours were in the range of 50 to 100 percent. The students of Group B had better safe working behaviours than students in Group A ranging between 20 to 80 percent.

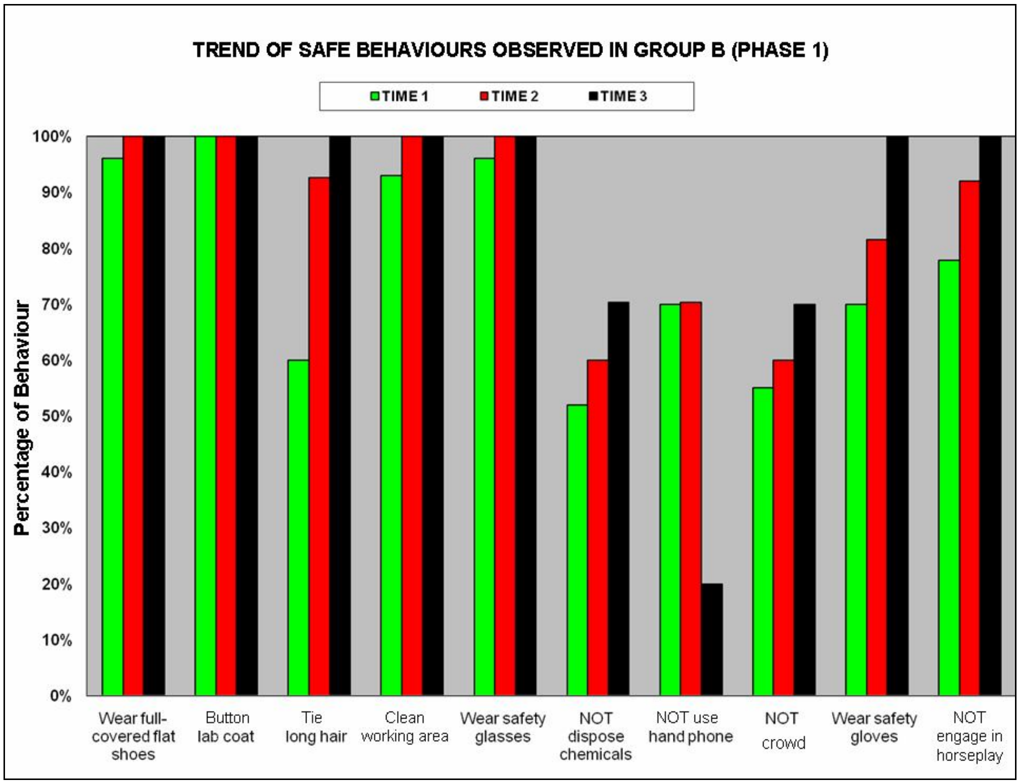


Fig. 4.13. Safe behaviours observed within Group B in semester 1 (Phase 1).

More students observed continuously practising the safe working behaviours in Time 2 especially students wore full-covered flat shoes, buttoned lab coat, cleaned the working area, and wore safety glasses. Observation results of Group B were better than observation of Group A for the same foursome behaviours mentioned.

Nine safe behaviours were becoming a habit to the students as shown by the increasing percentages in Time 3. Yet, there was a problem with handphone usage in the lab. Students using handphone inside the lab had been observed and reported to the Lab-ARBAIS. The same case of students using handphone inside the lab was also reported in Group A. Group A and Group B used the same lab which had an existing signage of ‘no handphone’ at the front door of the lab. Effort of posting the ‘no handphone’ signage and reminding students to not use handphone in the safety briefings did not give any effect to the students.

*Group B in semester 2*

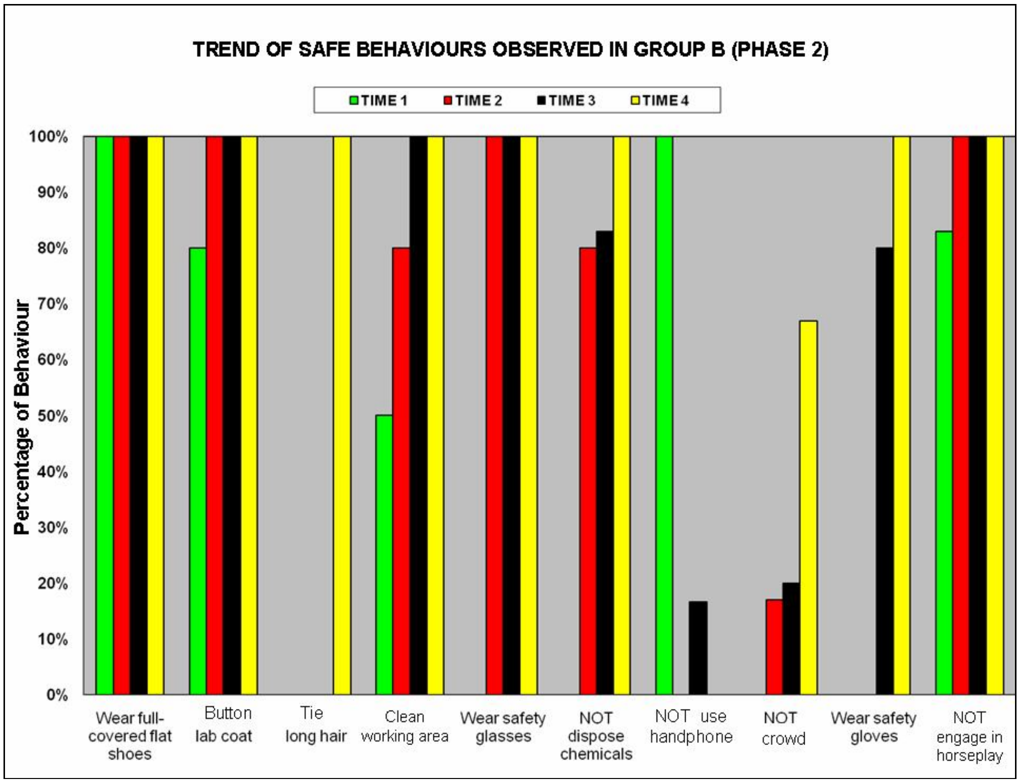


Fig. 4.14. Safe behaviours observed within Group B in semester 2 (Phase 2).

Group B had also gone through a continuous ten safe working behaviours observation in semester 2. Similar to Group A in semester 2, there were four observations according to the four experiments as scheduled by lecturers and lab demonstrators. And, there was also a time gap between semester 1 and semester 2 approximately two months.

The results in Time 1 revealed students did not tie long hair, did not wear safety glasses, disposed chemical into the sink, crowded working area, and did not wear safety gloves. All these unsafe behaviours were given a great attention. Those behaviours show nil percentage and it proved the students disobeyed the lab safety rules after they had accustomed to safe working behaviours in semester 1.

In Time 2, safe behaviours of tying long hair and wearing safety gloves were still showing nil percentage. Although the lab demonstrators kept reminding the students to follow lab safety rules in the safety briefing, the students were unwilling to follow the rules. And, students reluctant to not use handphone in the lab had caused zero percent. It was a sudden decrease from 100 percent to zero percent. Nevertheless, more students observed practising seven safe behaviours in this session 2 experiment, i.e. buttoned lab coat, wore full-covered flat shoes, cleaned the working area, wore safety glasses, did not dispose chemical into the sink, did not crowd working area, and did not engage in horseplay.

The results in Time 3 remained at zero percentage of untied long hair because no improvement was reported. Thus, it caused the lecturers and lab demonstrators to investigate this matter. The reported behaviour was actually done by the same student who was being stubborn to tie his or her hair. That student was given a warning and advice by the lecturers and lab demonstrators. For other nine safe behaviours, more students began practising safe working behaviours.

When the students were working in the fourth experiment sessions, they had already adapted nine safe working behaviours, including tie long hair. Yet, there was a fluctuate percentage for handphone usage in the lab. It was reported that the students used handphone in the lab. The students violated the instruction not to use handphone in the lab continuously even though the observation process continued until Time 4 in semester 2.

#### *4.1.2.2 Unsafe Mode Group*

The unsafe mode was to ease students in understanding the requirement of the Lab-ARBAIS observation in terms of observing the violated lab safety rules. The observers noticed the violation and thus, they reported it to Lab-ARBAIS. If the at-risk behaviours in the observation list showed some results in percentage terms, it meant that the observers observed students practised the at-risk behaviours. If the at-risk behaviour in the observation list showed zero percent, it meant that the observers found no students violated lab safety rules. Details observation results of Group C and Group D are explained below.

*Group C in semester 1*

Fig. 4.15 shows the trend of percentage of students violated lab safety rules according to experiment sessions. The experiment sessions were indicated by Time 1, Time 2, and Time 3, which referred to observation during first experiment session, second experiment sessions, and third experiment sessions, respectively.

Observation in Time 1 indicated two serious at-risk behaviours, which were students failed to not use handphone in the lab and students failed to wear safety glasses with 65 and 75 percent, respectively. The other eight at-risk behaviours i.e. wore non full-covered flat shoes, unbuttoned lab coat, did not tie long hair, failed to clean working area, disposed chemical, crowded working area, did not wear safety gloves, engaged in horseplay, had been reported too. It proved that the students violated lab safety rules although they had been frequently exposed to the lab safety rules and experiment procedures at the beginning of school year.

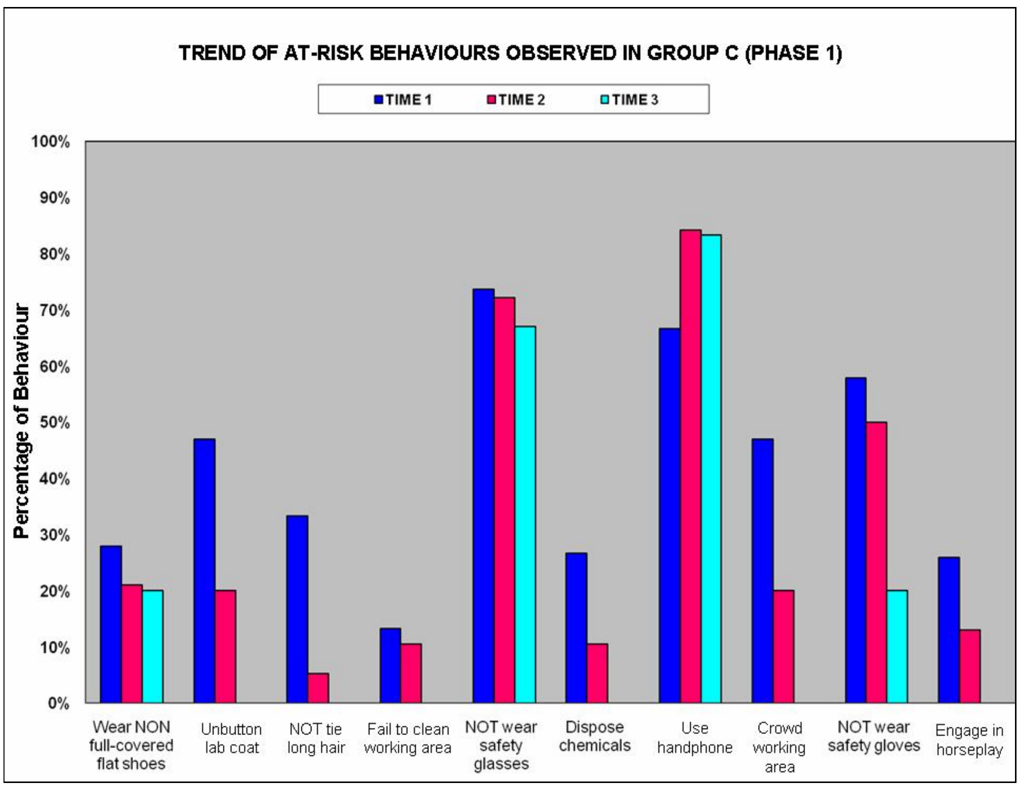


Fig. 4.15. At-risk behaviours observed within Group C in semester 1 (Phase 1).

As Lab-ARBAIS observation continued to Time 2, students who were not wearing safety glass had shown a tendency of a low practice because it reduced to 70 percent. The students were also less practising the same eight at-risk behaviours as in Time 1 because the percentage reduced to 5 percent. Handphone usage in the lab, on the other hand, was observed more thus 85 percent of the students were reported on this matter.

In Time 3, more students observed practising less at-risk behaviours. The students became norm to not practise; unbuttoned lab coat, did not tie long hair, failed to clean working area, disposed chemical into the sink, crowded working area, and engaged in horseplay. Yet, the problem of students used handphone in the lab, with 83 percent, remained a big issue in the Lab-ARBAIS observation until Time 3 observation.

*Group C in semester 2*

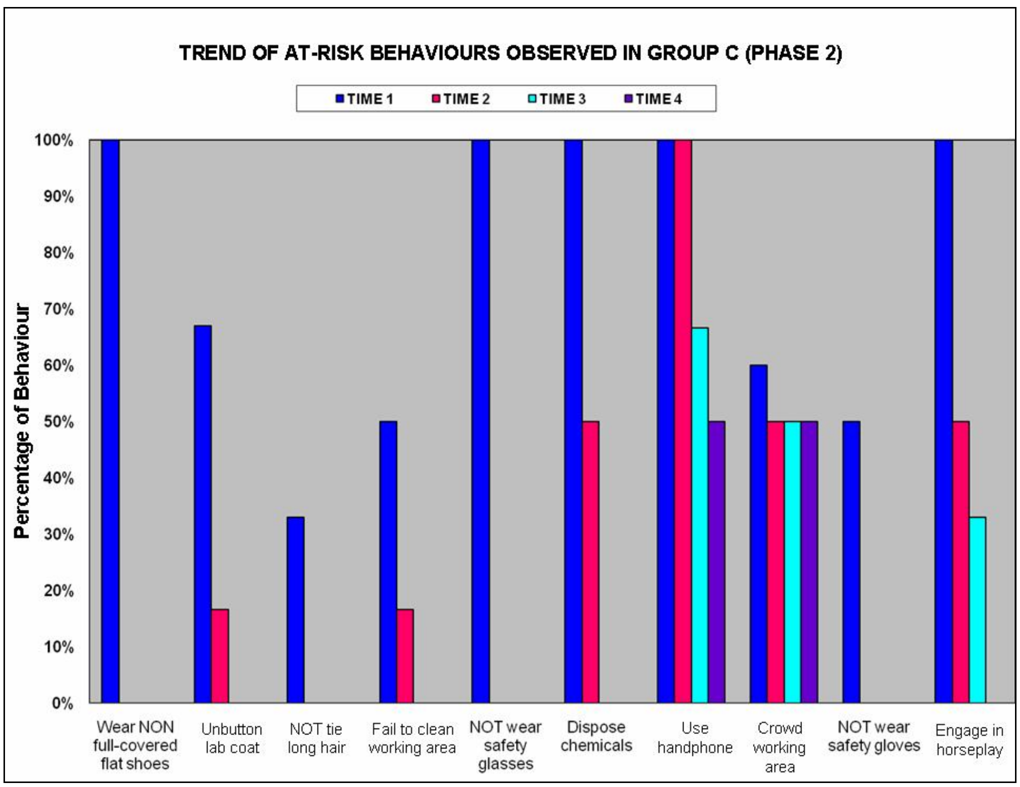


Fig. 4.16. At-risk behaviours observed within Group C in semester 2 (Phase 2).

The ten at-risk behaviours remained in the Lab-ARBAIS observation list for observation in semester 2. There were four (4) observation cycles which happened in first experiment session (Time 1), second experiment sessions (Time 2), third experiment sessions (Time 3), and fourth experiment sessions (Time 4). There was also a time gap between semester 1 and semester 2, which was about two months.

Time 1 (refer to Fig. 4.16) uncovered a surprising observation result. 100 percent students were wearing non full-covered flat shoes, not wearing safety glasses, disposing chemical into the sink, using handphone in the lab, and engaging in horseplay. This finding was similar to observation results of Group A and Group B in semester 2. It showed that the students failed to follow the lab safety rules in the following semester.

Observation continued to Time 2 and it produced a reduction to nine at-risk behaviours being practised. But, the observation was not effective to handphone usage in the lab because it remained 100 percent, beginning from observation in Time 1.

In Time 3, the percentage of students using handphone was decreasing until 60 percent. The percentage of students crowded the working area began to be static at 50 percent. The eight at-risk behaviours, i.e. wore non full-covered flat shoes, unbuttoned lab coat, did not tie long hair, failed to clean working area, failed to wear safety glasses, disposed chemical into the sink, failed to wear safety gloves, and engaged in horseplay, showed continuous reduction until this time.

Again, there was a reduction of the same eight at-risk behaviours until zero percent in Time 4. Lab-ARBAIS observation showed 50 percent for handphone use in the lab. The reduction of all at-risk behaviours might be due to frequent observation and reports cycles. It caused the students aware that somebody among their friends was watching their safety and at-risk behaviours.

For the case of students crowded the working area, it remained at 50 percent since observation in Time 2 until Time 4. When lecturers and lab demonstrators questioned the students in safety briefing, they told that they had no intention to crowd working area. Instead, they were having a discussion among themselves. However, it is reported as an unsafe practice.

*Group D in semester 1*

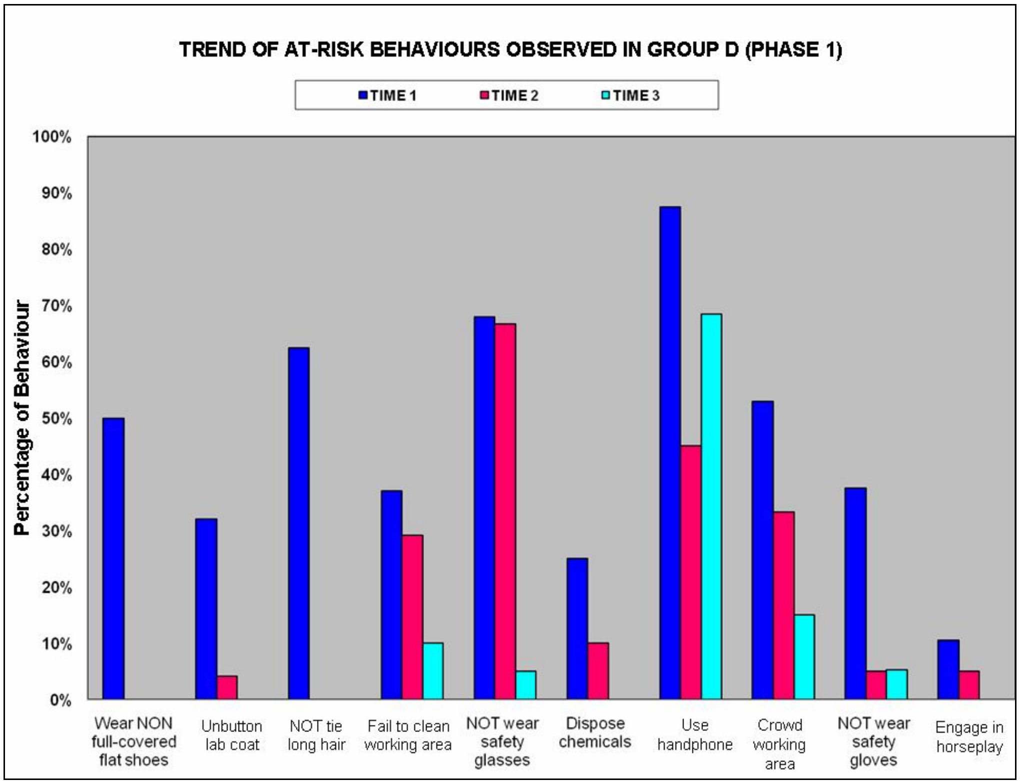


Fig. 4.17. At-risk behaviours observed within Group D in semester 1 (Phase 1).

The case study set Group D to be identical to Group C. Group C and Group D were alternating the lab room for each experiment session according to the schedule provided by the lecturers and lab demonstrators.

In Fig. 4.17, observation in Time 1 showed the highest (90 percent) among ten at-risk behaviours was the usage of handphone in the lab. Nine at-risk behaviours ranged from 65 to 10 percent. Group D had lower percentage for all ten at-risk behaviours in Time 1 compared to ten at-risk behaviours observed of Group C in Time 1 too.

Lab-ARBAIS continued to Time 2. It revealed two at-risk behaviours had the highest percentages among ten at-risk behaviours. Those behaviours were students failed to wear safety glasses and failed to not use handphone in the lab. These behaviours were also found problematic in Group C, which also happened in Time 2. In conjunction with these problems, the lecturers and lab demonstrators talked to the students of Group D in safety briefings. The students informed that they were wearing safety glasses whenever they were handling flame or chemical. The lecturers and lab demonstrators gave a further explanation to the students regarding misconception of safety glasses use. All students were actually compulsory to wear safety glasses all the time in the lab. Safety glass is a part of PPE and it is compulsory to wear it all the time in the lab.

The explanation had caused more students wearing safety glasses when they were doing next experimental works in the lab (Time 3). Eight at-risk behaviours had shown a reduction. But, it did not happen to handphone usage in the lab because the observers had reported seeing students using handphone. Thus, handphone use increased to 70 percent.

Observations for ten at-risk behaviours in Group D of semester 1 were brought forward to semester 2.

*Group D in semester 2*

The Lab-ARBAIS observation for Group D in semester 2 was set to have the same parameter as Group C in semester 2 in terms of four (4) observation cycles happened concurrent to experiment sessions. There was also a 2-month gap between semester 1 and semester 2 the same as Group C. The results of the observation are shown in Fig. 4.18.

There were some students who wore non full-covered flat shoes, unbuttoned lab coat, and did not tie long hair in Time 1. These behaviours had been reported and thus, it reached 100 percent. 80 percents of students used handphone and the same percentage students crowded the working area, while 70 percent of them were not wearing safety gloves. Students were not cleaning the working area, not wearing safety glasses, disposing chemical, and engaging in horseplay displayed a percentage of below 50.

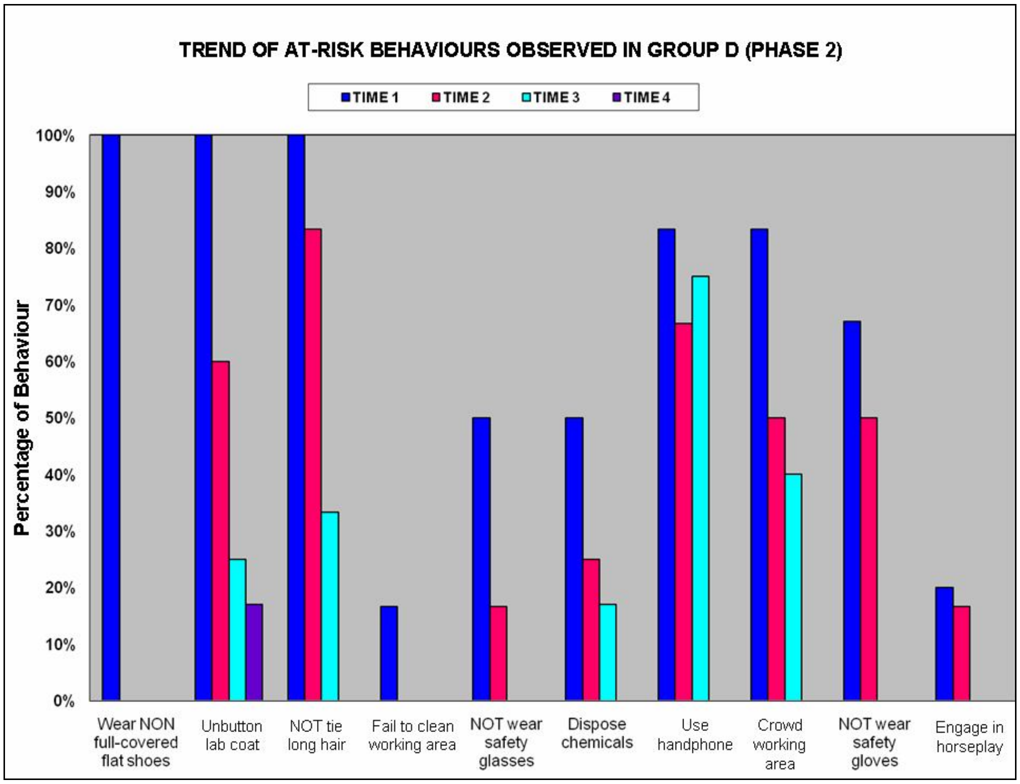


Fig. 4.18. At-risk behaviours observed within Group D in semester 2 (Phase 2).

Slowly, all these ten at-risk behaviours showed a reduction in Time 2. This reduction was a sign that the students realized their safety and at-risk behaviours were always being observed and reported by observers among their friends.

Nine at-risk behaviours were reducing as reported in Time 3 results. The percentage of handphone use, on the other hand, was increasing until 75 percent. Fluctuation in the percentage of handphone usage indicated this behaviour was not easy to be controlled by the Lab-ARBAIS.

Continuous observations in Time 4 reduced handphone usage in the lab. And, no student was seen practising the other eight at-risk behaviours. There were some students (15 percent) unbuttoned their lab coat. Based on these results of observation in semester 2, it proved that the frequent critical behaviour could be controlled through continuous observation during experimental works.

### 4.1.3 Factor Affecting Safe Behaviours of Students in PSLP Lab

In the case study of PSLP Lab, the main factor in ensuring behaviour improvement was a repetition of routine observations in two continuous semesters. Repetition was applied into routine observation questions. To be precise, the observation used the same ten behaviours questions for each observation session. Thus, the students had to answer the same set of observation questions repetitively. The students were spontaneously familiarized and memorized the observed behaviours through repetitive observation. The increase of observation occasions generally correlated with the increase in safe working behaviours. It happened because the observation actually encouraged students to review both theirs and other friends' potential at-risk behaviours that might lead to accident. And, the process of observing was to provide a prompt for the observer to engage in safe working behaviours. A student watched his or her friends while they were engaging in safe working behaviours. The student himself or herself was also aware that his or her behaviours were being observed. Therefore, most students tried their best to practise safe working behaviours in the lab. Through this approach, a psychology cognitive effect had been nurtured among students themselves.

Another factor that causes the students to change their unsafe working behaviours to safe working behaviours was reinforcement of posting statistic graphic feedback in the students' portal. For each observation, there was a statistic graphic feedback resulted from observation responses. As the observation completed, the statistic graphic feedback were immediately posted in the portal. Regular posting statistic graphic feedback influenced the students to behave safely in the lab. The statistic revealed students' behaviours had been observed by their friends. Thus, it had shown that reinforcing post statistic graphic feedback had resulted in an increase in safe behaviours.

### 4.1.4 Issue on Unimproved At-Risk Behaviours in PSLP Lab

As the Lab-ARBAIS implemented in the PSLP lab, the Lab-ARBAIS had identified a few students' at-risk behaviours which did not improve throughout observation cycles. The Lab-ARBAIS failed to control the unimproved at-risk behaviour. Thus, HSE committee discussed the problem of unimproved students' at-risk behaviours with the lecturers and lab demonstrators. They used ABC model as guidance.

There was an issue of handphone in the labs. The issue of handphone use at inappropriate times had been studied by Walsh et al. (2008). The study focused on psychology factors relating to handphone use amongst Australian youth. The study involved 32 participants aged between 16 and 24 years. Walsh et al. (2008) found some young people indicated they turned their handphone off at times when it would be considered inappropriate to use it. It may be that conflict with other activities differentiates people who are addicted from those who are not. For instance, people who were addicted to their handphone may be unable to resist using the handphone in situations where it was inappropriate, whilst people who were not addicted may be able to control their mobile phone use when required.

Based on findings of the study, Lab-ARBAIS study also proved the students had difficulties to not use handphone in the lab because they were addicted to use handphone and thus, they were reluctant to switch off the handphone.

Due to the outcome of the results, HSE committee together with lecturers and lab demonstrators used the ABC model to enforce rules on handphone use in the lab. Thus, they decided three (3) options, which were reminding students to use handphone outside the lab, instructing students to switch off the handphone, and giving a penalty such as lose 5 marks for lab report. Details of the options are shown in Table 4.1.

The information on seriousness of handphone use in the lab and restricted working area was particularly important to the reduction of workplace accidents. Shariff and Keng (2008) had reported facing critical handphone use by industrial workers in the restricted area with 35 percent. Henning et al. (2009) suggested individuals who were riskier in their personalities hold more negative safety attitude. He found that individuals with higher level of these traits tend to engage in more risk taking behaviours and experience more accidents.

Table 4.1. ABC model for handphone use in the lab

| Antecedent | Behaviour | Consequence |
|---|---|---|
| Hear handphone ringing | Pick up the call outside lab | Have a conversation outside lab safely |
| Switch off handphone | Let voice mail receives message | Perform experiments safely |
| Hear handphone ringing | Pick up the call inside lab | Lose 5 marks for lab report |

Two at-risk behaviours had also been frequently reported, which were not tying long hair and crowding. For the case of not tying long hair, a few students gave comments on unclear parameter related to that behaviour. Based on the academic lab safety rules, students were required to tie their long hair. However, the rules did not give detail how long is the hair that needs to be tied back. Thus, this rule confused the students in determining the exact parameter of long hair that should be tied back while working in the laboratory. The students who did not tie their hair felt that their hairs were short, thus did not require to be tied although other students considered the hair long. To tackle this issue, the HSE committee, lecturers and lab demonstrators provided solutions to the students. Those solutions can be placing a label or picture of properly tied long hair and provide a headscarf in the lab to the students, as described in Table 4.2.

Table 4.2. ABC model to solve long hair issue

| Antecedents | Behaviours | Consequences |
|---|---|---|
| See picture of properly tied long hair | Tie hair as in the picture | Perform experiments safely |
| Get a headscarf | Wear the headscarf to cover hair neatly | Perform experiments safely |

The HSE committee, lecturers and lab demonstrators identified students crowding the working area as a critical at-risk behaviour because some observers were uncertain on their observation and provide inaccurate feedback. Some students may not wander around their friends' working area; instead they may have a discussion. However, it was reported as an unsafe practice. As a solution to this unsafe practice, students can only have a discussion after they have finished the experiment.

Table 4.3. ABC model to solve inaccurate response of crowding

| Antecedents | Behaviours | Consequences |
| --- | --- | --- |
| Have questions about experiment | Keep the question until finish the experiment | Continue working safely |
| Have questions about experiment | Stay in the assigned group | Perform experiment safely |

### 4.1.5 Analysis of Safety Survey After Lab-ARBAIS

Based on responses received in this survey, all students had participated, i.e. 100 percent, and responded to the survey questions. Thus, it can be reported as an encouraging support. The result of each question is explained below.

#### *4.1.5.1 To Assess Students' Improvement on Safety and Safe Working Behaviours*

It was important that students developed awareness of safety issue so that they can maintain a safe place and create an environment where safety was positively reinforced. The question in the survey was to know students' opinion about their safety awareness and safety practices after they have participated in the Lab-ARBAIS. After the students had participated in the Lab-ARBAIS, 85 percent of them reported that their safety awareness and safety practices improved. Only 15 percent of them reported that safety awareness and safety practices did not improve although they had participated in the Lab-ARBAIS.

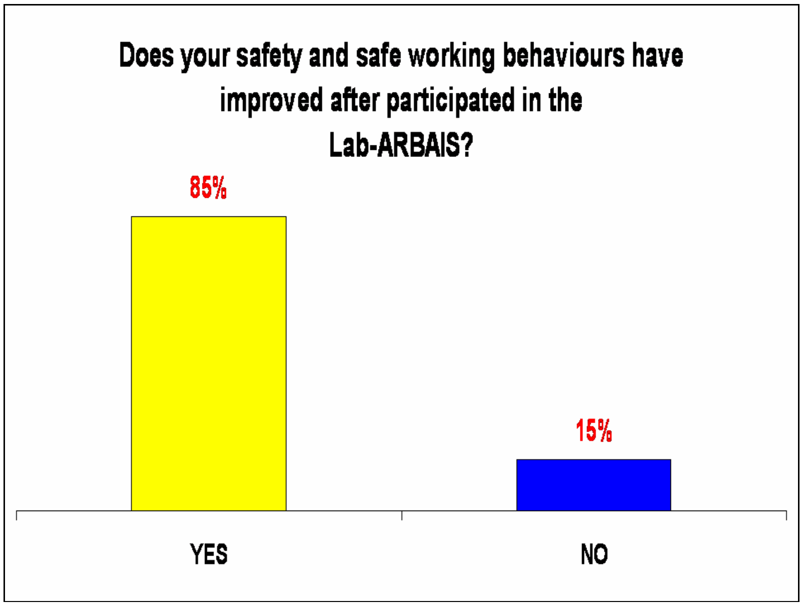


Fig. 4.19. Students show improvement on safety and safe working behaviours.

*4.1.5.2 To Assess Number of Students Dare to Break Lab Safety Rules*

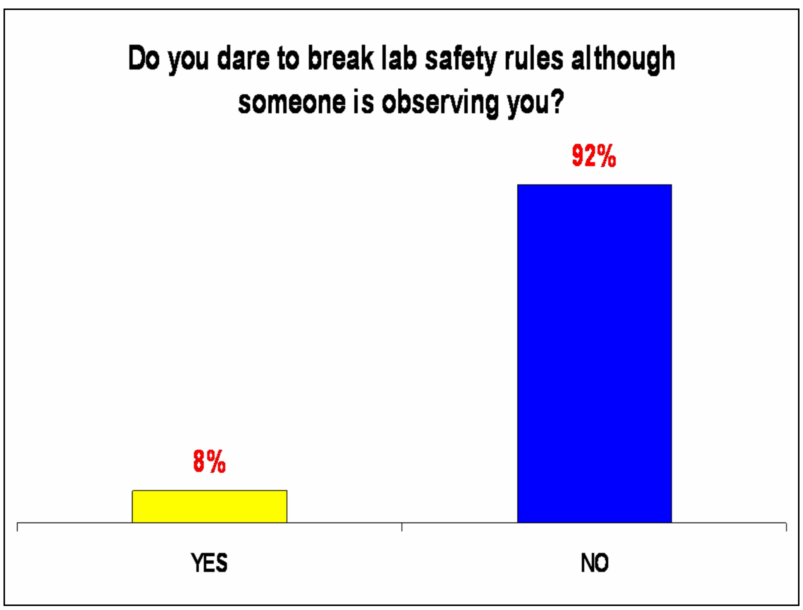


Fig. 4.20. Students dare to break lab safety rules.

In the Lab-ARBAIS, the students had been exposed with observation process and observation reports. Thus, it was interesting to know the effect of the observation to the students. Surprisingly, 8 percent of the students still dare to break lab safety rules even though they were being observed. The apparent reluctance to engage with behavioural improvement had been linked to the ethical status of behavioural manipulation, such as students were stubborn to wear sandals in the lab. This individual was inclined to take risks, seek adventure, and engage in risky behaviours while working in the hazardous environment. This individual was more likely to make rush decisions and to act with less caution (Henning et al., 2009).

*4.1.5.3 To Assess Number of Students Aware of Observation Results*

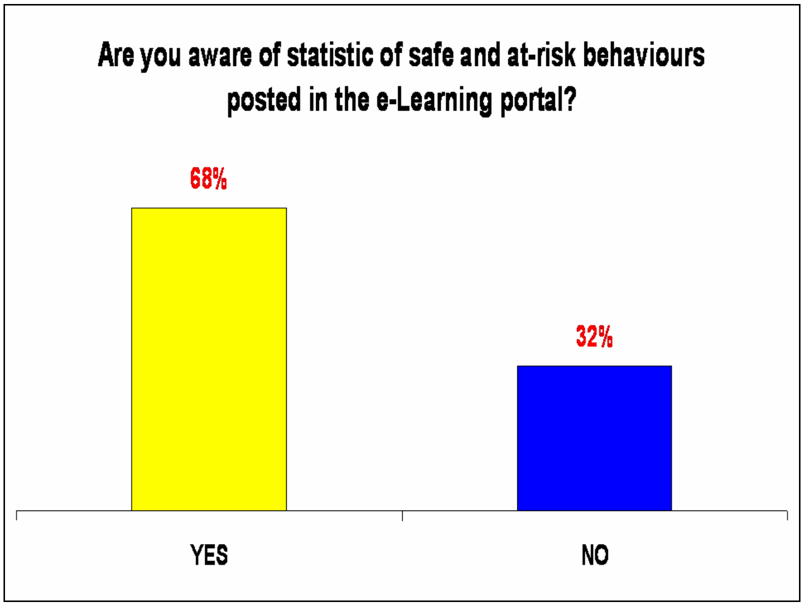


Fig. 4.21. Students notice the posted statistic.

Observation results in the form of statistic graphics were posted in the UTP students' e-Learning portal. It was actually to make sure that the students easily accessed the observation results at anytime. The survey was to evaluate attention of the students to the observation results. It showed that 68 percent of the students were aware of the results and 32 percent of them failed to notice it. The students should access and know the statistics of observation results. Since there were not many students accessing the observation results, the HSE committee or lecturers should find ways to make the students aware of the results to reduce the frequency of at-risk behaviours, especially handphone use in the labs.

It was important that each individual knew information in the statistics for safety precaution and safety awareness. As Ali (2006) informed, on site personnel, both workers and managers, were not too concerned with safety since they were not informed about the statistics of serious and fatal accidents, along with the number of disabilities resulting from such accidents.

*4.1.5.4 To Assess Number of Students Notice Critical Violation*

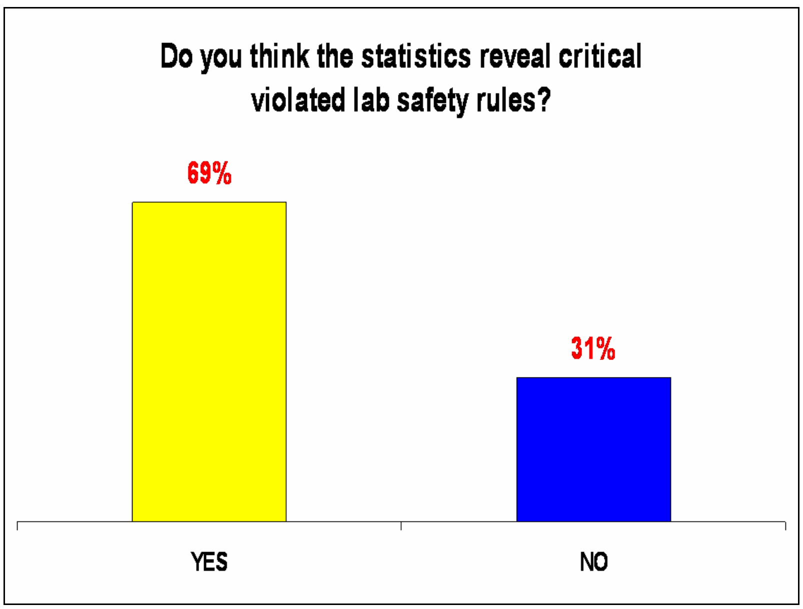


Fig. 4.22. Students notice critical violated lab safety rules.

Statistics posted in the UTP students' e-Learning portal was exactly the same as indicated in Fig. 4.11 until Fig. 4.18. Each time the students completed answering the observation question; the Lab-ARBAIS calculated the responses and transformed it into statistics format. Through this method, students accessed the portal to view the statistics for the latest observation process. As the students looked at the statistics, they could identify the highest at-risk behaviour observed and the most frequent at-risk behaviour practised by themselves and their friends.

In this survey, there was a need to recognize the Lab-ARBAIS effectiveness in revealing critical and frequent at-risk behaviour practised in the labs. 69 percent of the students agreed with the Lab-ARBAIS, which revealed critical and frequent violated lab safety rules in the students' e-Learning portal.

However, 31 percent of the students stated that the statistics failed to reveal critical and frequent violated lab safety rules. Those who failed to notice critical violation might be the same person (32 percent) who failed to notice the statistics posted in the portal. Both percentages proved that these students were unwilling to access the portal in order to notice and be aware of the statistics.

*4.1.5.5 To Assess Number of Students Notice Friends' Behaviours Have Improved*

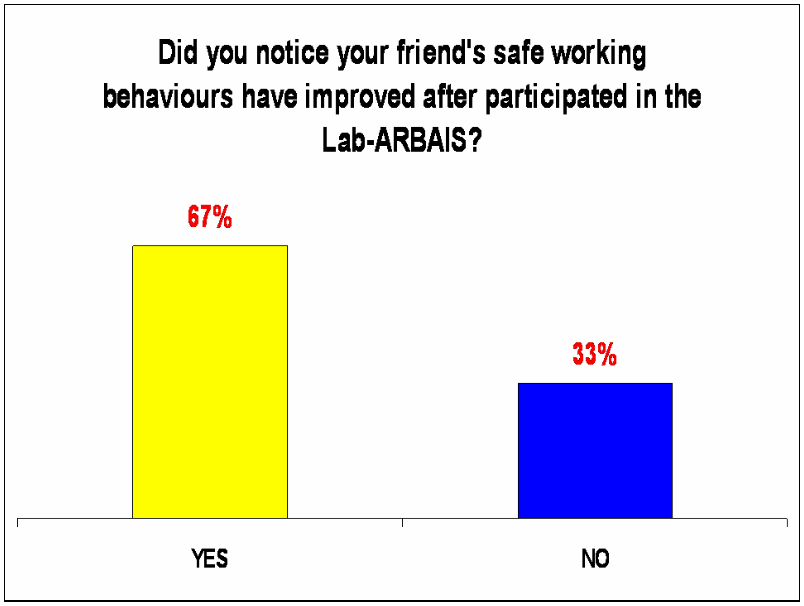


Fig. 4.23. Students notice the improvement on friends' safe working behaviours.

For the Lab-ARBAIS observation, each student was required to observe any individual who had violated lab safety rules and regulations. It was to encourage the students to observe safety practices of each other. The observation was done within the students' own group repeatedly. The repetition of observation could prompt students to witness and notice any differences of their friends' safe working behaviours or safety practices. Therefore, the survey was interested to assess sensitivity of the students in seeing any differences of safe working behaviours or safety practices done by their friends. 67 percent of the students noticed their friends' safe working behaviours or safety practices had improved after participated in the Lab-ARBAIS. Unfortunately, 33 percent of the students reported their friends' safe working behaviours or safety practices had no improvement.

*4.1.5.6 To Assess Number of Students Want A Continuity of the Lab-ARBAIS*

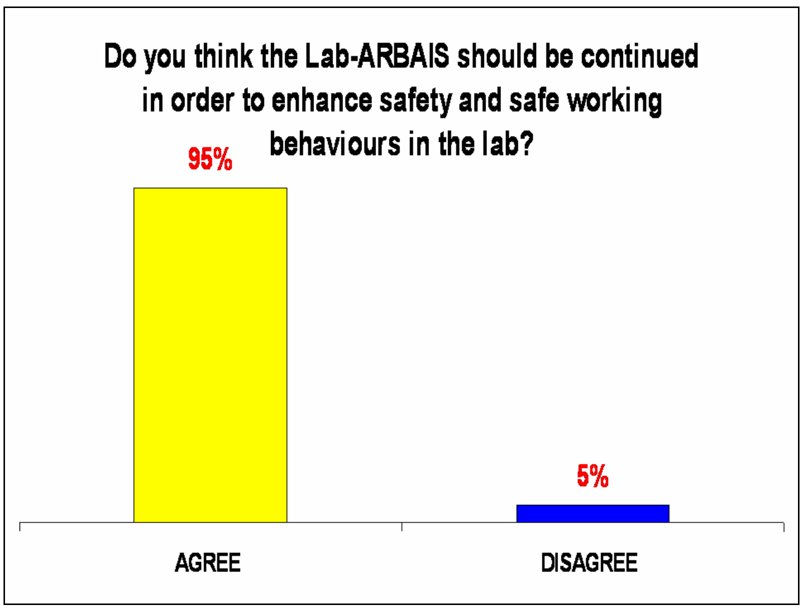


Fig. 4.24. Students allow continuity of the Lab-ARBAIS.

The Lab-ARABAIS was introduced to the same group of students for two consecutive semesters. This survey evaluated Lab-ARABIS recognition after the students had been exposed to the program in two consecutive semesters. 95 percent of the students agreed that the Lab-ARBAIS should be made available and continued for the following semester. This high percentage showed that the students were interested in the Lab-ARBAIS and accepted the Lab-ARBAIS voluntarily. Only 5 percent of the students disagreed and this percentage could be related to the 8-percent of students who dare to violate safety rules.

*4.1.5.7 To Assess Number of Students Willing to Participate Lab-ARBAIS in Website*

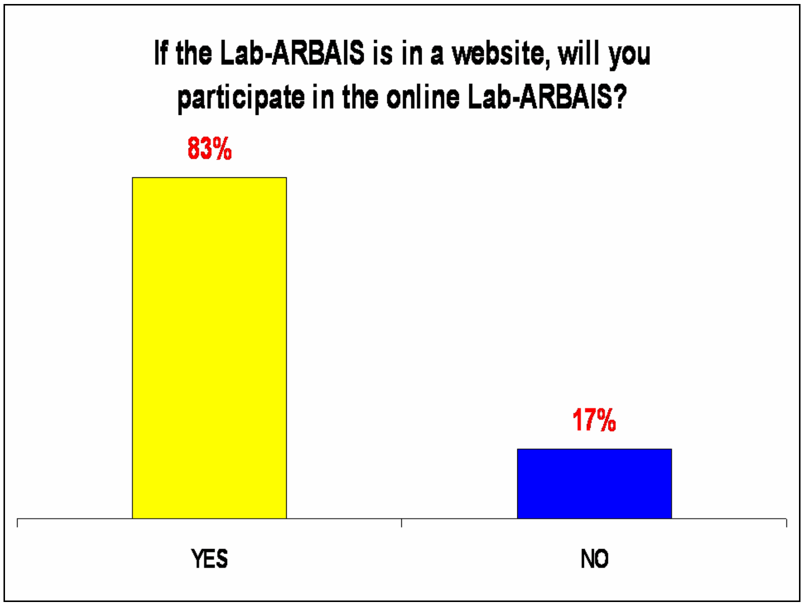


Fig. 4.25. Students ready to participate in the online Lab-ARBAIS.

The existing Lab-ARBAIS was only applicable to the students in the lab itself. The Lab-ARBAIS was accessed in one computer, which was provided in the lab. To access the Lab-ARBAIS, the students had to queue and wait for their turn. It was inconvenient to the students because it wasted a lot of time for queuing.

Therefore, the survey asked students' opinion to make the Lab-ARBAIS more user-friendly and readily. A contemporary method to make the program easier and more available for user to access is to develop the program in an online format. If the Lab- ARBAIS program will be continued and available in online form, 83 percent of the students agreed to participate in it. 17 percent of the students stated that they were not willing to participate in the online Lab-ARBAIS.

*4.1.5.8 To Assess Students' Opinion on Incentive in the Lab-ARBAIS*

Incentives were effective in improving compliance with safety rules (Haines III et al., 2001). A large number of studies had been performed on the use of incentives,

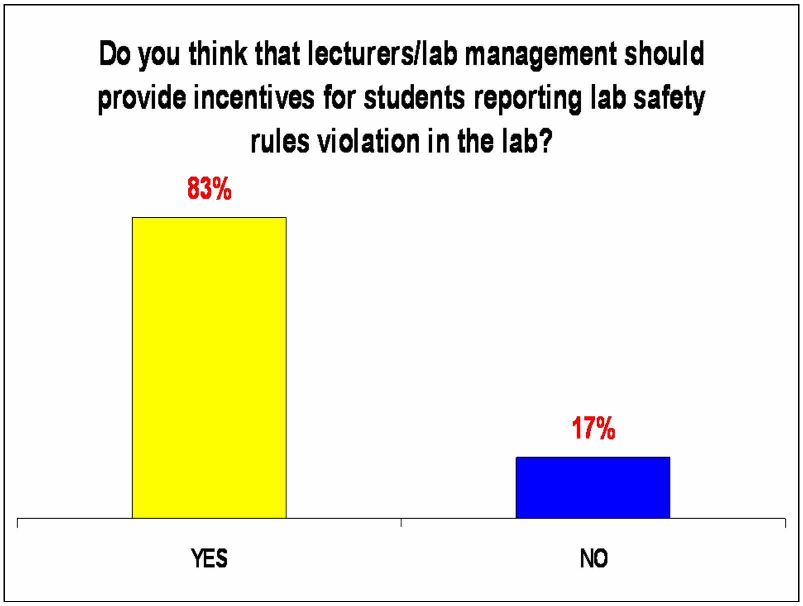


Fig. 4.26. Students agree on incentives for reporting.

often in combination with feedback about safety performance, to increase employees' compliance with safety rules. When properly performed, incentive was quite likely to bring about significant positive changes in compliance with safety rules. Cohen et al. (1979) noted that the use of safety incentives could arouse worker and company interest in job safety. Safety incentive plans were relatively simple to operate. The incentive approach was most effective when used to provide an added spur to an already well-designed safety program.

Hahn (2006) also emphasized on incentives or rewards to employees in the safety programs. He said that it was important to take time to acknowledge those members of the workforce who contribute to operational objectives through positive behaviours and work ethic. It was also important to believe that the 'positive performers' were the employees who lead their peers to practise positive behaviours in regards to safety. Rewards remained largely effective in influencing behaviours in human beings.

According to the studies on incentives and rewards implemented in the safety programs, the Lab-ARBAIS was motivated to implement incentives or rewards to the students for students to observe and report any safety rules violation. Thus, 83 percent of the students agreed that the lecturers or lab management provides incentives for informing at-risk behaviours. However, 17 percent of the students did not agree that incentives should be given for reporting the unsafe behaviours.

All results of the survey show majority of the students welcomed and accepted the Lab-ARBAIS in monitoring their safe working behaviours while conducting experimental works for two semesters.

## 4.2 Results of Case Study in Chemistry Lab

The results and discussion of the Lab-ARBAIS in Chemistry lab are discussed according to three (3) sections, which are analysis of Survey on Preferred Action, analysis of behaviour observed in Chemistry lab, and lastly, factor affecting behaviour of Chemistry students.

### 4.2.1 Analysis of Survey on Preferred Action

HSE committee, lecturers and lab demonstrators provided three (3) choices of action to be taken for student violated lab safety rules. In the survey, students were required to select their preferred action to be taken by lecturers and lab demonstrators for the lab safety rules violation and at-risk behaviours. The results of the survey are described according to safe mode and unsafe mode group.

#### *4.2.1.1 Unsafe Mode Group*

Students in the unsafe mode group gave a positive support in this survey because it had received 100 percent participation. The students of unsafe mode group were given three (3) choices of actions to be taken by lecturers and lab demonstrators for violating lab safety rules. Those choices were to be disallowed to enter the lab, to have a safety observer in the lab, and to lose marks of experiment report.

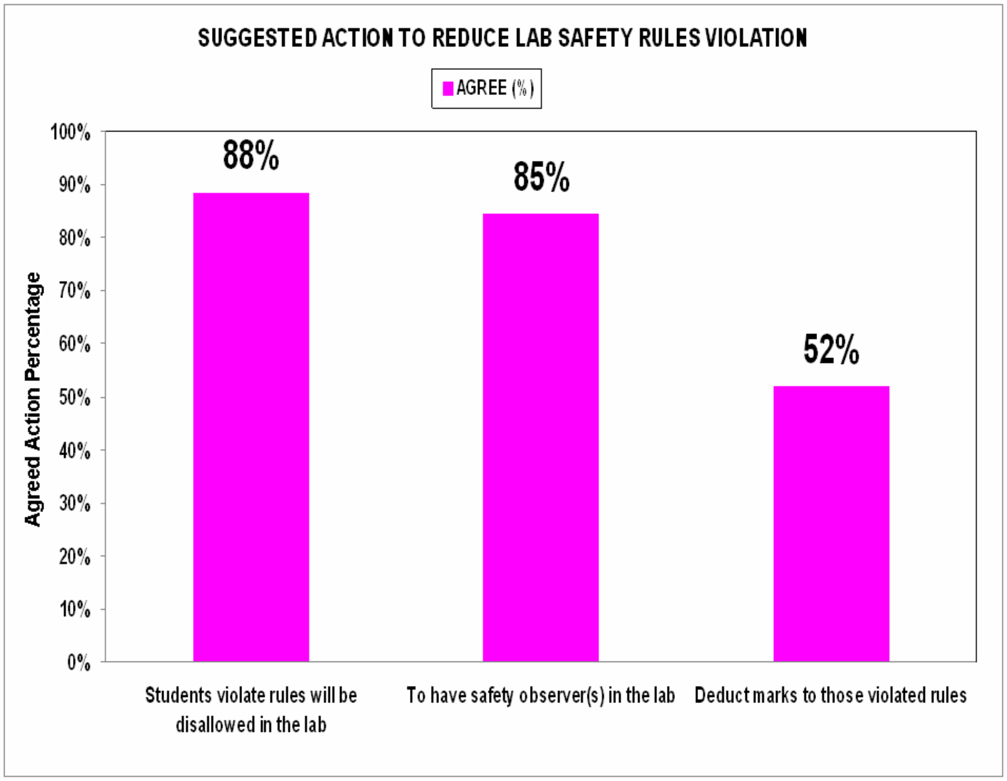


Fig. 4.27. Preferred action to be implemented in the unsafe mode group.

As shown in Fig. 4.27, action of being disallowed to enter the lab was the highest rated choice with 88 percent. The students expected those students practising unsafe or at-risk behaviours prohibited to be in the lab and consequently, they cannot do any experiments. Second preferred action was to have a safety observer in the lab, with 85 percent. Lastly, only 62 percent of the students were willing to lose marks of their lab report if they violated the lab safety.

Although the majority of students chose being disallowed to enter the lab room as the action to be taken, the lecturers and lab demonstrators decided to deduct 5 marks for students violating lab safety rules. They chose that action because it was easy, simple and practical instead of disallowed students from entering the lab room, which could cause the student to get zero marks for lab reports for not attending experiment session. The lecturers and lab demonstrators were more inclined to deduct 5 marks of the lab report than to assign a safety observer. They faced difficulty in finding a dedicated safety observer to observe students' behaviours in the lab for every experiment.

Therefore, the lecturers and lab demonstrators opted to deduct 5-marks of student's lab report marks for violating lab safety rules.

*4.2.1.2 Safe Mode Group*

Survey on Preferred Action received 100 percent participation in the unsafe mode group. Similar to the unsafe mode group, the students were given three (3) choices of actions to be taken by lecturers and lab demonstrators for violating lab safety rules. Two choices were unchanged, i.e. to be disallowed to enter the lab and to have a safety observer in the lab. The third choice was to receive rewards for upholding good safety practices.

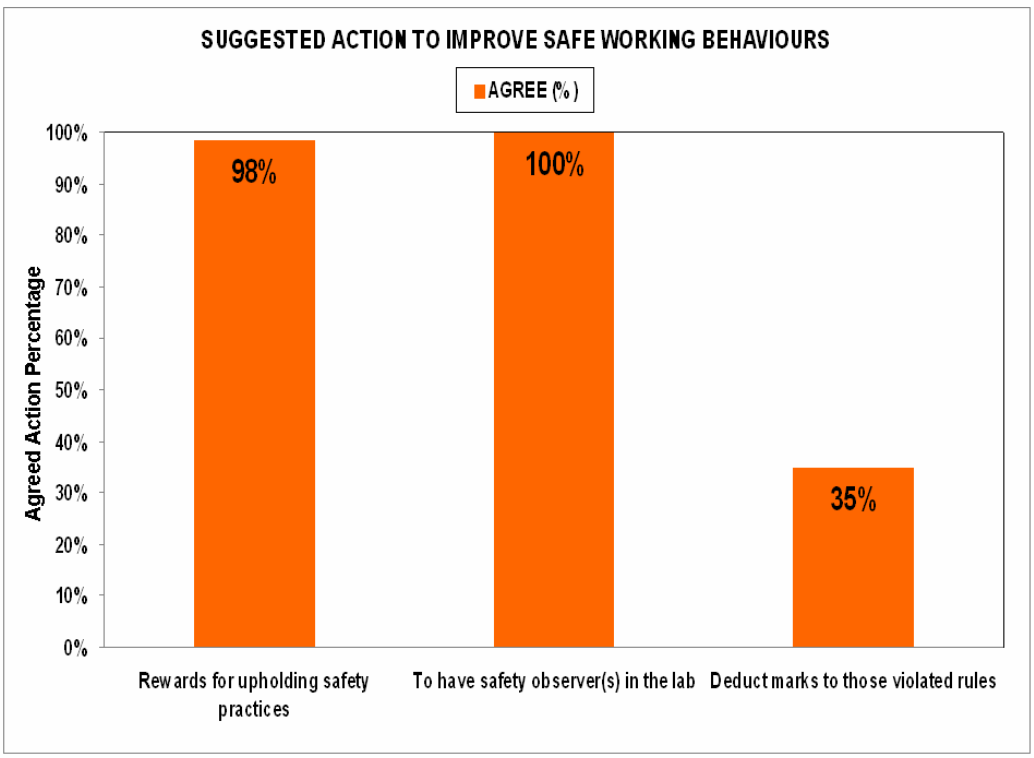


Fig. 4.28. Preferred action to be implemented in the safe mode group.

Fig. 4.28 reveals 100 percent of the students chose to have an assigned safety observer in the lab as their first choice of action. The second choice of action was to receive rewards for upholding safe behaviours, with 98 percent. And, only 35 percent of the students were willing to lose marks for their unsafe practices in the lab.

The lecturers and lab demonstrators considered the preferred actions given by the students in this group. However, they did not favour a safety observer and to give rewards to the students. It was because they could not find a person who can be a dedicated safety observer for each experiment. They were also reluctant to give rewards to student as it required a budget to provide rewards for every experiment session. Thus, the lecturers and lab demonstrators chose to deduct 5 marks of the lab report to students who violated lab safety rules.

### 4.2.2 Analysis Behaviours Observed in Chemistry Lab

In the Chemistry lab case study, the Lab-ARBAIS was combined with a disciplinary action, which was lecturers or lab demonstrators deduct five (5) marks of lab reports of identified students performing at-risk behaviours.

Responding to the Lab-ARBAIS pre-program questionnaire was a simple and quick process and could be completed within approximately two until five minutes. Feedbacks of questionnaire were automatically collected in a database. Then, the Lab-ARBAIS ran the process of identifying students who performed at-risk behaviours. The Lab-ARBAIS was screening reported particulars of the violator in the provided box. The Lab-ARBAIS had set a box of table’s number of violator. If the same students were frequently reported by the observers, the lecturers imposed the action to those students. The same processes of observing and taking action were repeated three times consistent with three experiment sessions. The results analysis of observing and taking action are reported and discussed as below.

*4.2.2.1 Unsafe Mode Group*

*Group A*

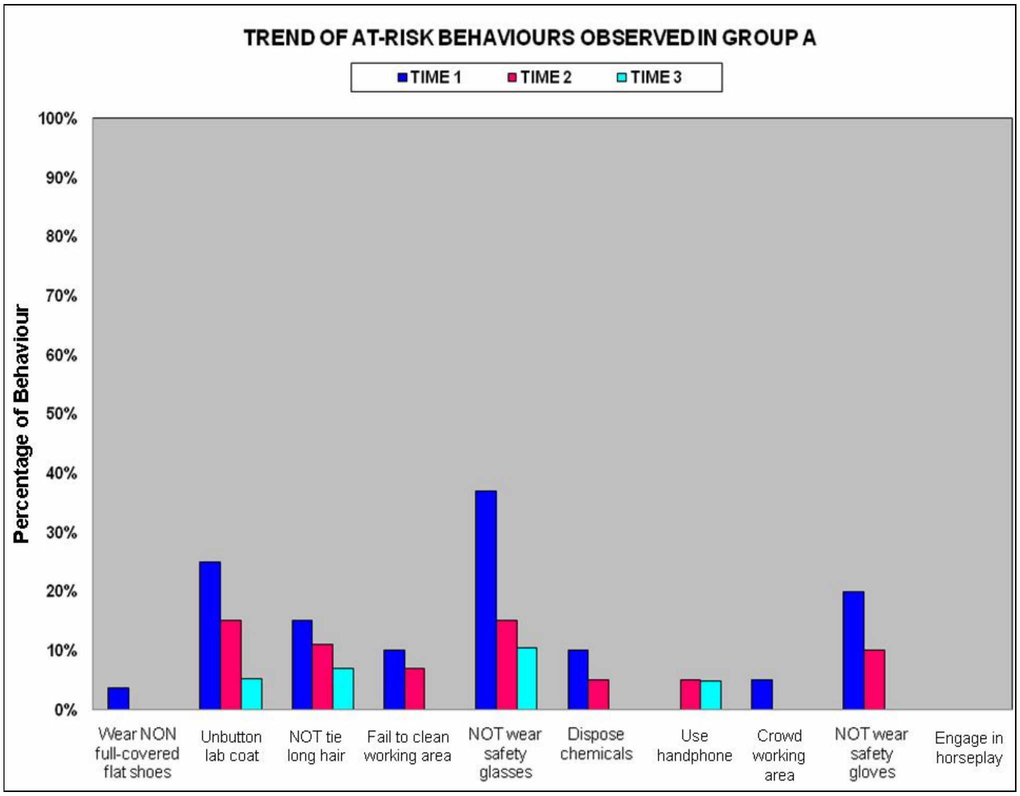


Fig. 4.29. At-risk behaviours observed within Group A.

Fig. 4.29 shows a percentage trend of ten at-risk behaviours observed in Group A. These behaviours were observed in three experiment sessions. And, these sessions were labelled as Time 1 for first experiment session, Time 2 for second experiment session, and Time 3 for third experiment session.

In Time 1, the students had practised eight at-risk behaviours. As reported to the Lab-ARBAIS, the highest percentage observed was 35 percent for students not wearing safety glasses. Next, the second highest was 25 percent which represented behaviour of students unbuttoned their lab coat. Other six behaviours ranged between 5 percent and 20 percent. No student was using handphone and engaging in horseplay in the lab during first experiment session.

The observation continued to Time 2. For serious cases of students not wearing safety glasses and students unbuttoned lab coat, the percentage of both cases decreased to 15 percent each. The number of students who did not tie long hair, failed to clean the working area, disposed chemical, failed to wear safety gloves were ranged from 10 to 5 percent. Surprisingly, the observers had observed the students using handphone. It had been reported at 5 percent. The observation also revealed that no student was wearing non full-covered flat shoes, crowding the working area, and engaging in horseplay.

In Time 3, six at-risk behaviours, i.e. wore non full-covered flat shoes, failed to clean working area, disposed chemical, crowded the working area, failed to wear safety gloves, and engaged in horseplay, showed zero percent. It meant that no student practised those behaviours. Previous serious cases in first and second experiment sessions, particularly students unbuttoned lab coat, did not tie long hair and failed to wear safety glasses have shown reduction in third experiment session. But, handphone use was still at 5 percent and it meant that the students were ignoring to not use handphone inside the lab.

*Group B*

Students of Group B used the Chemistry lab after the students of Group A had used it. And, Group B had similar observation periods as in Group A. For experimental work sessions, Group B had the same setting in experimental work sessions in Group A. Observation responses on students practising at-risk behaviours in Group B are represented in Fig. 4.30.

Based on the statistic, the highest percentage of at-risk behaviour observed in Time 1 was 95 percent where students disposed chemical into the sink. The second highest was 90 percent as student failed to wear safety glasses. This high percentage of students failed to wear safety glasses in Group B was the same case with students in Group A. The students of Group B were also reporting three at-risk behaviours; wore non full-covered flat shoes, did not tie long hair, and crowded the working area. However, no student unbuttoned lab coat, failed to clean working area, used handphone, failed to wear safety gloves, and engaged in horseplay.

In Time 2, the behaviours of disposing chemical into the sink was still reported as the highest percentage; 90 percent. The second highest reported at-risk behaviour was student not wearing safety gloves. The behaviour showed zero percent in Time 1 and it suddenly increased to 45 percent. It was considered an unexpected percentage increment. Students wore non full-covered flat shoes, failed to wear safety glasses, did not tie long hair, and crowded friends' working areas became less significant. Thus, there are percentage reductions for those behaviours. Nevertheless, it is interesting to discover that unsafe behaviours like unbuttoned lab coat, failed to clean working area, used handphone and engaged in horseplay were not practised by all the students.

The ten at-risk behaviours remained in the Lab-ARBAIS observation list for observation in Time 3. Although the observations were still going on in this session, the students failed to dispose chemical in the provided container. Instead, 40 percent

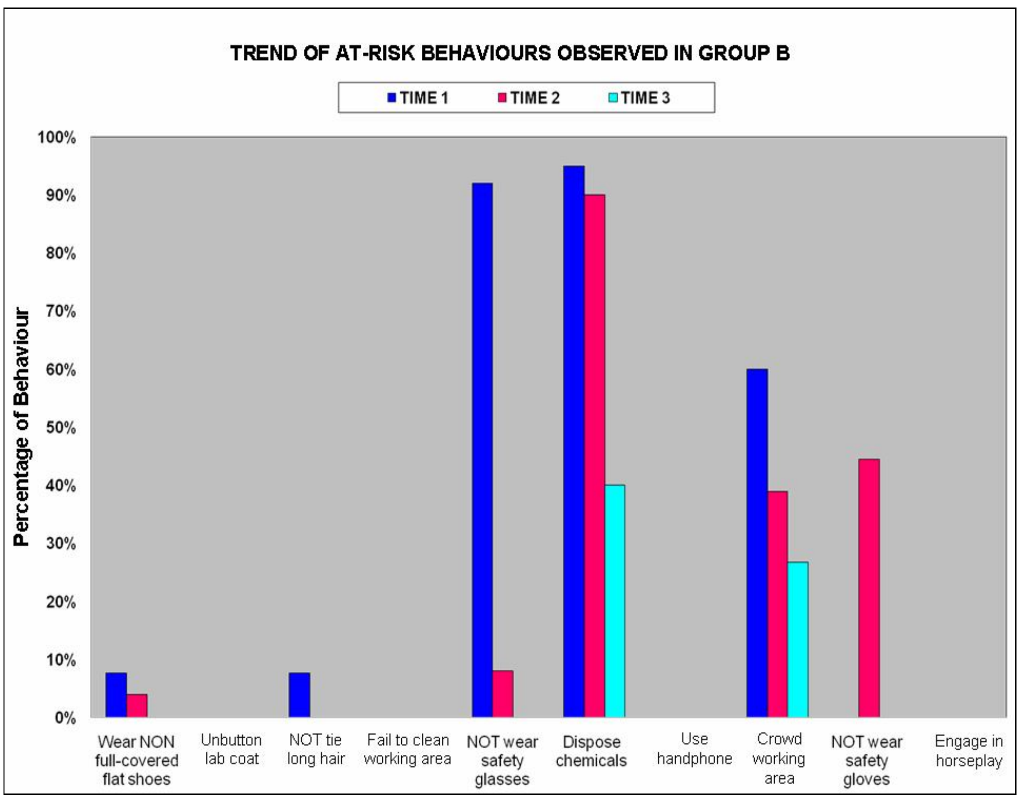


Fig. 4.30. At-risk behaviours observed within Group B.

of them insisted to dispose chemical into the sink. Meanwhile, students crowded working areas was the second highest with 25 percent of the subjects.

#### *4.2.2.2 Safe Mode Group*

The Lab-ARBAIS was set to perform observation for safe working behaviours. It was actually to track safe working behaviours performed by the students. Track safe working behaviours, rather than at-risk behaviours or accidents due to at-risk behaviours, helped students view safety in a more positive way.

*Group C*

Three observation cycles were set for students in Group C. The cycles of observation happened during experiment session. First experiment session referred to observation done in Time 1, second experiment sessions were for observation in Time 2, and finally, third experiment sessions were for observation in Time 3.

In Time 1, as illustrated in Fig. 4.31, students had practised four safe behaviours, which were buttoned lab coat, cleaned the working area, did not dispose chemical, and did not use handphone. However, there were some students who were not wearing full-covered flat shoes, not tying long hair, crowding the working area, not wearing safety gloves, and engaging in horseplay. The observation responses revealed those behaviours had high percentages about 80 to 95. And, the lowest percentage was 55, represented by smaller number of students wearing safety glasses.

Observation in Time 2 had prompted the students to maintain safe behaviours that they had practised since first experiment session. Thus, safe behaviours of buttoned lab coat, cleaned the working area, did not dispose chemical, and did not use handphone remained at 100 percent. Besides, more students were wearing full-covered flat shoes, not crowding the working area, and engaging in horseplay as they obtained 100 percent. There were also more students wearing safety glasses at 100 percent, which was previously less practised in Time 1.

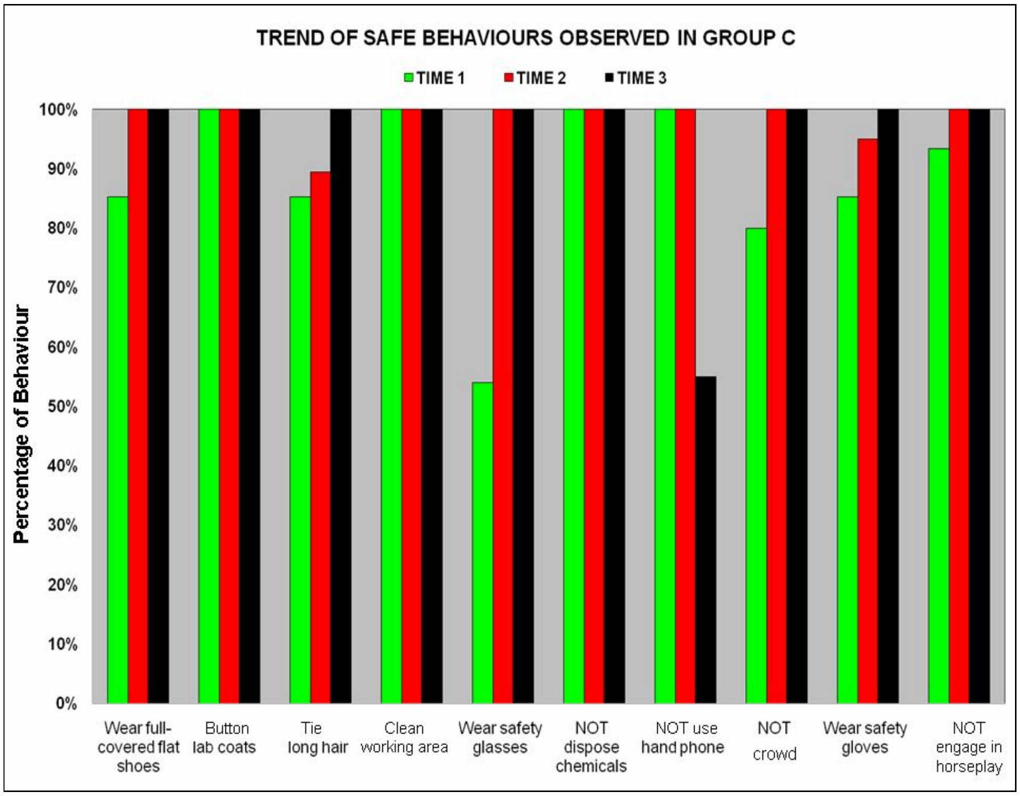


Fig. 4.31. Safe behaviours observed within Group C.

The students were becoming familiar to practise safe working behaviours. It was proved in observation responses in Time 3. Nine safe behaviours were fully practised and it resulted to 100 percent. However, there was a sudden change of students used handphone in the lab. Percentage of students not using handphone dropped to 50 percent. The Lab-ARBAIS was still unable to control this behaviour although the Lab-ARBAIS combined with a disciplinary action.

*Group D*

Students in Group D experienced the same observation periods as the students in Group C. Observations in Time 1 influenced the students to wear full-covered flat shoes, button lab coat, clean the working area, not dispose chemical, not use handphone, not crowd, and not engage in horseplay. Those safe behaviours had been reported and gave 100 percent result. This 100-percent indicated students understood and complied with the lab safety rules. But, there were only 95 percent students who

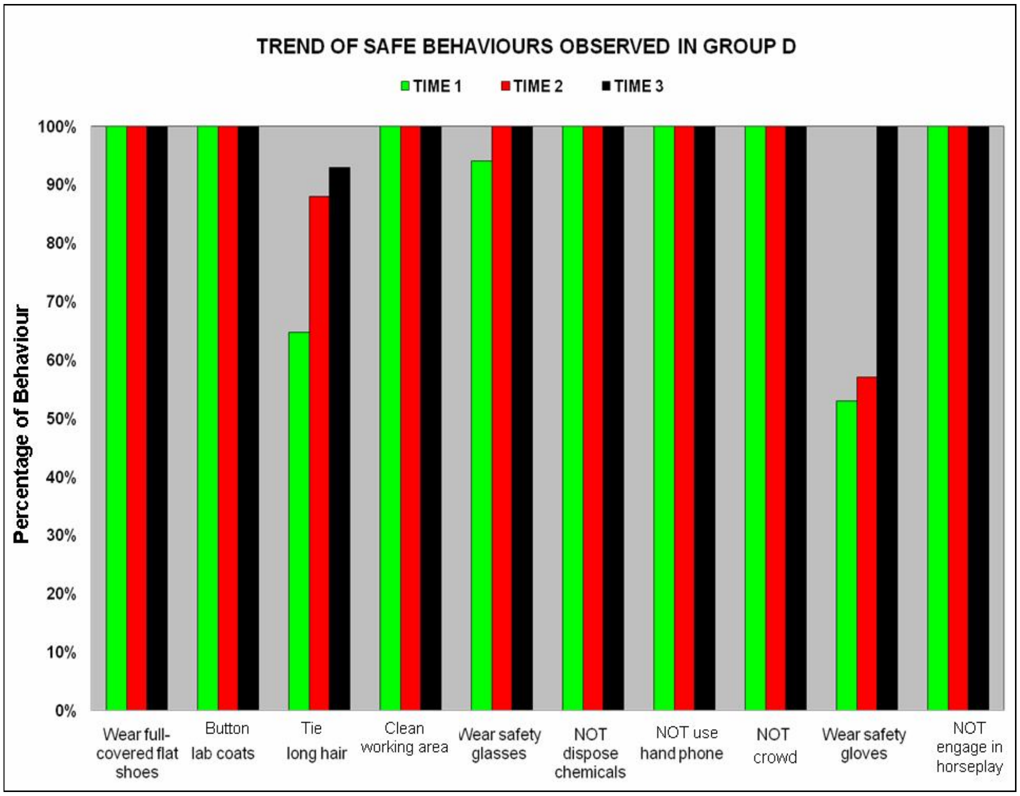


Fig. 4.32. Safe behaviours observed within Group D.

wore safety glasses. And, only 65 and 50 percent students tied their long hair and wore safety gloves, respectively.

In Time 2, the students maintained safe working behaviours especially wore full-covered flat shoes, buttoned lab coat, cleaned the working area, did not dispose chemical into the sink, did not use handphone, did not crowd, and did not engage in horseplay. More students wore safety glasses as a habit in this session because the percentage indicated increment until 100 percent. Other safe behaviours also showed improvement in terms of more students tied their long hair and wore safety gloves.

Those safe behaviours habit continued in third experiment sessions (refer to observation in Time 3). The students were seriously practised to the nine safe behaviours observed. However, there was still a report on students failed to tie their long hair.

### 4.2.3 Factors Affecting Behaviours of Students in Chemistry Lab

Disciplinary action was usually implemented in the industries. Many companies or industries combined safety training with the threat of disciplinary actions designed to encourage safe behaviours. Disciplinary action or at least the threat of disciplinary action widely used as a way of discouraging unsafe acts (Peters, 1991). A strategy implemented in the Lab-ARBAIS in order to adopt self-protective behaviours and avoid unsafe acts was to implement a disciplinary action.

In the case study of Chemistry lab, the frequent at-risk behaviours improved because routine observation process integrated with an action. The action of deduct 5-marks for lab report was used as a way of discouraging at-risk behaviours. Seriousness of action taken was associated with instruction and encouragement to perform works correctly and safely. As a result, the conditions and the environment helped to put safety as a top priority in the chemistry laboratory. This encouraging improvement proved that the lab management and the Lab-ARBAIS could broadly influence students' safe behaviours and expectations (DeJoy et al., 2004; Fernández-Muñiz, et al., 2007; Mohamed et al., 2009).

Continuous observation and posting the results of observation responses in accordance with each occasion were also factors that encouraged more students to practise safe behaviours. They believe that their safe work behaviours and any violated lab safety rules were being watched and reported by the other students in their groups. Therefore, the students tried to work safely and follow the lab safety rules.

### 4.2.4 Issue on Unimproved At-Risk Behaviour in Chemistry Lab

Based on the results of Group A, Group B, Group C, and Group D, the Lab-ARBAIS failed to encourage students to not use handphone in the lab and not dispose chemical into the sink. The lecturers and lab demonstrators used ABC model to find the appropriate solution. For handphone usage issue, the lecturer and lab demonstrators exercised similar solutions in the PSLP lab. However, there was another solution added as shown in Table 4.4.

Table 4.4. Additional ABC model for handphone use in the Chemistry lab

| Antecedent | Behaviour | Consequence |
|---|---|---|
| Hear handphone ringing | Answer the phone inside the lab | Lose 10 marks for lab report |

The lecturers and lab demonstrators decided labelling ‘Do Not Dispose Chemical’ near the sink and deducting 10 marks of the lab report to control students from disposing chemical into the sink. These solutions were based on ABC model. It is shown in Table 4.5.

Table 4.5. ABC model to control students disposed chemical into the sink

| Antecedents | Behaviours | Consequences |
|---|---|---|
| See label ‘Do Not Dispose Chemical’ | Dispose chemical in the labelled container | Perform experiment safely |
| See label ‘Do Not Dispose Chemical’ | Dispose chemical into the sink | Lose 10 marks for lab report |

### 4.3 Difference between At-Risk Behaviour in PSLP and Chemistry Labs

The Lab-ARBAIS completed the two case studies in PSLP and Chemistry labs. There was a difference of these two labs especially in the unsafe mode group. By comparing trend of at-risk behaviours observed in Phase 1 of Group C (PSLP), Fig. 4.15, with trend of at-risk behaviours observed of Group A (Chemistry), Fig. 4.29, the Lab-ARBAIS revealed the students of PSLP had higher percentage of at-risk behaviours practised than the students of Chemistry. The same comparison was also shown in the trend of at-risk behaviours observed in Phase 1 of Group D (PSLP), Fig. 4.17, and the trend of at-risk behaviours observed of Group B (Chemistry), Fig. 4.30. To be precise, students who had more working experience in the lab were more easily to breach lab safety rules than students who had no working experience in the lab. Shariff and Norazahar (2011a) explained that senior students were more likely to violate the lab safety rules as they adapted to practice at-risk behaviour repetitively. Then, the practices become a norm to some students.

One study by Van Vuuren and Van der Schaaf (1999) revealed the similar finding; unsafe behaviours became habit to employees. They found that the use of personal protective equipment (e.g. helmets, gloves, safety glasses) was often not taken seriously and considered to be an unnecessary burden, in particular in hot working conditions. They added, in these situations, the individual was aware that safety precautions and rules dealing with the risks were violated. However, performing the job unsafely was accepted by a group of employees.

Table 4.6 presented overall findings on frequent repeated at-risk behaviours identified by Lab-ARBAIS implementation in PSLP and Chemistry labs.

Table 4.6. Comparison of repeated at-risk behaviours in PSLP and Chemistry labs.

| Groups | PSLP lab | | Chemistry lab |
|---|---|---|---|
| | Semester 1 | Semester 2 | One semester only |
| A | - Using handphone in the lab | - Using handphone in the lab | - Using handphone in the lab |
| B | - Using handphone in the lab | - Using handphone in the lab<br>- Not tying back long hair | - Disposing chemical into sink |
| C | - Using handphone in the lab | - Using handphone in the lab<br>- Crowding working area | - Using handphone in the lab |
| D | - Using handphone in the lab | - Using handphone in the lab | - Not tying back long hair |

## 4.4 Limitations of Lab-ARBAIS

In spite of the success of reducing students' at-risk behaviours, the Lab-ARBAIS had a few limitations that contribute to false statistics. The Lab-ARBAIS statistics were calculated based on the students' observation feedback. If one person practised unsafe behaviour, maybe some of the students saw and reported the same mistake.

Further, the number of reported observations did not directly relate to the actual number of the at-risk behaviour practised. For example, one student did not wear full covered flat shoes and this behaviour was witnessed by all the students. Therefore, the observation result may give 100 percent. Hence, it was important to note that the Lab-ARBAIS could not be used to get the exact number of students who made the mistake.

Another limitation of the Lab-ARBAIS is the system failed to recognise between sincere observation response and dishonest observation response (Shariff and Norazahar, 2011a). Thus, the reliability of these observation responses can be questioned. The Lab-ARBAIS totally depended on sincerity of observers in doing surveillance and answering the observation questions.

# CHAPTER 5

# CONCLUSION

## 5.1 Conclusion

The framework of Lab-ARBAIS was practical in chemical engineering laboratories at Universiti Teknologi PETRONAS.

The Lab-ARBAIS was applied in two case studies which were PSLP and Chemistry labs. The routine processes, i.e., observes, responds and analyse, prompted the Lab-ARBAIS to reveal critical lab safety rules violation in PSLP and Chemistry labs.

Most of students' at-risk behaviours were improved by using the Lab-ARBAIS tool in both case studies. The students in PSLP and Chemistry labs had been influenced to practise safe behaviours due to a cognitive psychology effect of Lab-ARBAIS and actions taken by HSE committee, lecturers and lab demonstrators.

The case studies revealed some constraints to obtain accurate observation results in the Lab-ARBAIS. An inexact number of at-risk behaviour reported and of honest observation response could slightly affect statistics of behaviours and successfulness of the case studies.

All in all Lab-ARBAIS concept was practical. Some recommendations were presented in order to fine tune the Lab-ARBAIS in other laboratory setting. It could be more effective if the recommendations were considered.

## 5.2 Lab-ARBAIS Recommendations for Improvement

For future implementation of the Lab-ARBAIS in educational setting or industrial setting, the Lab-ARBAIS needs improvement in order to get effective results. It can be done using the following recommendations;

### 5.2.1 Set Exact Parameter

Rules can be amended accordingly depending on the appropriateness and conditions. Organisation or management is recommended to amend lab safety rules in order to make the user understand the rules more. Clearer parameter of behaviours would ease the students to recognise any discrepancies of safe and unsafe behaviours. Thus, the observation results would become meaningful.

### 5.2.2 Clear Communication on Lab-ARBAIS

Clear communication on Lab-ARBAIS program and observation requirements is important for users or students to understand Lab-ARBAIS concept and observation process. The users or students who have fully understood the Lab-ARBAIS concept and observation process could give sincere and honest observation responses to the Lab-ARBAIS observation questions.

### 5.2.3 Longer Lab-ARBAIS Observation Cycle

The organisation or management should apply the Lab-ARBAIS for a longer period. It means that the Lab-ARBAIS will have longer observation cycle. For instance, the Lab-ARBAIS has four (4) similar observations in a day. Increasing observation cycles will increase the observation responses and thus, the responses results will be more meaningful.

## 5.3 Impact on Industry

Basically, safe behaviour practice is very crucial in both educational and industrial settings. This behaviour should be practised and exposed at the early age of individuals.

Majority of chemical engineering students are hired by industry, which means that these graduates need to be prepared for professional work. The preparation could be done via introducing Lab-ARBAIS program which is able to foster student's personal safety responsibility. This responsibility should be greatly emphasized in every aspect of education and training as a way of preventing unintentional injuries (Blair et al., 2004). The responsibility would be upheld whenever the students are exposed to hazardous environment, especially in the industry.

The second impact of Lab-ARBAIS program is it could easily be extended to any type of laboratory setting including industrial laboratory. Academic laboratory and industrial laboratory are similar in terms of exposure to hazardous chemicals and equipment. The only difference is the scale, whereby the academic laboratory is normally smaller than industrial laboratory (Shariff and Norazahar, 2011b).

REFERENCES


Abu-Khalaf, A. M. (2001). Introducing safety in the chemical engineering laboratory course. *Chemical Health & Safety, January/February 2001*, 8 – 11.

Agraz-Boeneker, R., Groves, W. A., & Haight, J. M. (2007). An examination of observations and incidence rates for a behavior based safety program. *The Journal of SH&E Research, 4 (3).*

Ali, T. H. (2006). Influence of national culture on construction safety climate in Pakistan, PhD thesis, Gliffith University, Australia.

Alvero, A. M., Rost, K., & Austin, J. (2008). The safety observer effect: The effects of conducting safety observations. *Journal of Safety Research*, *39*, 365–373.

American Chemical Society [ACS] Committee on Chemical Safety (1973). Safety practices in the chemical laboratory. *Journal of Chemical Education*, *50*(8), A403.

Anderson, M. (2005). Behavioural safety and major accident hazards: Magic bullet or shot in the dark. *Process Safety and Environmental Protection, 83(B2)*, 109 – 116.

Attwood, D., Khan, F., & Veitch, B. (2006). Can we predict occupational accident frequency? *Process Safety and Environmental Protection*, *84*(B3), 208 – 221.

Benderly, B. L. (2009a). Taken for granted: The burning question of laboratory safety. [On-line]. Available: http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2009_05_01/caredit.a0900054.

Benderly, B. L. (2009b). Explosions in the Lab: What Can Be Learned From the Death of A Young Biochemist at UCLA? [On-line]. Available: http://www.slate.com/id/2218825.

Blair, E. H., Seo, D. –C., Torabi, M. R., & Kaldahl, M. A. (2004). Safety beliefs and safe behavior among midwestern college students. *Journal of Safety Research, 35*, 131 – 140.

Choudhry, R. M., Fang, D., & Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety Science*, *45*, 993 – 1012.

Choudhry, R. M., & Fang, D. (2008). Why operatives engage in unsafe work behaviour: Investigating factors on construction sites. *Safety Science*, *46*, 566 – 584.

Christensen, K. (2010). Serious lab accident at UCLA in 2007 was not reported. [On-line]. Available: http://articles.latimes.com/2010/mar/13/local/la-me-ucla13-2010mar13/2.

Cohen, A., Smith, M., & Anger, W. (1979). Self-protective measures against workplace hazards. *Journal of Safety Research*, *11*, 121 -131.

Cooper, M. D., Philips, R. A., Sutherland, V. J., and Makin, P. J. (1994). Reducing accidents with goal-setting and feedback: A field study. *Journal of Occupational and Organisational Psychology*, *67*, 219 – 240.

Cooper, M. D. (2000). Towards a model of safety culture. *Safety Science*, *36*, 111 – 136.

Cooper, M.D., & Philips, R.A. (2004). Exploratory analysis of the safety climate and safety behavior relationship. *Journal of Safety Research, 35*, 497 – 512.

Cox, S., & Jones. B. (2006). Behavioural safety and accident prevention: Short-term 'fad' or sustainable 'fix'? *Process Safety and Environmental Protection, 84(B3)*, 164 – 170.

DeJoy, D. M., Schaffer, B. S., Wilson, M. G., Vandenberg, R. J., & Butts, M. M. (2004). Creating safer workplaces: Assessing the determinants and role of safety climate. *Journal of Safety Research, 35*, 81 – 90.

DePasquale, J.P., & Geller, E.S. (1999). Critical success factors for behavior-based safety: A study of twenty industry-wide applications. *Journal of Safety Research, 30*(4), 237-249.

DuPont™. (2003). DuPont™ Science Safety Zone™: Science safety awareness program (online): http://thechallenge.dupont.com/DuPontSafetyZoneTGrv3.pdf

European Process Safety Centre [EPSC] (1996). Safety performance measurement, Editor Jacques van Steen. Institution of Chemical Engineers.

Foord, A. G., & Gulland, W. G. (2006). Can technology eliminate human error? *Process Safety and Environmental Protection, 84(B3)*, 171 – 173.

Fernández-Muñiz, B., Montes-Peón, J. M., & Vázquez-Ordás, C. J. (2007). Safety culture: Analysis of the causal relationships between its key dimensions. *Journal of Safety Research, 38*, 627 – 641.

Geller, E. S. (1988). Managing occupational health and safety. Make-A-Difference, Inc., Blacksburg, VA.

Goetsch, D. L. (2002). *Occupational safety and health for technologists, engineers, and managers,* 4th. Columbus – Prentice Hall.

Gupta, A. K. (2007). *Industrial safety and environment*, New Delhi: Laxmi Publications (P) Ltd.

Haines III, V.Y., Merrheim, G., & Roy, M. (2001). Understanding reactions to safety incentives. *Journal of Safety Research*, *32*, 17 – 30.

Hale, A. R. (1990). Safety rules o.k.? Possibilities and limitations in behavioural safety strategies. *Journal of Occupational Accidents*, *12,* 3 – 20.

Hammer, W., & Price, D. (2001). Occupational safety management and engineering, 5th. New Jersey: Prentice Hall.

Hahn, B. A. (2006). Analyzing the critical elements of behavioral safety and their impact on process implementation. M.S. thesis, Dept. Tech., Southern Illinois Univ., Carbondale, 2006.

Henning, J. B., Stufft, C. J., Payne, S. C., Bergman, M. E., Mannan, M. S., & Keren. N. (2009). The influence of individual differences on organizational safety attitudes. *Safety Science*, *47*, 337–345.

Hill Jr., R. H. (2004, May/June). Changing the way chemists think about safety. *Chemical Health & Safety*, 5 – 8.

Institution of Occupational Safety and Health [IOSH] (2006). Behavioural safety: Kicking bad habits. [Online]. Available: www.iosh.co.uk/information_and_resources/idoc.ashx

Irons, M. E. (2011). Yale lab accident kills Scituate woman: Safety investigations follow student's death. [Online]. Available: http://articles.boston.com/2011-04-14/news/29418162_1_yale-police-yale-officials-richard-c-levin

John, O., Donahue, E. M., & Kentle, R. L. (1991). The "Big Five" Inventory – Version 4[a] and 54, University of California, Institute of Personality and Social Research Berkeley, CA.

Johnson, J. (2010a). University lab accident under investigation. *Chemical & Engineering News, January 20, 2010*.

Johnson, J. (2010b). School labs go under microscope. [On-line]. Available: http://pubs.acs.org/cen/government/88/8805gov1.htm.

Keng, T. S. (2007). On-line at-risk behaviour analysis and improvement system (e-BAI). MSc thesis, Chemical Engineering Department, Universiti Teknologi PETRONAS, Malaysia.

Kemsley, J. N. (2009a). Researcher dies after lab fire. [On-line]. Available: http://pubs.acs.org/cen/news/87/i04/8704news1.html.

Kemsley, J. N. (2009b). Learning from UCLA. *Chemical & Engineering News, August 3, 2009*.

Kletz, T. A. (2002). Accident Investigation – missed opportunities. *Process Safety and Environmental Protection*, *80(B).*

Krause, T.R., Seymour, K.J., & Sloat., K.C.M. (1999). Long-term evaluation of a behaviour-based method for improving safety performance: A meta-analysis of 73 interrupted time-series replications. *Safety Science, 32*, 1 – 18.

Langerman, N. (2009). Laboratory safety? *Journal of Chemical Health and Safety, 6*(3), 49 - 50.

Lardner, R., and Scaife. R. (2006). Helping engineer to analyse and influence the human factors in accidents at work. *Process Safety and Environmental Protection*, *84*(B4), 179 – 183.

Laurence, D. (2005). Safety rules and regulations on mine sites – The problem and a solution. *Journal of Safety Research*, *36*, 39 – 50.

Mohamed, S., Ali, T.H., & Tam, W.Y.V. (2009). National culture and safe work behaviour of construction workers in Pakistan. *Safety Science, 47*, 29–35.

McSween, T. E. (2003). Value-based safety process: Improving your safety culture with behavior-based safety. Second edition. New Jersey: John Wiley & Sons.

Mullen, J. (2004). Investigating factors that influence individual safety behavior at work. *Journal of Safety Research, 35*, 275 – 285.

Occupational Safety and Health Reps at Work [OHSREP] (2008). [On-line]. Available: http://www.ohsrep.org.au/toolkit/behaviour-based-safety-programs/index.cfm

Peñas, F. J., Barona, A., Elías, A., and Olazar, M. (2006, March/April). Implementation of industrial health and safety in chemical engineering teaching laboratories. *Journal of Chemical Health & Safety*, 19 – 23.

Perrin, L., and Laurent, A. (2008). Current situation and future implementation of safety curricula for chemical engineering education in France. *Education for Chemical Engineers, 3*¸e84 – e91.

Quinn, R. (2011). Yale Student Suffocates in Freak Lab Accident. [Online]. Available: http://www.newser.com/story/116351/yale-student-suffocates-in-freak-lab-accident.html

Quintana, R. (1999). A task – delineated safety approach for slip, trip, and fall hazards. *Safety Science, 33,* 31 – 45.

Reason, J. T. (1989). Human error. Cambridge University Press.

Reason, J. (1998). Achieving a safe culture: Theory and practice. *Work and Stress, 12*(3), 293 – 306.

Reber, R. A., Wallin, J. A., and Duhon, D. L. (1989). Safety programs that work. *Personnel Administrator, 34,* 66 – 69.

Russell, L. (1999). Incident investigation: Fix the problem – not the blame. *Chemical Health & Safety, January/February 1999*, 32 – 34. American Chemical Society.

Schulz, W. G. (2005). Fighting lab fires: Explosion and fire at an Ohio State University chemistry lab highlight safety issues in academia. *Chemical & Engineering News, May 23, 2005*.

Shariff, A. M., and Keng, T.S. (2008). On-line at-risk behaviour analysis and improvement system (e-ARBAIS). *Journal of Loss Prevention in the Process Industries, 21,* 326 - 335.

Shariff, A. M., and Norazahar, N. (2011a). At-risk behaviour analysis and improvement study in chemical engineering laboratories. *International Journal of Chemical and Environmental Engineering, 2*(1), 51 – 55.

Shariff, A. M., and Norazahar, N. (2011b). At-risk behaviour analysis and improvement study in an academic laboratory. *Safety Science,* In Press, Corrected Proof.

Simmons, F., Quigley, D., Whyte, H., Robertson, J., and Freshwater, D. (2009, May/June). Chemical safety: Asking the right questions. *Journal of Chemical Health & Safety*, 34 – 39.

Trager, R. (2009a). UCLA Lab Assistant Dies. [On-line]. Available: http://www.rsc.org/chemistryworld/News/2009/January/23010903.asp.

Trager, R. (2009b). UCLA fined following fatal lab accident. [On-line]. Available: http://rsc.org/chemistryworld/News/2009/May/06050901.asp.

U.S. Chemical Safety Board [CSB] (2010). CSB to investigate laboratory explosion at Texas Tech University Chemistry Department. [On-line]. Available: http://www.csb.gov/newsroom/detail.aspx?nid=301.

Van Vuuren, W., and Van Der Schaaf., T. W. (1999). The influence of safety culture on risks and risk management. 10th European Conf. Safety and Reliability, 1999, vol. 2, pp. 1261 – 1265.

Walsh, S. P., White, K. M., and Young, R. M. (2008). Over-connected? A qualitative exploration of the relationship between Australian youth and their mobile phones. *Journal of Adolescence, 31*, 77 – 92.

Williams, J. H., & Geller, E. S. (2000). Behavior-based intervention for occupational safety: Critical impact of social comparison feedback. *Journal of Safety Research*, *31*(3), 135 – 142.

Wu, T. –C., Liu, C. –W., & Lu. M. –C. (2007). Safety climate in university and college laboratories: Impact of organizational and individual factors. *Journal of Safety Research*, *38*, 91 – 102.

Zakzeski, J. (2009). Improving engineering research laboratory safety by addressing the human aspects of research management. *Journal of Chemical Health & Safety, May/June 2009*, 5 – 20.

APPENDIX A

LABORATORY SAFETY RULES AND REGULATIONS FOR STUDENTS

Life threatening injuries can happen in the laboratory. For that reason, students need to be informed of the correct way to act and things to do in the laboratory. The following is a safety checklist that can be used as a handout to students to acquaint them with the safety do's and don'ts in the laboratory.

Conduct

a) Do not engage in practical jokes or boisterous conduct in the laboratory.
b) Never run in the laboratory.
c) The use of personal audio or video equipment is prohibited in the laboratory.
d) The performance of unauthorized experiments is strictly forbidden.
e) Do not sit on laboratory benches.

General Work Procedure

a) Know emergency procedures.
b) Never work in the laboratory without the supervision of a teacher.
c) Always perform the experiments or work precisely as directed by the teacher.
d) Report any spills, accidents, or injuries to a teacher immediately.
e) Never leave experiments while in progress.
f) Never attempt to catch a falling object.
g) Be careful when handling hot glassware and apparatus in the laboratory.
h) Hot glassware looks just like cold glassware.
i) Never point the open end of a test tube containing a substance at yourself or others.
j) Never fill a pipette using mouth suction. Always use a pipetting device.

k) Make sure no flammable solvents are in the surrounding area when lighting a flame.
l) Do not leave lit Bunsen burners unattended.
m) Turn off all heating apparatus, gas valves, and water faucets when not in use.
n) Do not remove any equipment or chemicals from the laboratory.
o) Coats, bags, and other personal items must be stored in designated areas, not on the bench tops or in the aisle ways.
p) Notify your teacher of any sensitivity that you may have to particular chemicals if known.
q) Keep the floor clear of all objects (e.g. small objects, and spilled liquids).

Housekeeping

a) Keep work area neat and free of any unnecessary objects.
b) Thoroughly clean your laboratory work space at the end of the laboratory session.
c) Do not block the sink drains with debris.
d) Never block access to exits or emergency equipment.
e) Inspect all equipment for damage (cracks, defects, etc.) prior to use; do not use damaged equipment.
f) Never pour chemical waste into the sink drains or wastebaskets.
g) Place chemical waste in appropriately labelled waste containers.
h) Properly dispose of broken glassware and other sharp objects (e.g., syringe needles) immediately in designated containers.
i) Properly dispose of weigh boats, gloves, filter paper, and paper towels in the laboratory.

Apparel in the Laboratory

a) Always wear appropriate eye protection (i.e. chemical splash goggles) in the laboratory.
b) Wear disposable gloves, as provided in the laboratory, when handling hazardous materials. Remove the gloves before exiting the laboratory.
c) Wear a full-length, long-sleeved laboratory coat or chemical-resistant apron.

d) Wear shoes that adequately cover the whole foot; low-heeled shoes with non-slip soles are preferable. Do not wear sandals, open-toed shoes, open-backed shoes, or high-heeled shoes in the laboratory.
e) Avoid wearing shirts exposing the torso, shorts, or short skirts; long pants that completely cover the legs are preferable.
f) Secure long hair and loose clothing (especially loose long sleeves, neck ties, or scarves).
g) Remove jewellery (especially dangling jewellery).
h) Synthetic finger nails are not recommended in the laboratory; they are made of extremely flammable polymers which can burn to completion and are not easily extinguished.

Hygiene Practices

a) Keep your hands away from your face, eyes, mouth, and body while using chemicals.
b) Food and drink, open or closed, should never be brought into the laboratory or chemical storage area.
c) Never use laboratory glassware for eating or drinking purposes.
d) Do not apply cosmetics while in the laboratory or storage area.
e) Wash hands after removing gloves, and before leaving the laboratory.
f) Remove any protective equipment (i.e. gloves, lab coat or apron, goggles) before leaving the laboratory.

Emergency Procedure

a) Know the location of all the exits in the laboratory and building.
b) Know the location of the emergency phone.
c) Know the location of and know how to operate the following:
   − Fire extinguishers
   − Alarm systems with pull stations
   − Fire blankets
   − Eye washes

− First-aid kits

− Deluge safety showers

d) In case of an emergency or accident, follow the established emergency plan as explained by the teacher and evacuate the building via the nearest exit.

Chemical Handling

a) Check the label to verify it is the correct substance before using it.
b) Wear appropriate chemical resistant gloves before handling chemicals.
c) Label chemical containers as to the contents, concentration, hazard, date and initial if transfer chemicals from their original containers.
d) Always use a spatula or scapula to remove a solid reagent from a container.
e) Do not directly touch any chemical with your hands.
f) Never use a metal spatula when working with peroxides. Metals will decompose explosively with peroxides.
g) Hold containers away from the body when transferring a chemical or solution from one container to another.
h) Use a hot water bath to heat flammable liquids. Never heat directly with a flame.
i) Add concentrated acid to water slowly. Never add water to a concentrated acid.
j) Weigh out or remove only the amount of chemical you will need. Do not return the excess to its original container, but properly dispose of it in the appropriate waste container.
k) Never touch, taste, or smell any reagents.
l) Never place the container directly under your nose and inhale the vapours.
m) Never mix or use chemicals not called for in the laboratory exercise.
n) Use the laboratory chemical hood, if available, when there is a possibility of release of toxic chemical vapours, dust, or gases. When using a hood, the sash opening should be kept at a minimum to protect the user and to ensure efficient operation of the hood. Keep head and body outside of the hood face. Chemicals and equipment should be placed at least six inches within the hood to ensure proper air flow.

o) Clean up all spills properly and promptly as instructed by the teacher.

p) Dispose of chemicals as instructed by the teacher.

q) When transporting chemicals (especially 250 mL or more), place the immediate container in a secondary container or bucket (rubber, metal or plastic) designed to be carried and large enough to hold the entire contents of the chemical.

r) Never handle bottles that are wet or too heavy for you.

s) Use equipment (glassware, Bunsen burner, etc.) in the correct way, as indicated by the teacher.

# APPENDIX B

## LABORATORY SAFETY RULES AND REGULATIONS IN THE CHEMICAL ENGINEERING LABORATORY, UNIVERSITI TEKNOLOGI PETRONAS.

Chemical Engineering Laboratory is a serious place of work. Most of the chemical have toxic effects and are hazardous for human health. Therefore, the chemical and reagent must be handled carefully.

Lab demonstrator is required to read and elaborate lab safety regulations to the students in the lab. The student should be watched very carefully to ensure that they strictly follow the safety regulations.

The students are required to have a business-like attitude while in the lab. Students are advised to read, understand and strictly follow the instructions given below.

Student's Attire

1. All students must wear proper attire. Wear a fully covered low heels shoes. Sandals or slippers are not allowed.
2. Wear a lab coat while working in the lab. Buttoned-up the lab coat.
3. Students with long hair must ensure their hair is neatly tied up. Students wear headscarves must ensure that their headscarves are neatly tuck into their lab coat.
4. Always wear safety glasses in the lab.

Student's Manner

1. The student is expected to behave in a proper and safe manner in the lab.
2. The student should be aware and know the positions and the use of safety

equipment and the fire extinguishers, safety eye wash, eye protector, safety shower and first aid box.

3. The student should be aware of the building's exit locations.
4. Avoid crowding while using apparatus or conducting experiments.
5. Horseplay, smoking, eating and drinking in the lab are strictly prohibited.
6. Keep a note pad to record experiment readings. Do not memorize the readings.
7. Ask the demonstrator for help when student do not understand things.

Handling Chemical

1. Always wear safety gloves when handling chemical.
2. Read the label of chemical container carefully before using it.
3. Be cautious of unlabelled containers. Do not use chemical from unlabelled containers.
4. Be careful to label all test tubes and bottles when in use.
5. Do not touch any chemical with bare hands.
6. Do not taste any chemical in the lab.
7. All chemical especially organic substances are flammable, toxic or both. Avoid holding, tasting, touching, sniffing or inhaling the vapour directly.
8. Concentrated acids and alkalis should be handled very carefully.
9. Do not use carcinogenic (cancer causing) compound such as benzene, toluene, etc. without seeking permission of demonstrators.
10. Return all the chemical bottles and containers to their original places after use.
11. When using a pipette, the student should use a pipette filler or rubber bulb. Do not suck liquid into the pipette using mouth.
12. Do not spill chemical on a working table.
13. Put the chemical waste into the labelled bottle or labelled containers as instructed.
14. Do not dispose any chemical in the sink or down the drain. Disposed chemical will pollute the water and damage public health. Consult the demonstrators or laboratory technicians on duty for proper disposal guidelines.

Conducting Experiment

1. Read the experiment carefully and prepare a flow sheet before you start doing the experiment.
2. Check the glassware apparatus for any defect or crack and have it replaced. Do not use broken or cracked glassware. Do not try to use it, as it may be dangerous.
3. Use the fume hood cupboard as the demonstrators instruct.
4. While heating, do not direct the test tube's mouth or any apparatus used towards other students.

Housekeeping

1. The student is advised to practise good housekeeping to ensure a dry, tidy and clutter-free work area.
2. Working table must be clean and dry; free from books, paper, any chemical spills, and anything that is not being used.
3. Any chemical spill must immediately be wiped clean.
4. Do not throw solid waste into the sink or on the floor. Use the waste-box provided by demonstrators or lab technicians.
5. Never throw a burning matchstick into the waste box. Hold the matchstick under water tap before disposing it.
6. Collect all the waste organic substances in the waste bottle for proper disposal.
7. Ask demonstrators for guidelines to dispose inorganic waste chemicals.
8. Be sure to clean and dry all apparatus after each laboratory session.
9. All apparatus must be returned to their original locations after use.
10. Turn off electric switches, gas valves and water taps when not in use.

Hygiene Practice

1. Wash hands with soap before leaving the lab.

Emergency

1. If any accident occurs, no matter how small it is, immediately notify the demonstrators and lab technicians.

2. If chemical splash enters the eye, quickly wash it with lots of water using eyewash.
3. If chemical spills on any part of the body, wash with lots of water or use safety shower provided.
4. If any student's clothes catch on fire, quickly roll the student over the floor and cover him/her with a safety blanket.
5. In the event of a fire in the lab, immediately inform the demonstrators and lab technicians on duty. Use the fire extinguisher if possible to avoid it from spreading. If the condition gets worse, evacuate the lab quickly and safely.

APPENDIX C

SURVEY TO PRIORITIZE AT-RISK BEHAVIOURS

To lecturers, lab demonstrators, and lab technicians, please answer survey questions as below. The survey is to identify types of lab safety rules and regulations that students frequently violated while they are working in the labs. Please tick (/) in 'Yes' or 'No' box. If necessary, please include your comment or suggestion.

Name: ____________________________________________

Position: __________________________________________

Laboratory Block: ___________________________________

| **NO.** | **STUDENTS' BEHAVIOUR OBSERVED BY LAB DEMONSTRATORS & LAB TECHNICIAN ON DUTY** | **YES** | **NO** |
|---|---|---|---|
| 1 | Did you see a student untying her/his long hair? | | |
| 2 | Did you see a student not tucking headscarf into the lab coat? | | |
| 3 | Did you see a student wearing non full-covered flat shoes? | | |
| 4 | Did you see a student not cleaning the working area? | | |
| 5 | Did you see a student not wearing a lab coat? | | |
| 6 | Did you see a student not buttoning a lab coat? | | |
| 7 | Did you see a student leaving a lit burner unattended? | | |
| 8 | Did you see a student pointing the open end of the test tube to other student while heating chemical substances? | | |
| 9 | Did you see a student not wearing safety glasses in the lab? | | |
| 10 | Did you see a student disposing chemical into the sink? | | |

| NO. | STUDENTS' BEHAVIOUR OBSERVED BY LAB DEMONSTRATORS & LAB TECHNICIAN ON DUTY | YES | NO |
|---|---|---|---|
| 11 | Did you see a student not wearing safety gloves when handling chemicals? | | |
| 12 | Did you see a student smoking in the lab? | | |
| 13 | Did you see a student drinking in the lab? | | |
| 14 | Did you see a student eating in the lab? | | |
| 15 | Did you see a student not returning chair to original location before leaving the lab? | | |
| 16 | Did you see students doing horseplay in the lab? | | |
| 17 | Did you see a student using handphone in the lab? | | |
| 18 | Did you see students crowding a working area while conducting experiments? | | |
| 19 | Did you see a student throwing solid waste into the sink? | | |
| 20 | Did you see a student spilling chemical on a working table? | | |
| 21 | Did you see a student filling a pipette using mouth suction? | | |
| 22 | Did you see a student running in the lab? | | |
| 23 | Did you see a student not using fume hood cupboard as instructed? | | |

There are comments received from lab demonstrators and lab technicians. Those comments are as follows:

1. All of the students know safety rules in the lab, but some students take it easy and do not follow that rules.

2. Safety awareness among the students is considerable low.

3. Need to improve students' safe behaviours in the lab.

APPENDIX D

FORM FOR SURVEY BEFORE Lab-ARBAIS

Please answer the following questions. Tick (/) in ‘Yes’ or ‘No’ box.

Date: ________________________________

Student ID: ___________________________

| NO. | QUESTIONS | YES | NO |
|---|---|---|---|
| 1 | Did you read laboratory safety rules & regulations and experiment procedures before starting the experiment? | | |
| 2 | Did you attend safety briefing conducted by lab demonstrators? | | |
| 3 | Do you feel worried to be injured while conducting the experiment? | | |
| 4 | Will you allow someone observes your safety practices in the lab? | | |
| 5 | Did someone tell you that you have broken lab safety rules while working in the lab? | | |
| 6 | Did you notice your friends violate lab safety rules in the lab? | | |
| 7 | Have you advised your friends, who broke lab safety rules, to not violate the rules again? | | |
| 8 | Are you willing to report lab safety rules violation done by your friends to the lab demonstrator/coordinator? | | |
| 9 | Do you think safety practices can be improved by reporting safety rules violation? | | |
| 10 | Do you agree if lab management provides a safety program to reduce lab safety rules violation in the lab? | | |

APPENDIX E

FORM FOR SURVEY AFTER Lab-ARBAIS

Please answer the following questions. Tick (/) in ‘Yes’ or ‘No’ box.

Date: ________________________________

Student ID: ___________________________

| NO. | QUESTIONS | YES | NO |
|---|---|---|---|
| 1 | Do you agree your safety awareness and practices have improved after participated in the Lab-ARBAIS? | | |
| 2 | Do you dare to violate lab safety rules although someone observes your behaviours? | | |
| 3 | Are you aware of the results of observation responses posted in the e-Learning portal? | | |
| 4 | Do you agree statistics of observation responses reveal critical and frequent violated lab safety rules? | | |
| 5 | Did you notice your friend's safety practices have improved after participated in the Lab-ARBAIS? | | |
| 6 | Do you think the Lab-ARBAIS program should be continued in order to improve you and your friends’ safety practices? | | |
| 7 | If the Lab-ARBAIS is in an online format (website), will you access the Lab-ARBAIS to give your observation response? | | |
| 8 | Should university management (LFSU/HSE) provide a reward for informing lab safety rules violation in the lab? | | |

APPENDIX F

SURVEY FORM FOR PREFERENCE(S) OF ACTION

For Unsafe Mode Group

Student ID: ___________________ Group: ________________________

Which method(s) do you prefer in order to reduce lab safety rules violation?

Please tick (/) in 'Yes' or 'No' box.

| NO. | ACTION TYPE | YES | NO |
|---|---|---|---|
| 1 | Those students violate lab safety rules are disallowed to enter the lab and do the experiment. | | |
| 2 | To have safety observers in the lab to watch students' behaviours and safety practices. | | |
| 3 | To lose lab report marks for violating lab safety rules and for not following lab demonstrators' safety instructions. | | |
| 4 | OTHER(S): | | |

For Safe Mode Group

Student ID: ___________________ Group: _______________________

Which method(s) do you prefer to improve you and your friends' safe behaviour practices in the lab?

Please tick (/) in 'Yes' or 'No' box.

| **NO.** | **ACTION TYPE** | **YES** | **NO** |
|---|---|---|---|
| 1 | Lecturers/lab demo compliment students on their safe behaviours practised in the lab. | | |
| 2 | To have safety observers in the lab to watch students' behaviours and safety practices. | | |
| 3 | To lose lab report marks for violating lab safety rules and for not following lab demonstrators' safety instructions. | | |
| 4 | OTHER(S): | | |

# APPENDIX G

## EXAMPLE OF DATA SAVED IN 'HISTORY' WORKSHEET

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Action Number** | **Date** | **Time** | **Who** | **Change** | **Sheet** | **Range** | **New Value** | **Old Value** | **Action Type** | **Losing Action** |
| 2 | 18 | 1/29/2009 | 9:10 AM | user | Cell Change | Input | B6 | 1 | 0 | | |
| 3 | 19 | 1/29/2009 | 9:39 AM | user | Cell Change | Input | B6 | 0 | 1 | | |
| 4 | 20 | 1/29/2009 | 10:07 AM | user | Cell Change | Input | B6 | 9720 | 0 | | |
| 5 | 21 | 1/29/2009 | 10:07 AM | user | Cell Change | Input | B11 | 1 | 0 | | |
| 6 | 22 | 1/29/2009 | 10:07 AM | user | Cell Change | Input | B12 | 1 | 0 | | |
| 7 | 23 | 1/29/2009 | 10:07 AM | user | Cell Change | Input | B14 | 1 | 0 | | |
| 8 | 24 | 1/29/2009 | 10:07 AM | user | Cell Change | Input | B17 | 1 | 0 | | |
| 9 | 25 | 1/29/2009 | 10:07 AM | user | Cell Change | Input | B20 | 1 | 0 | | |
| 10 | 26 | 1/29/2009 | 10:08 AM | user | Cell Change | Input | B6 | 9705 | 9720 | | |
| 11 | 27 | 1/29/2009 | 10:09 AM | user | Cell Change | Input | B6 | 9707 | 9705 | | |
| 12 | 28 | 1/29/2009 | 10:09 AM | user | Cell Change | Input | B17 | 0 | 1 | | |
| 13 | 29 | 1/29/2009 | 10:11 AM | user | Cell Change | Input | B6 | 9713 | 9707 | | |
| 14 | 30 | 1/29/2009 | 10:11 AM | user | Cell Change | Input | B18 | 1 | 0 | | |
| 15 | 31 | 1/29/2009 | 10:12 AM | user | Cell Change | Input | B6 | 9735 | 9713 | | |
| 16 | 32 | 1/29/2009 | 10:19 AM | user | Cell Change | Input | B6 | 9284 | 9735 | | |
| 17 | 33 | 1/29/2009 | 10:19 AM | user | Cell Change | Input | B15 | 1 | 0 | | |
| 18 | 34 | 1/29/2009 | 10:19 AM | user | Cell Change | Input | B17 | 1 | 0 | | |
| 19 | 35 | 1/29/2009 | 10:20 AM | user | Cell Change | Input | B6 | 9603 | 9284 | | |
| 20 | 36 | 1/29/2009 | 10:20 AM | user | Cell Change | Input | B6 | 9621 | 9603 | | |
| 21 | 37 | 1/29/2009 | 10:35 AM | user | Cell Change | Input | B15 | 0 | 1 | | |
| 22 | 38 | 1/29/2009 | 10:35 AM | user | Cell Change | Input | B17 | 0 | 1 | | |
| 23 | 39 | 1/29/2009 | 10:35 AM | user | Cell Change | Input | B20 | 0 | 1 | | |

Input | Qs | original data | data | 1 (Grp A) FFS 290109

# APPENDIX H

## EXAMPLE OF CALCULATION

For Safe Mode Group

Question 1

Have you seen your friend wearing full-covered flat shoes?

Total participation of students in safe mode group

= observer 1 + observer 2 + observer 3 + … + observer n

= 30

Total answers of 'yes' given by observers

= Response from observer 1 + Response from observer 2 + Response from observer 3 + … + Response from observer n

= 27

Safe Behaviour Percentage

$$= \frac{\text{Total safe behaviour observed}}{\text{Total participation of students}} \times 100\%$$

$$= \frac{27}{30} \times 100\ \%$$

= **90 %**

For Unsafe Mode Group

Question 1

Have you seen your friend wearing NON full-covered flat shoes?

Total participation of students in unsafe mode group

= observer 1 + observer 2 + observer 3 + … + observer n

= 28

Total answers of ‘yes’ given by observers

= Response from observer 1 + Response from observer 2 + Response from observer 3 + … + Response from observer n

= 7

At-Risk Behaviour Percentage

$$= \frac{\text{Total at-risk behaviour observed}}{\text{Total participation of students}} \times 100\%$$

$$= \frac{7}{28} \times 100\ \%$$

= **25 %**