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Developing Puzzles Laboratory Safety Symbols for Laboratory Introduction

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Abstract. *Zamhari M, Setiawati E M. 2017. Developing Puzzles Laboratory Safety Symbols for Laboratory Introduction. Proc Internat Conf Sci Engin 1: 219-223.* This work describes a study of puzzles development of laboratory safety symbols for laboratory introduction. The puzzles were purposed as a learning media for students prior to work in chemistry and science laboratory. The puzzles consisted of two different standard systems, Material Safety Data Sheet (MSDS) and National Fire Protection Association (NFPA) 704. For instructional development, the media was developed using four-D model (Define, Design, Develop, and Disseminate). This work was in develop stage and the media was qualitatively tested in State Islamic University Sunan Kalijaga, Yogyakarta, Indonesia and non-university student visited to laboratory in Faculty of Science, Prince of Songkla University, Thailand by quiz-team method.

Keywords: Four-D model, Material Safety Data Sheet, National Fire Protection Association 704, Puzzle

INTRODUCTION

Taking laboratory session as science class is an inevitable part in the formal education to help student examine their theory understanding. Not only theoretical aspect, the practical aspect in the laboratory could improve their interest in science learning (Adane and Abeje, 2012). Laboratory activity, nowadays, has been considered as an important aspect of science curriculum. Chemistry is one of subjects which often used laboratory (Walters et al., 2017). This subject is not only found in chemistry department. It is also a compulsory course in other departments.

However, The laboratory environment is a hazardous place to work and the workers can be exposed to numerous potential hazard including chemical, biological, physical and radioactive hazard (OSHA, 2011). Accident during laboratory work raised the question whether the people working in laboratory had adequate understanding to hazardous of chemical (Schröder et al., 2016). Laboratory accident could happen because of lack understanding of student with the hazardous of chemicals. It also could happen because of the chemicals misplacing by laboratory technician. Even, it could happen because of unpredictable condition. There are a number of factor affects to the accident of laboratory (Adane and Abeje, 2012; Eguna et.al., 2011; Walters et.al., 2017). The damage of lab, actually, could not be removed totally. However, it could be reduced by the hazardous understanding. An early detection of the hazard materials is an important strategy to prevent these exposures into human body and environment. Introducing student to chemicals of differing types and properties and how to use it is an important aspect to control potential risk, prevent the damage and help students safe during their work (Karapantsios et al., 2008).

In Faculty of Science and Technology, State Islamic University Sunan Kalijaga Yogyakarta, there is a number of laboratory works done by student as their science class part, especially class related with chemistry. However, not all the student came with adequate understanding with chemicals hazard. Alongside chemistry or chemistry education, the student came from biology, biology education, and physics. They rarely did chemistry lab work and even had less class of chemistry. Less hazards understanding could be found to student with fewer laboratories working experience (Schröder et al., 2016). Chemicals hazard understanding had been tried to improve by lecturer and technician to ensure the student understanding. They should list the chemical that would be used and detailed the material safety data sheets (MSDS) prior to laboratory session. However, it did not help their understanding of chemicals lab proven by pretest activity.

Introducing of chemicals' hazard to students could be done with interesting media. It could improve their understanding and easily remember after their lab working. Interactive media was proven to help student retain their memory (Arsyad, 2002). Puzzle is an alternative media to overcome this problem. It can be found easily in our daily life and it is related with children life and happiness. This media is related with visual and psychomotor aspect which could help and improve student understanding and resist the memory (Arsyad, 2002). Therefore, it could be employed as the media to improve the student knowledge to chemicals hazard.

The purpose of this work was to develop puzzle as media of safety laboratory for laboratory introduction. To the best of our knowledge, puzzle development for this purpose was not investigated before. The use of puzzle would enhance student understanding to hazard properties of chemical and it helped them to identify and control potential risk from the chemicals. The applicable and interesting puzzle would also be possible to be introduced and applied to non-university student as chemistry learning media.

MATERIALS AND METHODS

To obtain puzzle of laboratory safety symbol for laboratory introduction, this research adapted four-D model (Thiagarajan et al., 1974) for instructional development method. The method consists of four stages, i.e., define, design, develop, and disseminate. However, this research was limited to developmental stage. The method was detailed below.

1. Define

The aim of this stage was to establish instructional requirement. Analysis was the main of the define stage. It helped determine the instructional material. The step was described below.

a. Curriculum analysis of the department of Faculty of Science and Technology, State Islamic University Sunan Kalijaga which used the chemistry laboratory. It was done to know the media which relevant to the curriculum and helps the student to do the laboratory work
b. Material safety data sheet (MSDS) and national fire protection association (NFPA) 704 were selected as the contents to be used. Then, material which related to MSDS and NFPA 704 were accumulated.

2. Design

The purpose of this step was to design prototype instructional material. Puzzle was selected as an appropriate media for the presentation of the instructional content. After MSDS and NFPA 704 were selected, the puzzle design which applicable and relevant to introduce chemistry laboratory was executed. Not only design, the method to use them was also planned.

3. Develop

The purpose of this stage is to modify the prototype instructional material. In this stage, feedback is received through formative evaluation and the materials are suitably revised. In this research, this stage was done only up to expert appraisal and developmental testing. Expert appraisal was followed to obtain suggestion for the improvement of the material. Then, developmental testing qualitatively was executed to try out the media with student to locate section for revision. On the basis of response, reactions, and comment, the material would be modified.

RESULTS AND DISCUSSION

This research successfully developed puzzle as the media of laboratory safety symbols for laboratory introduction and qualitatively tested in State Islamic University Sunan Kalijaga, Yogyakarta, Indonesia and elementary school student visited to open-lab in Faculty of Science, Prince of Songkla University, Thailand by quiz-team method. The media consisted of two types of puzzles, material safety data sheet (MSDS) and national fire protection association (NFPA) 704.

To obtain the puzzles, this research adapted four-D model (Thiagarajan et al., 1974) for instructional development method. It was detailed below.

1. Define

The step of define stage was explained below.

a. Curriculum analysis was done to know how important the media will be. It was also help to select appropriate media. There were 31 classes from 5 departments in faculty of science and technology, UIN Sunan Kalijaga which used chemistry laboratory (Table 1). They did not only from chemistry and chemistry education departments that more understood in chemistry lab work and chemical, but also from biology, biology education, and physics departments. Less of laboratory experience was also identified to some classes which was taken by new students. To minimize and prevent laboratory accident, development media for understanding hazardous of chemical was needed.
b. MSDS and NFPA 704 were used as the contents of the media because they are commonly used in chemicals and internationally understood. To accumulate these materials, literature of MSDS was obtained from European Chemicals Agency (ECHA, 2017) and literature of NFPA 704 was obtained from Standard system for the identification of the hazards material for emergency response, National Fire Protection Association (NFPA, 2007).

Table 1. Class with laboratory work in chemistry laboratory.

Numb	Class	Department	Semester
1	Fundamental of chemical reaction	Chemistry	2
2	Chemical thermodynamics	Chemistry	3
3	Analytical chemistry	Chemistry	3
4	Fundamental of organic chemistry	Chemistry	3
5	Inorganic chemistry	Chemistry	3
6	Atomic theory and structure	Chemistry	4
7	Mechanism of organic reaction	Chemistry	4
8	Chemical coordination	Chemistry	4
9	Chemical kinetics	Chemistry	4
10	Instrumentation for chemical analysis	Chemistry	5
11	Biochemistry	Chemistry	5
12	Material chemistry	Chemistry	6
13	Fundamental of chemistry	Chemistry Education	2
14	Chemical thermodynamics	Chemistry Education	3
15	Chemical kinetics	Chemistry Education	3
16	Analytical chemistry	Chemistry Education	3
17	Inorganic chemistry	Chemistry Education	3
18	Chemical elements	Chemistry Education	4
19	Organic chemistry	Chemistry Education	4
20	Instrumentation for chemical analysis	Chemistry Education	5
21	Chemistry for school II	Chemistry Education	5
22	Organic compound synthesis	Chemistry Education	5
23	Biochemistry	Chemistry Education	6
24	Research based learning	Chemistry Education	alternative course
25	Chemical workshop	Chemistry Education	alternative course
26	Fundamental of chemistry	Biology	2
27	Biochemistry A	Biology	3
28	Biochemistry B	Biology	3
29	Fundamental of chemistry	Biology Education	2
30	Biochemistry	Biology Education	3
31	Material physics	Physics	6

2. Design

Media with visual and psychomotor aspect to enhance student understanding to chemical hazard was needed. Alongside fulfill visual and psychomotor media requirement, puzzle was selected as the media for laboratory introduction because it was a cheap media, easy to use, and can be duplicated easily with low price. The prototype of the puzzle was designed. Two types of media for MSDS and NFPA 704 included the manuals to use them were developed. They were explained below.

a. MSDS puzzle

Ten symbols of MSDS were designed for this media. Figure 1(A) shows the shape of like a book MSDS puzzle. There were 5 symbols in each part. The design enabled student to use it as quiz team competition. The team that could arrange the puzzle correctly, they would get appropriate picture behind. If there was wrong position, the pictures were not arranged properly and produced a picture. It helped the student to improve and assess their understanding in MSDS independently. The media utilized reused material. Therefore, it could help student aware with environment and it became green learning media.

b. NFPA 704 puzzle

It was difficult to adjust the type of NFPA 704 puzzle like MSDS puzzle. It was because NFPA 704 was not as simple as MSDS model and it had many rules. Therefore, different type of puzzle was developed (Figure 1 (B)). This puzzle had some pieces of puzzle with different color and number or symbol which represented each part of NFPA 704. They were red, blue, yellow, and white that represented flammability, health hazard, reactivity, and special hazard, respectively. For degree of hazard, the puzzle of flammability, health hazard, and reactivity had 5 number (0, 1, 2, 3, and 4) and special hazard had oxidizer, radioactive, water react, acid, alkali, corrosive and no special hazard symbol. The student would get some card described each number of NFPA 704 randomly. Then, the student should arrange the number and the color which represent the description. There were two puzzle kits for each two team to make it possible for quiz team competition.

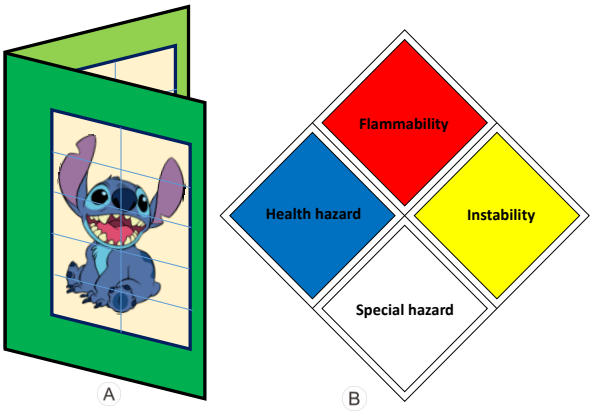

Figure 1. The shape of (A) a book like of material safety data sheets (MSDS) and (B) national fire protection association (NFPA) 704 puzzles.

3. Develop

Development stage was done to modify the prototype instructional material. It was detailed below.

a. MSDS puzzle

Feedback of the media was directly received from chemistry education students, class of 2007 during prototype development of the puzzle. The media was better to utilize reused material to improve student awareness to environment. It was also decorated with sand and covered with leaves to improve environmental aspects. It was qualitatively tested Faculty of Science and Technology, State Islamic University of Sunan Kalijaga Yogyakarta, Indonesia (Figure 2 (A–B)). It was qualitatively assessed by lecturer of chemistry education and chemistry and science teacher, as chemistry media experts. They confirmed the good quality of the product and could be used as learning media for laboratory introduction.

This media was also tested in Prince of Songkla University, Thailand. Some modification, especially language translation was done to make the media could be understood. It was qualitatively tested to non-university student visited to open-lab by quiz-team method (Figure 2 (D–B)). Prior to do this game, the student were allowed to see the list of MSDS for five minutes. It was done because they never obtained this knowledge. This media successfully applied to the student. It was proven by their ability to put in the right position.

b. NFPA 704 puzzle

This media was only tested in State Islamic University Sunan Kalijaga (Figure 2(E–F)). Ph.D students in biophysics lab, Faculty of Science, Prince of Songkla University suggested if it was difficult for non-university student. It was because more complicated than MSDS puzzle. Even though this puzzle could be applied to student, NFPA 704 puzzle obtained less attention than MSDS puzzle. It might because it less interactive and student could not assess their understanding by this media independently. They need a guidance to check their answer.

CONCLUSIONS

In conclusion, the puzzle of MSDS and NFPA 704 for laboratory introduction were successfully developed using four-D model as instructional development. The puzzles were qualitatively assessed by media expert, teacher, and students. However, more development process and feedback was needed to improve the puzzle quality. Then, disseminate stage was needed to do to know the applicability and the effect of the puzzle for student understanding of lab safety.

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Figure 2. Qualitative development test of (A–B) MSDS puzzle and (E–F) NFPA 704 puzzle to university student in Faculty of Science and Technology Sunan Kalijaga, Yogyakarta, Indonesia and test of (C–D) MSDS puzzle to non-university student who visited to open-lab in Faculty of Science, Prince of Songkla University, Thailand by quiz-team method.

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