The Development of Science Laboratory Safety Educational Comic for Secondary School Students in Malaysia

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Abstract

The traditional method of teaching science laboratory safety often involves lengthy, complex manuals that are difficult for students to understand. Despite the existence of the School Science Laboratory Management and Safety (SLMS) guidebook, students' knowledge and awareness of lab safety remain low. Research shows that comics can enhance students' interest and understanding of safety protocols. This study aimed to develop a science laboratory safety educational comic for secondary school students to raise awareness about lab safety. The educational comic was developed following the analysis, design, development, implement, and evaluate (ADDIE) model, with this study focusing on the first three stages. A needs analysis involved questionnaires given to 131 students in Kuala Lumpur and Kedah, revealing a moderate awareness of lab regulations (average score: 3.53) and strong support for developing a safety educational comic (average score: 3.90). The educational comic, designed by six experts from university academic and science teachers, and illustrated by a professional illustrator, covers topics such as laboratory preparation, waste disposal, laboratory accidents, and fire extinguishers. Validation was performed by experts in materials aspect (2 education academic experts), learning aspect (2 science teachers), and media design aspect (2 art and design academic expert), with scores of 4.80, 4.85, and 4.65, respectively, indicating high qualifications. In conclusion, the science laboratory safety educational comic was found to be valid and highly effective in meeting educational standards for lab safety.

Keywords: Development, Educational Comic, Laboratory Safety, Science, Secondary School

INTRODUCTION

In Malaysia, students typically engage in practical work, experiments, and laboratory activities in student-oriented laboratories as a crucial part of science education. This emphasis on practical work aims to foster scientific inquiry and the acquisition of knowledge with scientific skills. By employing an inquiry-discovery approach, both teachers and students in science laboratories can explore scientific concepts through hands-on activities. Adane and Abeje (2012) recognize that the use of science laboratories to test theories and nurture scientific ability is universally acknowledged, while Hofstein and Rachel (2007) state that science laboratories help students build experience through interactions with various materials and equipment (Adane & Abeje, 2012; Nee & Yunus, 2020).

However, it is important to recognize the risks involved in practical work, as the materials and equipment used in science laboratories can be dangerous if not handled correctly. Therefore, it is crucial to prioritize safety in science laboratories and for all parties involved, including students and teachers, to understand the safety aspects of science laboratory work (Hill Jr & Finster, 2013; Joy & Thomas, 2023). Ritch and Rank (2001) emphasize the importance of science laboratory safety at all levels, from primary to tertiary education, and the need for awareness on the importance of prioritizing safety in science laboratories due to the frequent occurrence of accidents in such environments around the world (Ansah et al., 2024; Ritch & Rank, 2001).

Malaysia Ministry of Education (MOE) has published the School Science Laboratory Management and Safety (SLMS) guidebook. This guidebook, first published in 1987 and revised in 1999 and 2010, aims to improve the quality of school science laboratories and equip school administrators and teachers to handle issues related to their management (Malaysia, 2010). The SLMS guidebook covers two main management fields, including the management of science laboratories and laboratory safety. Moreover, the national science curriculum emphasizes the need for increased laboratory safety, with improved textbooks and science-based practical workbooks that include icons such as warning signs and precautionary measures for every experiment. These efforts highlight the MOE's commitment to science education and demonstrate that school science laboratory safety is taken seriously. The traditional instructional method of science laboratory safety was implemented via verbal explanation from educators using laboratory manuals with 5 to 10 pages which are too complex to

comprehend without additional summarised information (Doran, 2002; Lunetta et al., 2013). Consequently, the level of knowledge and exposure to workplace safety in science laboratories among secondary school students is still low, despite the availability of the SLMS guidebook (Kamarudin et al., 2009).

A comic is a form of cartoon that portrays characters and unfolds a story in a sequence of images, designed to entertain readers (Humphrey, 2020; Tilley & Weiner, 2016). It is created with a coherent and structured storyline, making it easier to remember and more engaging for students. Comics can serve as independent learning tools for students or as an alternative resource for teachers to support classroom instruction (Akcanca, 2020; Toh et al., 2017). Research has shown that comic media is effective for learning, particularly in storytelling, and has been proven to improve learning outcomes (Bintoro et al., 2022).

Comics have been proven to increase students' interest and awareness of safety in chemistry laboratories (Di Raddo, 2006; Kumasaki et al., 2018). Comics have been widely utilized for educational purposes, as they make the teaching-learning process more engaging and entertaining (Hosler, 2011; Moreno, 2021). Researchers have also investigated whether comics have direct benefits in the instructional process, leading to the identification of three main uses of comics and caricatures: as a warm-up activity, as an instructional tool, and as an assessment tool (Montaña Rincón, 2021). Comics are a suitable learning tool for economically and educationally disadvantaged children (Trent & Kinlaw, 1979; Wyk, 2011). Moreover, Beard and Rhodes (2002) highlighted the advantages of comics in effectively communicating information, simplifying instructions, promoting discussions, and enhancing cognitive retention as a mnemonic tool (Kaufman, 2016; Özdemir, 2010; Bañez, 2024). Therefore, this study aims to develop science laboratory safety educational comic for secondary school students whose validity has been tested. This research is expected to attract and enhance the awareness towards science laboratory safety among secondary school students.

METHOD

Research Design

This research was designed based on developement research using the ADDIE model (see Figure 1), which includes five phases: analysis, design, development, implementation, and evaluation (Dousay & Logan, 2011; Li & Abidin, 2024). However, in this study, the procedure involved only two stages: the design phase focused on creating a product design that met those needs, and the development phase included the production and testing of the product.

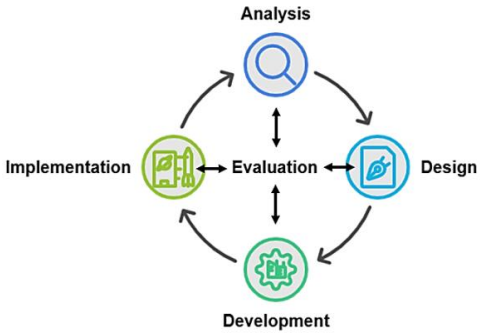

Figure 1. ADDIE Model

Population and Sampling

The sample chosen for the implementation of this study consists of secondary school students across Malaysia. The study sample was selected using simple random sampling. In this sampling method, the sample is selected randomly and by chance, ensuring that the quality of the sample is not compromised because each member of the population has an equal chance of being selected as a sample (Shaafi et al., 2023). Only 131 secondary school students voluntarily participated in this study by completing a questionnaire in the form of a Google Form. This google form was shared within the respective student whatsapp group. Students filled in the questionnaire using their mobile devices, and the statistics were monitored within the Google Form application. The effectiveness of conducting this online study will be supported by Van Selm et al. (2006), who state that "when most of a society has internet access and savvy, the basic drawback for the use of online survey research the lack of representativeness will disappear" (Van Selm & Jankowski, 2006). The internet was an even more valued tool to obtain information from respondents living in different parts of a country or around the world, simply and at a low cost (James, 2005; West, 2015).

Instrument

The research instrument takes the form of a questionnaire adapted from the literature studies (Danielsen et al., 2015; Man et al., 2023)(see Table 1). This questionnaire consists of two parts: Part A, Part B, and Part C. Part A outlines the demographics of the respondents, such as gender, grade level, type of school, and laboratory accident experience. Part B, on the other hand, focuses on addressing the two research objectives, where items one through five list questions regarding the need for development of science laboratory educational comic on improving science laboratory safety awareness among secondary school students, while items six through nine are used to assess students' awareness and knowledge towards science laboratory safety. Meanwhile, Part C focuses on items in developing the science laboratory educational comic on improving science laboratory safety awareness among secondary school student.

Table 1. Details of the Research Instrument

Part	Component
Part A	Demography of respondents
Part B	Item 1 to item 5 – students' awareness towards science laboratory safety
Part C	Item 1 to item 21 – needs analysis to develop the science laboratory safety educational comic

Section B and C consist of three types of items, namely dichotomous items, Likert scale items, and open-ended question items. The Likert scale used is a five-point Likert scale as shown in Table 2. The use of this type of Likert scale is more suitable for testing the content validity of the instrument (Nee & Yunus, 2020; (Tojib & Sugianto, 2006).

Table 2. Five-point Likert scale

Level	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Validity and Reliability

After the instrument was developed, two experts in the field were appointed to conduct validation on the questionnaire (Elangovan & Sundaravel, 2021; Nunnally, 1978). The validation experts comprised of a science educational module expert, namely an education lecturer, and an outstanding science teacher. The instrument subsequently underwent analysis and refinement according to the comments and suggestion from the experts as shown in Table 3.

Table 3. Comments and Suggestions from the Experts

Expert	Comments and suggestions
Expert 1	Overall, it is good and appropriate. However, there is repeated item (refer to the instrument): directly focus on the topic (item no. 7)
Expert 2	The research instrument produced is excellent. The presented ideas are original, have high validity, the language used is appropriate for the students' level, and it is systematically organized. This module is highly suitable for future use.

Furthermore, to determine the agreement value of face validity and content validity among experts, the content validity index (CVI) was utilized. For new instruments, the CVI value to be achieved is ≥ 0.8 (Davis, 1992). In this study, CVI was analyzed according to the following formula and CVI values were recorded in Table 4.

Table 4. Mean Score Values and Levels Based on (Landell, 1997)

Mean value	Level
1.00 – 2.33	Low
2.34 – 3.67	Moderate
3.68 – 5.00	High

The average I-CVI score for face validity is recorded as 0.92, while the average I-CVI score for content validity is recorded as 0.875. This indicates that the CVI values for each construct meet the accepted CVI criteria (Davis, 1992), which is a CVI value ≥ 0.8. After ensuring that the questionnaire is suitable for use, the instrument was distributed to the respondents via WhatsApp and email.

Reliability, which pertains to the consistency of measurements, ensures that the outcomes from participants using an instrument designed to gauge depression, for instance, remain relatively consistent each time the test is administered in the future. The Kuder-Richardson Formula 20 (KR-20) is employed to assess reliability for test instruments involving binary variables (0 and 1), where responses are either true or false, right or wrong, and yes or no (Balasubramanian et al., 2023; Uyanah & Nsikhe, 2023). In this study, the reliability value is determined to be .88 (refer to Table 5). McGrath et. al (2005) suggests that low test reliability is anticipated in concept inventories when the content proves excessively challenging or straightforward for respondents to comprehend (McGrath, 2005). This proves that the questions asked in the survey forms in this study were clear and easy to comprehend.

Data Collection Procedure

Data collection is the process of gathering relevant information to address the research questions of this study (Olsen, 2011; Willson & Miller, 2014). To collect data, a questionnaire for needs analysis was distributed to 131 secondary school students in the science-streamed classes across Malaysia. The questionnaire was distributed to each respondent using google forms, allowing them sufficient time to complete it based on their awareness and knowledge towards science laboratory safety, and developing the science laboratory educational comic. The questionnaire solely focuses on questions relevant to the research, ensuring the study's main purpose is maintained. The responses were analyzed, with each item scrutinized, and the total marks tallied across respondents. The findings from this analysis will address the research questions, leading to conclusions and recommendations discussed towards the end of the study.

Several activities were carried out during the design stage, including creating a dialogue script, developing a storyline, and applying color. At the development

stage, activities focused on the creation of a science laboratory safety educational comic based on the school science laboratory management and safety (SLMS) guidebook. After the educational comic was developed, further trials were conducted. Six experts, comprising two material experts (academic lecturers), two learning experts (science teachers), and two media experts (art and design professionals), reviewed the educational comic. After the initial evaluation, the experts provided feedback, which was analyzed, and revisions were made to the educational comic.

Data Analysis

Data analysis was conducted descriptively, using frequencies and percentages. The collected data were analyzed using statistical package for social science (SPSS) version 23.0 software. The Likert scale used was assigned scores to facilitate calculation. The scale of strongly disagree was assigned a value of one, while the scale of strongly agree was assigned a value of five. For the analysis of items using a five-point Likert scale, mean score values for the items were calculated based on Landell's mean score value and levels as stated in Table 4. All received responses were analyzed to derive conclusive findings.

The data in this study consisted of both qualitative and quantitative data. A questionnaire was used to collect the data, with the instrument being a rating scale. The data collected were numerical and then interpreted descriptively. The rating scale used in this study ranged from 5 to 1. The instrument's validity was ensured through several steps, including drafting the instrument grid, consulting with the supervisor, arranging the instruments, and obtaining assessments from expert judges. The instrument validity sheet for the science laboratory safety educational comic included six aspects: visual elements, typography, characterization, material, language, and integration, which were detailed in Table 1, Table 2, and Table 3.

The validation grid for the science laboratory safety educational comic was reviewed by the supervisor. After this consultation, the instruments were finalized, and expert evaluations were conducted. The expert assessments were analyzed using Gregory's formula to determine the content validity coefficient. The content validity of the educational comic learning media on the SLMS topic was 1.00, with all instrument items deemed relevant, falling within the range of 0.80 to 1.00, indicating very high content validity.

RESULTS AND DISCUSSION

The findings for item 1 indicate that a minimum score of 3.62 was obtained in Table 5. This suggests a

moderate level of awareness of laboratory safety regulations, with only 70 (53%) out of 131 respondents aware of the existence of safety regulations in the laboratory. A total of 67 (51%) respondents with a mean score of 3.54 expressed difficulty in understanding all safety regulations easily, while 71 (54%) respondents stated that they adhere to all established laboratory safety regulations. These findings also show that 76 (58%) and 63 (48%) respondents are aware that they need to comply with safety instructions given and understand that failure to adhere to established safety regulations could result in accidents for themselves and their peers. Overall, the awareness level of safety in the laboratory is moderate with an average mean score of 3.53. The analysis of mean value for the level of awareness towards the science laboratory safety was interpreted as moderate with the value of 2.34 – 3.67 (Landell, 1997; Mustaffa et al., 2023). These findings clearly indicate that, on average, respondents are still not fully aware of the importance and compliance with laboratory safety. The findings are likely driven by factors such as a lack of clear understanding of existing regulations and an attitude that does not take laboratory safety seriously (Ali et al., 2018). Although these figures do not represent all students at secondary schools across Malaysia, the findings clearly indicate that the level of awareness of regulations in the laboratory among average students is still low and needs to be improved (Olajumoke & Benjamin, 2017; Wu et al., 2023). Additionally, based on an average mean score of 3.53, it was found that this awareness level is not influenced by age and level of form factors (Luketic & Dolan, 2013; Walters, Lawrence, & Jalsa, 2017).

Table 5. Findings for Level of Awareness Towards the Science Laboratory Safety

No.	Items	Mean	Level
1	I know that there are safety rules in the laboratory.	3.62	Moderate
2	I easily understand all the safety rules in the laboratory.	3.54	Moderate
3	I follow all the established laboratory safety rules.	3.51	Moderate
4	I know I need to follow the safety instructions given while in the laboratory.	3.65	Moderate
5	I understand that failing to comply with the established safety rules can lead to accidents for me and my colleagues.	3.31	Moderate
	Average mean score	**3.53**	**Moderate**

There are 12 items adapted and adopted from Sulistyarini (2022) and Syafilta (2023) to assess the needs in developing an educational comic on science laboratory safety. These items consist of students' perceptions of the requirements for the development of educational comics (see Table 6), and appropriate methodological approaches are incorporated in the development of educational comics on science laboratory safety to meet the preferences of high

school students (see Table 7). In examining students' perceptions of the needs for developing educational comics on science laboratory safety, the analysis of item 1 showed a mean score of 3.38, indicating a moderate level that respondents read comics. Meanwhile, the item 2 showed a higher level of mean score which is 3.68, indicating the respondents prefer to read the educational comics. Apart from that, high level of mean scores with the range value of 3.68 to 4.23, indicating that the respondents agreed that the educational comics could offer various significant benefits i.e., reduce stress, enjoyable, stimulate thinking skills, convey good moral values and religious understanding, assist to memorize facts and complex technical concepts (Brown, 2023; Mallia, 2008). In facts, the educational comics were highly agreed to be used as science learning materials, and reference materials for science laboratory safety with the mean scores of 3.95 and 4.10 respectively. Therefore, from the analysis, it can be concluded that most respondents, with a mean score of 3.90 (indicating a high level of mean score), provided positive responses towards the development of an educational comic for science laboratory safety.

Table 6. Aspects of Needs to Develop the Educational Comic for Science Laboratory Safety

No.	Items	Mean	Level
1	I read comics.	3.38	Moderate
2	I read educational comics.	3.68	High
3	Reading comics helps reduce stress in my daily routine.	3.82	High
4	Reading comics is enjoyable.	4.14	High
5	The nature of comics, with less text and messages easily conveyed through sequential picture frames, makes me prefer reading comics over novels, general books, and others.	3.77	High
6	The messages conveyed in the comics I read can stimulate my mind and thinking skills.	3.88	High
7	Educational comics produced can be a scholarly reference for readers.	4.23	High
8	Educational comics can teach good moral values and religious understanding.	4.10	High
9	Educational comics help me remember and memorize facts more effectively.	3.93	High
10	Educational comics assist me in understanding complex technical concepts.	3.84	High
11	Educational comics are suitable to be used as science learning materials.	3.95	High
12	Educational comics are suitable to be used as learning/reference materials for science laboratory safety.	4.10	High
	Average mean score	**3.90**	**High**

Furthermore, to develop an educational comic on science laboratory safety that aligns with students' needs, items in Table 7 were developed and responded to by the respondents. These items encompass learning approaches in educational comics on science laboratory safety that are suitable for inclusion in the intended educational comic. Based on Table 7, an approach with more than 5 pages received a high mean score of 3.72, as chosen by the respondents. They tend to prefer educational comics that can improve understanding and memory in learning, with a notably high mean score value of 4.27. Most respondents agree that they prefer science learning materials in the form of comics (with a high mean score of 3.82) because educational comics supported by images and photos provide a better understanding of science concepts, as indicated by a high mean score value of 4.28. The analysis of mean value for the level of awareness towards the science laboratory safety was interpreted as moderate with the value of 3.68 – 5.00 (Landell, 1997; Mustaffa et al., 2023). Additionally, respondents concur that content selection should include more detailed academic facts, depict Malaysian culture, and maintain a balance between academic facts and storytelling, reflected in mean score values of 3.79, 4.05, and 3.82, respectively. From the analysis of Table 7, it is evident that most respondents agree that emphasis should be placed on content and technical approaches in educational comics to develop a science laboratory safety educational comic that suits the needs of students, with a high average mean score of 3.73.

Table 7. Aspects of Criteria to Develop the Educational Comic

No.	Items	Mean	Level
13	I prefer reading educational comics with short and less dense pages (1-2 pages only).	2.73	Moderate
14	I prefer reading educational comics with moderate and moderately dense pages (3-4 pages only).	3.08	Moderate
15	I prefer reading educational comics with long and denser pages (more than 5 pages).	3.72	High
16	I am interested in reading educational comics that can help me improve understanding and memory in learning.	4.27	High
17	I choose Science learning materials in comic form.	3.82	High
18	I find it easier to understand Science with the help of pictures/photos.	4.28	High
19	Educational comics produced detail academic facts.	3.79	High
20	Comics produced must have the identity and image of Malaysia.	4.05	High
21	The content of educational comics produced must be balanced in terms of academic facts and storytelling.	3.82	High
	Average mean score	**3.73**	**High**

At the design stage, the activities carried out involved designing the science laboratory safety comic based on the content of the SLMS guidelines. The design included creating learning content, comic characters, conversation scripts, and designing storylines. The science laboratory safety comic developed was 21 x 29.7 cm in size with 15 pages. The storyline design is shown in Figure 2. Once the design was approved, it proceeded to the development stage. In the development stage, the science laboratory safety comic was created according to the design and input from six experts, including university academics and science teachers, and illustrated by a professional illustrator. The comic was divided into four parts: Part 1: Laboratory Preparation, Part 2: Waste Disposal, Part 3: Laboratory Accidents, and Part 4: Fire Extinguisher.

Part 1 (Laboratory Preparation) includes laboratory rules and personal protective equipment (see Figure 3). Part 2 (Waste Disposal) covers procedures for waste disposal in sinks and standard operating procedures (SOP) for the disposal of biological waste (see Figure 4). Part 3 (Laboratory Accidents) discusses types of accidents in the lab, factors leading to accidents, and actions to take in case of mercury spills (see Figure 5). Part 4 (Fire Extinguishers) covers the types and parts of fire extinguishers, fire types, and the proper use of extinguishers (see Figure 6). The final section of the comic includes a space for self-reflection and notes for students to use (see Figure 7).

Figure 3: Laboratory Preparation

Figure 5: Laboratory Accidents

Figure 4: Waste Disposal

Figure 6: Fire Extinguishers

Figure 7: Self-reflection

Since the science laboratory safety comic has completed the development process, the next step is to test its validity with experts. The validity test for the science laboratory safety comic is conducted both online and offline by providing validity test sheets to experts in materials (2 education academic experts)(Razi, 2024), teaching (2 science teachers), and media design
(2 art and design academic experts) (Mayasari et al., 2022).

For the materials aspect, the science laboratory safety comic content received a mean score of 4.80, indicating very high qualifications based on a five-point scale. Therefore, the comic developed in this study is suitable for use from a learning materials perspective. In the learning aspect, the comic received an average score of 4.85, also with very good qualifications, indicating its suitability for learning applications. Regarding media design, the comic earned an average score of 4.65, with very good qualifications, confirming its appropriateness for illustration and comic character design. Based on the validity test results, each item received a mean validity score, with very good qualifications when falling within the range of $3.75 < X \leq 5$ (Lockhart, 2014; Van der Elst et al., 2014). During the validity test, expert reviews were gathered from two academic experts in the materials aspect, two science teachers for the learning aspect, and two art and design academic experts for the media design aspect. The results confirmed that the science laboratory safety comic developed in this study is valid and suitable for use.

CONCLUSION

In conclusion, the findings of this study underscore the significance of conducting a thorough needs analysis in the design and development of educational materials, particularly in the context of science laboratory safety awareness among secondary school students. The quantitative survey, involving 131 secondary school students across Malaysia, revealed a consensus among respondents regarding the suitability of the proposed science laboratory educational comic in addressing their needs. However, the moderate average mean score of 3.53 highlights a concerning low level of awareness regarding laboratory regulations among the surveyed students, emphasizing the urgency for improvement. Encouragingly, the high average mean score of 3.90 indicates strong agreement among respondents about the necessity of developing a science laboratory safety educational comic to enhance awareness. The study also emphasizes the importance of

focusing on content and technical approaches, with a high average mean score of 3.73, signaling a consensus on the key aspects that should be prioritized in crafting an effective educational comic. The design and development of science laboratory safety comic in this study were developed through validation and revision with very high qualifications of mean score for the materials (4.80), learning (4.85), and media design (4.65) aspects. Therefore, the science laboratory safety comic in this study was confirmed to be valid and suitable for use. Overall, these results emphasize the imperative for targeted educational initiative to enhance science laboratory safety awareness among secondary school students. Thus, it is suggested that future researchers for further investigation to determine the effectiveness of science laboratory safety comic in the field.

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