Evaluation of Embedding Learning Tool of Active and Passive Fire Safety System for Undergraduate Studies Via Experts

Khairilmizal Samsudin*, Nur Ezzate Mohamad Hatta, Zakaria Kassim, Md Khairul Azuan Che Azid, Mohd Aminorddin Darus Mohamed Noor, Mohamad Fahmi Bin Hussin, Ainul Husna Kamarudin and Mohd Haikal Kasri

Abstract—**Challenges are faced by students during the learning process of the fire safety subject. Different learning styles possessed by the students require diverse teaching approaches to facilitate their understanding of active and passive fire safety system interconnection. With the pandemic COVID-19 outbreak both educator and learners now faced difficulties in the teaching and learning process of fire safety courses which need to be delivered virtually. This study aimed to develop a feasible learning tools for the active and passive fire safety systems and to validate the developed model of Fire Safety Interconnection multimedia in using it as an educational tool for fire safety subjects. The methodology were based on documentation review methods and the content is validated through concrete reference. Face validity methods were utilized to further validate the developed materials by using a survey questionnaire which functioned as a tool for the SMEs to validate the developed learning tools. With the developed learning tools developed, the results indicate that all SMEs are satisfied with the developed learning tools and it is suitable to be used as an educational instrument in fire safety subjects.**

Index Terms— **firefighting, fire safety, learning styles, teaching multimedia, tertiary education.**

I. Introduction

FIRE is a chemical reaction known as combustion which can spread in minutes and kill in seconds [1]. Fire does not only pose a significant threat to human life but also to the structure of a building, property, and environment [2]–[4]. Therefore, the provision of necessary fire safety in buildings is crucial to mitigate the adverse effects of fire hazards [5]. According to (Kodur, Kumar & Rafi, 2019), fire safety is defined as "the set of practices to prevent or avert the occurrence of fire and manage growth and effects of accidental or intentional fires while keeping resulting losses to an acceptable level." The authors also stated that fire safety provisions in buildings that consist of active and passive fire protection systems are usually recommended by building codes of practice. Uniform Building By-laws (UBBL) 1984 and Fire Services Act 1988 are regulated as norms in Malaysia to protect life, including firefighters, as well as buildings and their contents [1]. Besides Malaysian fire safety regulations, international fire safety guidelines and standards such as Fire Safety Engineering Approach, Performance Based Criteria, and National Fire Protection Association (NFPA) standards are also adopted when the professionals have to venture beyond the perimeter of UBBL 1984 [1], [6].

Fire safety in tertiary education involves fundamental concepts where basics of fire safety are introduced to them, such as the science of fire, fire safety legislation, and fire protection systems. The undergraduate fire safety educational process can be challenging as the students may respond differently to various teaching styles [7], [8]. Those challenges include less commitment to the subject, low motivation during the lecture, and poor engagement with the subject content [9]. Undergraduate students in the USM Environmental and Occupational Health Programme (EOH) are introduced to fire safety subjects, which is a core subject for Second Year EOH students with three credit units. The subject is delivered through lectures and tutorials

Challenges faced during the fire safety subject teaching and learning process for undergraduate students include less commitment to the subject, low motivation, and poor engagement with the subject content [9]. In addition, different students have their preferred modes of gaining new information, such as auditory, tactile, or visual learning styles, which require a variety of teaching approaches to help them become more effective learners [8]. Different learning modalities among the students, namely auditory, tactile or visual learning styles, require a variety of teaching approaches to help them become more effective learners [8]. Auditory

This manuscript is submitted on 18 May 2022 and accepted on 14 December 2022.

Khairilmizal Samsudin is with School of Health Science, USM, 15200, Kota Bharu, Kelantan, Malaysia (e-mail: khairilmizal@usm.my)
Nur Ezzate Mohamad Hatta is with School of Health Science, USM, 15200, Kota Bharu, Kelantan, Malaysia (e-mail: nurezzate@student.usm.my)
Zakaria Kassim is with School of Health Science, USM, 15200, Kota Bharu, Kelantan, Malaysia (e-mail: zakaria@usm.my)
Md Khairul Azuan Che Azid is with School of Health Science, USM, 15200, Kota Bharu, Kelantan, Malaysia (e-mail: azuan@usm.my)
Mohd Aminorddin Darus Mohamed Noor is with School of Health Science, USM, 15200, Kota Bharu, Kelantan, Malaysia (e-mail: aminorddin@usm.my)
Mohamad Fahmi Bin Hussin @ Mohamad is with School of Electrical Engineering, UiTM, 40450 Selangor (e-mail: fahmi478@uitm.edu.my)
Ainul Husna Kamarudin is with UniKL, MESTECH, 43000 Kajang, Selangor, Malaysia (e-mail: ainulhusna@unikl.edu.my)
Mohd Haikal Kasri is with Fire and Rescue Department Malaysia, 62250, Putrajaya, Malaysia (e-mail: Haikalkasripgb@gmail.com).

*Corresponding author
Email address: khairilmizal@usm.my

learners grasp better when listening to the information, while visual learners are captivated by pictures, images, and graphs while absorbing new information. In contrast, tactile learners are more inclined towards active participation experiences [8]. Hence, by developing learning tools for active and passive fire safety systems, the educational process in fire safety subjects will be more efficient as sustainable retention of knowledge and application of fire safety for undergraduate students with different learning styles can be achieved. Delivering a face-to-face course virtually has been a challenge, especially in fire safety. Adding up, changes are frequent in safety education and specifically fire-safety education as there are always benefits and challenges in delivering fire safety courses virtually [10]. Throughout the years, virtual learning is becoming more crucial, especially in supporting Longlife learning [11], [12]. However, several studies have also indicated the usability of digitalization in delivering fire safety topics, this includes a blended learning approach in supporting this paper [7], [13].

Moreover, the high cost of installing and maintaining fire protection systems is also a big concern for universities with limited monetary resources [5]. For example, the price rate for the main fire alarm panel for conventional automatic fire detection and alarm system that comes with only a mimic diagram, relays, wiring and indications is estimated at around RM 4,500 [14]. Therefore, by developing a lower-cost learning tool for undergraduate students, the universities can allocate their resources for more critical uses while enhancing the educational process in a fire safety subject. Interconnection and coordination of active and passive fire safety systems also need to be well-comprehend for successful fire suppression [15]. Thus, validation of the learning tool by subject matter experts (SMEs) is necessary to ensure its accuracy with a real fire safety system.

Significant to this study, the outbreak of the COVID-19 epidemic has also affected the teaching and learning process in universities [11], [16]. Courses which usually delivered face-to-face were forced to be delivered virtually due to the declared pandemic which started in early 2020 by the World Health Organization [17]. It creates new challenges in delivering effective teaching and learning process in universities [11], [16]. Hence, improvising the university teaching and learning process to fully online via an online platform can ensure desirable learning outcomes are accomplished. This includes having digitalized learning tools to support the teaching and learning of fire safety courses. Having these tools also support the lifelong learning initiatives for the future of education [12].

Consequently, this study aimed to design and develop a cost-effective Model of Fire Safety Interconnection and fire development process learning tool for active and passive fire safety systems for undergraduate students in the School of Health Sciences, Universiti Sains Malaysia (USM). Auditory, tactile, and visual learning styles were introduced in the learning tool to cater to different learning styles among undergraduate students. Validation by SMEs will be an added value for the learning tool to be utilized in tertiary education on fire safety.

II. METHODOLOGY

Both quantitative and qualitative research design was used in this study to validate the active and passive fire safety system learning tool through SME evaluation. Development of the Model of Fire Safety Interconnection and fire development process learning tool concentrated on the firefighting equipment contributed by Steel Recon Industries (SRI) Sdn Bhd. The study was conducted in two phases namely learning tool development and SME validation.

During the first phase, the document analysis method was used to systematically review and evaluate both printed and electronic materials related to building fire safety, learning styles, and educational processes at the tertiary level [18], [19]. Documents include legislation, standards books, and article in regard to Malaysia's fire safety requirements and systems [7], [20]–[25]. This create knowledge base for the model to be developed. Eventually, other relevant journal articles were referred to in the process of developing the learning tool including references given by the company. Using the same method, different teaching approaches were also incorporated into the learning tool through graphic posters and narrated animation videos.

High-quality images were recorded based on the contributed fire fighting equipment. Using the structured knowledge-based earlier, the images were arranged to visualise the interconnection of all equipment available. Special attention was given to ensuring no stacked images and interconnection lines to prevent confusion and misunderstanding of the interconnection models. As depicted in Figure 1, different colours were used to indicate different interconnection purposes, hence ensuring a clear understanding of the flows from each piece of equipment. The Fire Safety Interconnection model was designed using normal graphical editing and productivity software readily available in the market.

The finalized designed of the Fire Safety Interconnection model was later used to build the meta frame display unit (Figure 2) of all the pieces of equipment available and used. Due to the weight of several pieces of equipment, the structure used a metal frame and boards. All pieces of equipment are arranged based on the model and the structure itself which can be disassembled into sections in ensuring the portability and movability of the meta frame display unit. The poster (Figure 3) which was also designed from the knowledge-based process was displayed at the meta frame display unit to provide theoretical information on fire development process.

High-resolution animated videos were later developed based on the developed Fire Safety Interconnection model and poster. This ensures clear explanations of each piece of equipment and how it interacted with other pieces of equipment, fires and building tenants. The explanations in the video are also based on knowledge-based development earlier.

In ensuring the quality, appropriateness and usefulness of the developed tools, it is crucial to be validated by subject matter experts (SME) principally before opening to end-user. This process was supported by several latest publications in different fields including knowledge management, language learning and information technology [26]–[30]. Hence, The second phase of this study involved the validation of the Model of Fire Safety Interconnection and fire development process learning tool by the subject matter expert (SME). The SME validation process combines the Fire Safety Interconnection model (Figure 1) and Fire development process poster (Figure 3) together as it is interrelated as both presented in the developed video. Face validity, which has been widely used in education, was implemented in this phase [16], [29], [31]. A validated survey questionnaire was adapted and modified according to this study during the document analysis, in which the references had been validated with content validity to examine and interpret the data [16], [29], [32]. The questionnaire was constructed in Google Form and divided into four sections: Quality, Usefulness, Usage Characteristics, and Overall Satisfaction. Likert scale ranging from 1- Strongly Disagree; 2- Disagree; 3- Neutral; 4- Agree; and 5- Strongly Agree was used as response format in the questionnaire.

Purposive sampling was implemented for this study in which the participants were deliberately chosen based on the qualities of the participants as SMEs. Therefore, a set number of participants was not required [33]. 10 personnel from Fire and Rescue Department Malaysia (FRDM) and industrial experts were selected as respondents due to their vital roles in fire safety [29], [34]. The selected participants are academically qualified personnel, with backgrounds and experiences exceeding 10 years, as well as acknowledged in the field [29], [33], [35]. Approval from The Human Research Ethics Committee of USM (JEPeM) was obtained before data collection from the selected participants (USM/JEPeM/21010097). Confidentiality agreements were presented at the beginning of the data collection process to acquire informed consent from the participants. Narrated animation video and the questionnaire were distributed online to all SMEs. The narrated animation video was presented to each SME before the questionnaire was administered for the SME to validate the learning tool. Online questionnaire administration using Google Form is more cost-effective than other survey methods as data collection could also be simplified and feedback from the SMEs was automatically recorded, allowing for simpler statistical analysis [29], [36].

The data were analyzed descriptively, in which the mean score in each section of the questionnaire was calculated to determine the usefulness of the Model of Fire Safety Interconnection and fire development process learning tool. Every section in the questionnaire was analyzed separately to interpret the participants' views on the learning tool. The mean score of overall respondents which was below 3.5 would indicate that improvement should be made to the learning tool, and revalidation should be conducted. Otherwise, the mean score of overall respondents that is above 3.5 would signify that the learning tool was ready to be utilized as a tool in the undergraduate educational process. Nonetheless, minor improvements would still be made accordingly based on the participants' recommendations.

III. Result and Discussion

The SRI firefighting equipment was arranged and images were taken and edited to develop the Model of Fire Safety Interconnection and fire development process learning tool. Absent components (e.g. building layout plan, water tanks pumps, and gas cylinders) were substituted with printed graphics to complement the interconnection of the firefighting system. The interconnection was established to be as real as possible to aid students with tactile learning styles.

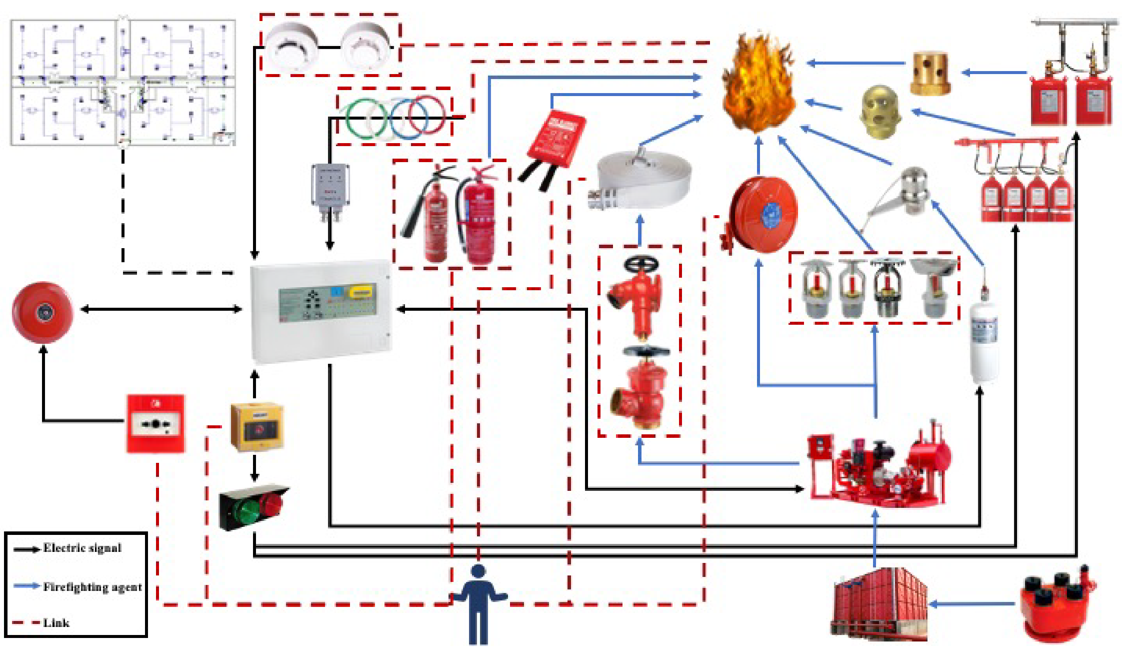

Fig.1. Model of Fire Safety Interconnection as a learning tool

A. Model of Fire Safety Interconnection and Fire Development Process Poster as a learning tool

Active and passive fire safety system learning tool was developed using the firefighting equipment contributed by SRI. The function and mechanism of each firefighting equipment were understood first by referring to documents, journal articles, local legislations, and website pages which related to fire safety [7], [20]–[23], [37]. Subsequently, the interconnection between the equipment could be linked appropriately as shown in Figure 1.

The different types and colours of lines demonstrate the interconnection and interaction of the firefighting systems. Black arrows represent an electrical signal to and from the fire alarm control panel, as well as between other equipment for the actuation of the firefighting systems during fire emergencies. In contrast, blue arrows show the direction of firefighting agents, such as water and inert gases, from one firefighting system component to another. On the other hand, the red dashes portray the fire detection by the firefighting equipment, namely smoke, and heat detectors, sprinkler heads as well as linear heat detectors, which then trigger the fire alarm control panel. The requirement for human intervention in operating the firefighting equipment like portable fire extinguishers, fire blankets, manual call points, and hose reels is also illustrated by the red dashes.

The structurised Fire Safety Interconnection (Figure 2) were based on the developed model. It was manually assembled on a metal frame with consideration for mobility and portability during demonstartions. Steel frame was used in order to ensure stability and strength to carry load of the equipment displayed. LED was installed with circuits to indicate flow of the interconnections. Portable display panel with speakers was included for the multimedia explanation of the overall system. The total cost of the structurised Fire Safety Interconnection is RM1850 which is cheaper then the previously developed [14].

Fig.2. Structurised Fire Safety Interconnection Based on Developed Model

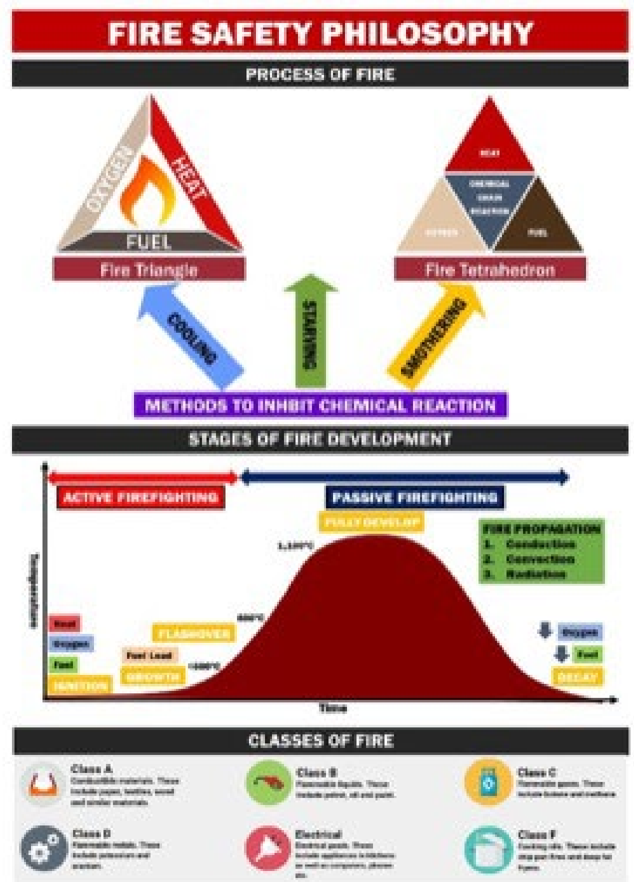

Fig.3. Fire Development process poster learning tool

The learning tool is supported by a fire safety philosophy poster as shown in Figure 3. The poster demonstrates the fire development process based on the Fire Triangle and Fire Tetrahedron concepts, fire extinguishing methods (e.g. cooling, starving, and smothering), fire development stages (e.g. ignition, growth, fully-developed, and decay), fire propagation methods (e.g. conduction, convection, and radiation) and fire classes (class A, B, C, D. E, and F) [22].

B. Learning Tool elements for Fire Safety Interconnection Model and Fire Development Process

As an approach for students with auditory and visual learning styles, an animated video was developed as part of the learning tools [7]. A transcript was prepared to elaborate on the fire safety philosophy and interconnection of the firefighting systems, based on the model of Fire Safety Interconnection. The transcript is based on the knowledge base from the initial document analysis process and later improved after validation from SME.

The first part of the learning tools discusses fire and fire hazards, this includes the concept of Fire Triangle and Fire Tetrahedron. Each triangle side represents each of the elements needed for a fire to present, given the right proportion for the combustion process to take place. These elements are the source of heat, fuel, and oxygen [21]. The explanation then goes to Fire Tetrahedron which comprises the same three elements in the Fire Triangle, however with an addition of a fourth element, namely the chemical chain reaction. The chemical reaction is continuously sustained by constantly producing more energy to form a complex chain reaction series from the fire [22], [25]. This provides learners with the understanding that removal of any of the Fire Triangle and Fire Tetrahedron elements via smothering, starving, and cooling can inhibit the chemical chain reaction of the combustion process and put the fire out [22]. The first part later discussed six classes of fire. Each of the fire classes is assigned to the fuel which causes the fire namely Class A fire for solid materials such as papers, textiles, and woods; Class B fire includes flammable liquids such as acetone, gasoline, and toluene; Class C fires involving gases, such as hydrogen, propane, and methane; Class D fires involving metals such as magnesium, sodium, and titanium and; Class E fire involves electrical equipment and; finally, Class F fire involves fats and cooking oils [21], [22]. The classes of fire provide learners with an understanding of the most suitable extinguishing reagent for effective extinguishment. The following figure is the screenshot of part 1.

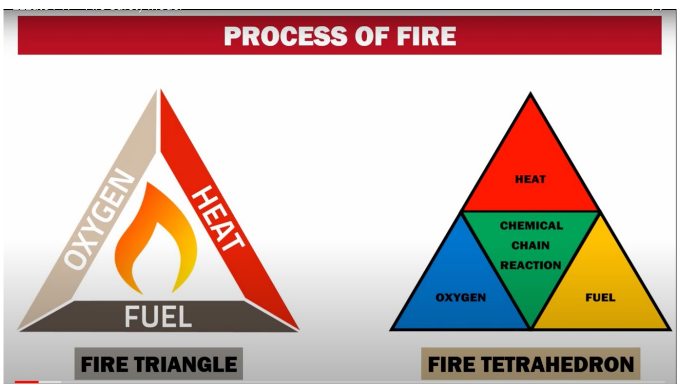

Fig. 1. Screenshot of Part 1 developed Learning Tools

The second part of the learning tools explains the development of fire through five stages, namely Ignition, Growth, Flashover, Fully Develop and Decay [22]. The explanation includes a brief explanation of the Growth stage of fire where the fire grows rapidly once burned due to the conditions created during the ignition stage. Part 2 also explained that during the growth stage, the temperatures are considered as low, which is under 600°C and in an enclosed compartment, a critical stage may be reached [22]. This provides learners with a visual understanding that the growth-critical stage is where all the combustible materials are heated to flammable concentrations of gases before fire flashes abruptly throughout the compartment [20], [21]. The second part also explained to the learners that the growth stage period will be determined by fuel load, the quantity of potentially combustible materials, and the oxygen supply available. The second part later explained flashover stages where the flammable gasses are produced and sufficiently hot to maintain combustion. The flashover stage is a quick phase that arises when the ceiling temperature reaches 600°C, and all combustible materials are ignited simultaneously in an enclosed area. The learners are then introduced to a Fully Developed stage of fire where the temperature of the fire slowly increases and can reach up to 1,100°C [24], [25]. During this process, the rapid development process is continued as the fire spreads further into other areas of the building and when there is a lack of fuel or oxygen to sustain the combustion process, the fire will enter the Decay stage and die. Toward the end of part 2, the learners are exposed to three methods of fire spreads, and the need for active and passive fire protection systems. The explanation of this process is based on normal structural fire and the following figure is the screenshot of part 2.

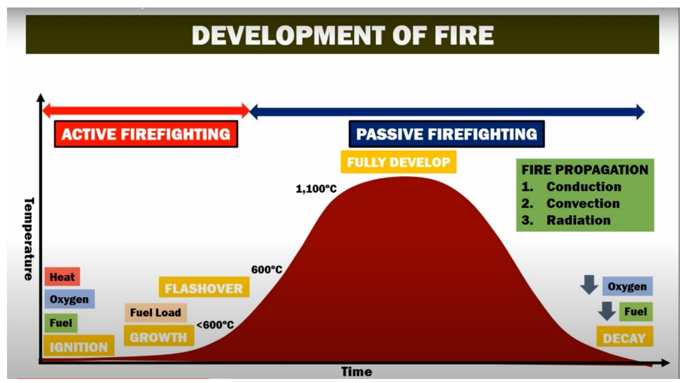

Fig. 2. Screenshot of Part 2 developed Learning Tools

Part 3 of the learning tool exposed learners to an active firefighting system, which consists of manual or automatic fire protection systems to detect, and alert the occupants of the fire and suppress and extinguish the fire accordingly [22], [24]. During the explanation which is supported by real images recorded, the explanation includes fire detection and alarm systems which are designed to pinpoint and warn the building occupants of the fire incident in the building, enabling relevant firefighting measures to be carried out before the situation worsens. The learners are also exposed to a fire alarm control panel which acts as the central hub for all the detection, warning, and extinguishing information to be processed. Different system setups for fire alarm control panels were also given explaining that depending on the requirement of the building, a generic fire detection system typically includes smoke detectors, heat detectors, and manual call points [20], [21], [25]. Part 3 of the learning tool also animates how some critical or major firefighting systems are wired to the nearest fire department for immediate response. Adding up, a conventional fire detection system contains physical cabling that connects the manual call points and fire detectors and the signals are then wired back to the fire alarm control panel to indicate the activated alarm's location. Finally, part 3 includes human intervention in an active firefighting system where human intervention in detecting fires is also available through a manual call point and tenants shall activate a manual Call Point to trigger the alarm to alert the building residents [20], [24]. The following figure is the screenshot of part 3.

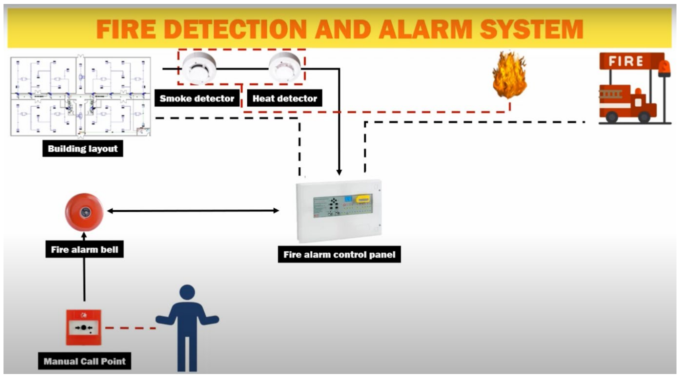

Fig. 3. Screenshot of Part 3 developed Learning Tools

The next part of the learning tools explained fire sprinklers which is an example of the detection system that comes with an extinguishment process. Part 4 explain the elements for fire sprinklers including the different type of sprinkler heads and sprinkler bulbs where the temperature setting for the sprinkler system is classified into Ordinary, Intermediate, High, Extra High, Very Extra High, and Ultra High with different colours for the glass bulbs [20], [21], [24]. The learners are exposed also to a different type of riser system including the wet riser system where the water fills the firefighting pipework and is readily available to be discharged when needed. This includes how the firewater pump is activated automatically and sends signals to the fire alarm control panel to indicate a firefighting process by a system is in place. Critical elements such as firewater tanks, series of firefighting pipework, riser pipe, hose reel and landing valves [20], [21] were also introduced in the learning tools supported with animation on how the system works and how the system is supported by the firefighters as per the figure below.

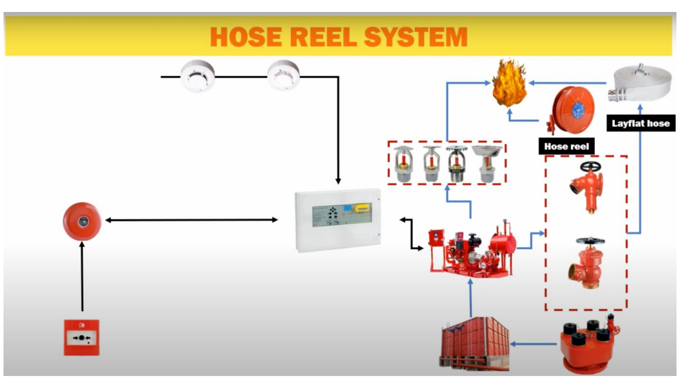

Fig. 4. Screenshot of Part 4 developed Learning Tools

Part 5 of the learning tool explains the gas suppression systems which use chemical agents or inert gases stored in tanks or cylinders to extinguish almost all classes of fire. Learners will be exposed to the advantages and limitations of the system which later lead to the operational details of the system. The animation is also covering the flow of the system and the safety precaution where abort switches momentarily interrupt the release of the extinguishing reagent when the control unit is in the alarm state in case of detection error or system malfunction.

The final part of the learning tool provides learners with human intervention equipment such as fire extinguishers and fire blankets. Learners will understand that during the early stage of fire growth, portable fire extinguishers are rudimentary equipment but highly effective in curbing the fire from fully developing and extinguishing it. On many occasions, a small fire can be restrained and extinguished successfully with the appropriate utilization of portable fire extinguishers by properly trained personnel even before the arrival of emergency responders. Based on the early presentation in part 1 learners will understand that water is only suitable for Class A fires, foam can put out fires in Class A and B, and Dry powder extinguishers are ideal for Class A, B, C, and E fires and Non-conductive extinguishing agents such as ABC powder and carbon dioxide can extinguish electrical fires without electrocuting the user [22], [25]. As a fire extinguisher may not be able to be utilized due to its pressurized contents, a fire blanket can be used as an alternative commonly used to suffocate a fire that is small in size. The following figure is the screenshot of part 6.

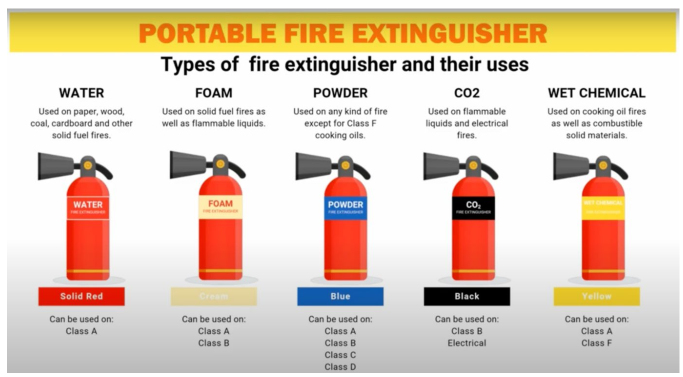

Fig.5. Screenshot of Part 6 developed Learning Tools

Through the developed learning tools which are supported by clear explanations and animations, learners will comprehend and may be able to visualize near-to real-life conditions of the fire process, fire development stages, fire propagation methods, and fire protection systems thoroughly to devise strategies for fire safety in buildings. This shall create awareness of fire safety which plays a vital role in deciding on the proper action to take during fire emergencies.

C. Learning Tool Validation

The result from the validation is recorded and presented in Table I below. The mean score indicates that the SMEs were satisfied with the learning tool quality ($\overline{X}$ = 4.3). The usefulness of the learning tool was found to satisfy the SMEs ($\overline{X}$ = 4.3). The SMEs also agreed that the learning tool is easy to use and comprehend ($\overline{X}$= 4.1) in the Usage Characteristics Section. Evidently, the SMEs were satisfied with the overall learning tool ($\bar{X}$ = 4.5). Using the mean scores obtained from each section, the overall mean score was calculated ($\bar{X}$ = 4.3) and achieved the minimum requirement to be valid as an educational tool in an undergraduate fire safety subject.

TABLE I
MEAN SCORES OF DEVELOPED TOOL VALIDATION

Questionnaire Sections	Mean Scores
Quality	4.3
Usefulness	4.3
Usage Characteristics	4.1
Overall Satisfaction	4.5

Nevertheless, the SMEs had proposed several suggestions to improve the learning tool. In Quality Section, a respondent suggested that elements in the interactive guide should be highlighted to facilitate understanding of the firefighting system. On the other hand, another respondent recommended that the details on the first part of the interactive guide should be improved in the Usefulness Section. Whereas, in the Usage Characteristics Section, one respondent proposed more animation in the learning tool

IV. CONCLUSION

Learners have different learning styles and understanding these differences gives a better and more effective teaching and learning process. In this study, it can be concluded that the learning tool of active and passive fire safety systems are developed to enhance the undergraduate educational process in a fire safety subject. In ensuring the quality of the delivery materials, the developed learning tool had gone through validation from subject matter experts (SME). The overall mean score of 4.5 proved that most of the SMEs in fire safety agreed that the learning tool is valid to be utilized in tertiary fire safety education. Nonetheless, some improvements still need to be made to the learning tool as suggested by the SMEs. To the author's discernments, the learning tool could cater for the needs of the undergraduate students with different learning styles to help them grasp better the interconnection of the firefighting system. It can be also concluded that the developed teaching model and interactive guide are valid to be used as a cost-effective teaching approach for the undergraduate teaching and learning process in the fire safety subject. The novelty of this study can be found in the interconnection model of the firefighting system presented in the developed tool.

As the developed tools were validated by subject matter experts, future studies shall include a systematic analysis of the effectiveness of these studies towards learners and educators.

V. ACKNOWLEDGEMENT

The authors would like to thank the Universiti Sains Malaysia School of Health Science and SRI Sdn Bhd for their contribution. This study is conducted with ethics committee approval (USM/JEPeM/21010097) from the Human Research Ethics Committee of USM and supported by USM grant (304/PPSK/6315498).

VI. REFERENCES

[1] A. B. Hamzah, *Guide to Fire Protection in Malaysia*, 2nd ed. Kuala Lumpur: The Institution of Fire Engineers (UK) Malaysia Branch (IEFM), 2011.

[2] D. Martin, M. Tomida, and B. Meacham, "Environmental Impact of Fire," *Fire Sci Rev*, vol. 5, no. 5, p. 21, 2016, doi: 10.1186/s40038-016-0014-1.

[3] N. Brushlinsky, M. Ahrens, S. Sokolov, and P. Wagner, "World Fire Statistics," 2017.

[4] H. Haynes, "U.S. Firefighter Injuries in 2016," *NFPA Journal*, 2017.

[5] V. Kodur, P. Kumar, and M. M. Rafi, "Fire hazard in buildings: review, assessment and strategies for improving fire safety," *PSU Research Review*, vol. 4, no. 1, pp. 1–23, Sep. 2019, doi: 10.1108/PRR-12-2018-0033.

[6] Z. Djunaidi, N. A. A. Tuah, and G. Rafifa, "Analysis of the Active and Passive Fire Protection Systems in the Government Building, Depok City, Indonesia," *KnE Life Sciences*, vol. 4, no. 5, p. 384, 2018, doi: 10.18502/kls.v4i5.2569.

[7] J. Drotárová, D. Kačíková, M. Kelemen, and M. Bodor, "THE POSSIBILITIES OF USING BLENDED LEARNING IN FIRE SAFETY EDUCATION," *CBU International Conference Proceedings*, vol. 4, 2016, doi: 10.12955/cbup.v4.769.

[8] N. Shamsuddin and J. Kaur, "Students' learning style and its effect on blended learning, does it matter?," *International Journal of Evaluation and Research in Education*, vol. 9, no. 1, 2020, doi: 10.11591/ijere.v9i1.20422.

[9] C. Mulryan-Kyne, "Teaching large classes at college and university level: Challenges and opportunities," *Teaching in Higher Education*, vol. 15, no. 2, pp. 175–185, 2010, doi: 10.1080/13562511003620001.

[10] J. Drotárová, D. Kačíková, M. Kelemen, and M. Bodor, "THE POSSIBILITIES OF USING BLENDED LEARNING IN FIRE SAFETY EDUCATION," *CBU International Conference Proceedings*, vol. 4, pp. 283–286, Sep. 2016, doi: 10.12955/cbup.v4.769.

[11] S. Dhawan, "Online Learning: A Panacea in the Time of COVID-19 Crisis," *Journal of Educational Technology Systems*, vol. 49, no. 1, pp. 5–22, Sep. 2020, doi: 10.1177/0047239520934018.

[12] D. W. L. Hung, J.-S. Huang, C. Y.-X. Tan, M.-L. How, and E. R. Koh, "Learning Initiatives for the Future of Education (LIFE)," 2021, pp. 335–351. doi: 10.1007/978-981-16-4469-6_17.

[13] J. Jiang and S. Hu, "Application of Gamification Teaching in Primary School Fire Safety Course in Smart Learning Environment," in *2021 16th International Conference on Computer Science & Education (ICCSE)*, Aug. 2021, pp. 72–75. doi: 10.1109/ICCSE51940.2021.9569628.

[14] Jabatan Kerja Raya, "Garis Panduan Anggaran Harga Sistem Mekanikal dalam Bangunan Tahun 2013." p. 71, 2013.

[15] R. F. Accosta Jr. and J. Barrot, "Designing Passive and Active Fire Protection Systems," 2017. https://www.csemag.com/articles/designing-passive-and-active-fire-protection-systems (accessed Oct. 25, 2020).

[16] K. Samsudin *et al.*, "Evaluating User Satisfaction Towards E-learning Platform During COVID-19 Crisis," *International Journal of Academic Research in Business and Social Sciences*, vol. 11, no. 12, pp. 2471–2481, 2021, doi: 10.6007/ijarbss/v11-i12/11976.

[17] WHO, "WHO Coronavirus (COVID-19) Dashboard," 2021. https://covid19.who.int/ (accessed Sep. 28, 2021).

[18] E. Pinsker, "Quantitative and qualitative content analysis methods for document review for monitoring purposes," *Eur J Public Health*, vol. 30, no. Supplement_5, 2020, doi: 10.1093/eurpub/ckaa165.1206.

[19] D. E. McNabb, "Document Analysis Methods," in *Case Research in Public Management*, 2020. doi: 10.4324/9781315705941-15.

[20] UBBL, *Uniform Building By-Laws*. Malaysia: Ministry of Housing and Local Government, 1984.

[21] A. B. Hamzah, *Guide to Fire Protection in Malaysia*, 2nd ed. Kuala Lumpur: The Institution of Fire Engineers (UK) Malaysia Branch (IFEM), 2006.

[22] M. di Prisco, P. di Milano, S.-H. Chen, and G. Solari, *Advances in Fire Safety Engineering*, vol. 1. Cham: Springer International Publishing, 2020. doi: 10.1007/978-3-030-36240-9.

[23] M. THE COMMISSIONER OF LAW REVISION, "Fire Services Act 1988," *Laws of Malaysia*, 2009.

[24] J. A. Purkiss and L. Y. Li, *Fire safety engineering design of structures, third edition*. 2013. doi: 10.1201/b16059.

[25] D. Helmerking, *Basics Fire Safety*. 2019. doi: 10.1515/9783035619362.

[26] A. CRAPO and A. MOITRA, “TOWARD A UNIFIED ENGLISH-LIKE REPRESENTATION OF SEMANTIC MODELS, DATA, AND GRAPH PATTERNS FOR SUBJECT MATTER EXPERTS,” *Int J Semant Comput*, vol. 07, no. 03, pp. 215–236, Sep. 2013, doi: 10.1142/S1793351X13500025.

[27] M. Cooper, Y. Levy, L. Wang, and L. Dringus, “Subject matter experts’ feedback on a prototype development of an audio, visual, and haptic phishing email alert system,” *Online Journal of Applied Knowledge Management*, vol. 8, no. 2, pp. 107–121, Dec. 2020, doi: 10.36965/OJAKM.2020.8(2)107-121.

[28] K. D. Kuhn, “Using structural topic modeling to identify latent topics and trends in aviation incident reports,” *Transp Res Part C Emerg Technol*, vol. 87, pp. 105–122, Feb. 2018, doi: 10.1016/j.trc.2017.12.018.

[29] K. Samsudin, M. F. Hussin, K. Ainul Husna, A. I. Mohd Yassin, K. Mohd Haikal, and A. R. Hussain, “Expert System Development Process of Integrated Disaster Management System for Lead Responding Agency in Malaysia during Response and Early Recovery Phases,” *International Journal of Electrical & Electronic Systems Research (IEESR)*, vol. 16, 2020.

[30] S. Khairilmizal *et al.*, “Design and Development of Strategic Disaster Management Database for Lead Responding Agency in Malaysia during Response and Early Recovery Phases,” *International Journal of Electrical & Electronic Systems Research (IEESR)*, vol. 10, 2017.

[31] M. F. Hussin, B. Wang, and R. Hipnie, “The reliability and validity of Basic Offshore Safety and Emergency Training knowledge test,” *Journal of King Saud University - Engineering Sciences*, vol. 24, no. 2, pp. 95–105, 2012, doi: 10.1016/j.jksues.2011.05.002.

[32] B. Armstrong, G. Fogarty, D. Dingsdag, and J. Dimbleby, “Validation of a Computer User Satisfaction Questionnaire to Measure IS Success in Small Business,” *Journal of Research and Practice in Information Technology*, vol. 37, no. 1, pp. 27–41, 2005.

[33] I. Etikan, A. M. Sulaiman, and S. A. Rukayya, “Comparison of Convenience Sampling and Purposive Sampling,” *American Journal of Theoretical and Applied Statistics*, vol. 5, no. 1, pp. 1–4, 2016, doi: 10.11648/j.ajtas.20160501.11.

[34] A. R. Nor Rasidamayat, N. Siti Safrina, and W. A. R. Shazree Idzham, “Change Communication Strategies , Model of Change Management Using in Organization , Change Management Competencies : A Study at Fire and Rescue Department of Malaysia,” *International Journal of Business and Management Invention (IJBMI*, vol. 8, no. 5, pp. 34–40, 2019.

[35] Z. Pourzolfaghar, R. Ibrahim, R. Abdullah, and N. M. Adam, “A technique to capture multi-disciplinary tacit knowledge during the conceptual design phase of a building project,” *Journal of Information and Knowledge Management*, vol. 13, no. 2, 2014, doi: 10.1142/S0219649214500130.

[36] R. N. Vasantha and N. S. Harinarayana, “Online survey tools : A case study of Google Forms Online,” *National Conference on "Scientific, Computational & Information Research Trends in Engineering, GSSS-IETW, Mysore*, no. January 2016, pp. 1–12, 2016.

[37] K. Zhang, J. Suo, J. Chen, X. Liu, and L. Gao, “Design and implementation of fire safety education system on campus based on virtual reality technology,” 2017. doi: 10.15439/2017F376.