Development of Backdraft and Flashover Simulation as Video-Based Learning Media for Fire Dynamics

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ABSTRACT

During the Covid-19 pandemic that we are currently experiencing, lectures can beheld online. The purpose of this research is to improve learning, which is video-basedsimulation on backdraft and flashover materials for the Fire Dynamics course using the ADDIE method with limitations only to the Analysis, Design, and Development stages. In theAnalysis stage, it is done by collecting literature studies also guided by the RPS for the Fire Dynamics course. The next stage is a Design based on the flowchart and scenario created.The next planning stage is Development, with reference to scenarios, material guides and studies that have been carried out previously and then the video making process is carried outusing Fire Dynamic Simulator with hardware facilities in the form of a laptop. The results of the video were then tested by material experts and media experts regarding the feasibility of learning videos. The results showed that the learning video on the flashover and backdraft material for the Fire Dynamics course had met the assessment of the material expert in the very good category and was considered feasible, while the validation results from the media expert stated that this learning video was in the good category and was considered feasible.

Key Words: Learning Media, Video, Fire Dynamics, ADDIE

INTRODUCTION

Learning materials in the form of learning media serve as intermediaries in the learning communication process because media act as tools to transmit messages from the sender to the recipient, thereby stimulating thinking, emotions, interest, and attention [1]. Well-designed learning media can enhance communication effectiveness and efficiency in the classroom, improving students' understanding and engagement with the learning material [2].

Learning media can be classified into four types: audio, visual, audiovisual, and video. However, with technological advancements, these media can now be integrated through Android-based applications [3]. During the COVID-19 pandemic, face-to-face learning, especially at Jakarta State University, became challenging because some subjects, particularly those requiring demonstrations such as Fire Dynamics, could not be effectively delivered through text alone [4]–[7].

Flashover occurs when flames spread across all surfaces of a compartment, leading to simultaneous ignition and total combustion [8]–[11]. The gases produced during combustion increase danger to firefighters and may trigger a backdraft — a phenomenon often referred to as a smoke explosion [12]. Backdraft and flashover are among the most dangerous conditions firefighters face, as both can cause severe damage and injuries [13].

Simulation videos utilizing Fire Dynamic Simulator (FDS) software can effectively model these fire phenomena [14]. Firmansyah et al. [15] used FDS to simulate fire behavior in a two-room building model, producing visual heat release and temperature graphs. Similarly, Panjaitan [16] applied FDS to simulate a fire scenario aboard the OTONG KOSASIH vessel, demonstrating the tool's capability to analyze ignition sources and fire propagation.

Virtual simulation has also been successfully implemented as a learning tool. Suhandi et al. [17] and Sinulingga et al. [18] demonstrated that simulation-based learning enhances conceptual understanding and student performance. Romadhona [19] developed an educational game–based simulation that significantly improved student achievement compared to traditional instruction.

This research adopts a case and field study approach to analyze students' learning needs in Fire Dynamics courses during the COVID-19 pandemic. The goal is to develop simulation-based media that enhance learning effectiveness for backdraft and flashover materials.

MATERIALS AND METHODS

This field research refers to the steps with the ADDIE method which are only limited to Analysis, Design, and Development. The initial stage is used to collect the data needed in the application of video-based learning media. At the Analysis stage, the researcher analyzes related data in the form of competency standards and describes information both in terms of indicators and material. This is done so that the media that is made still refers to the learning objectives. At the planning stage of media development, researchers formulate based on data obtained from the analysis stage, including:

a. Determine competency standards in the subject matter and determine the purpose of making learning media by adjusting the Semester Learning Plan (RPS) for the Fire Dynamics course.
b. Determining Course Learning Outcomes (CPMK) in the RPS subject for the FireDynamics course.

With the CPMK targets to be achieved, namely:

- Able to explain knowledge about fire and burning.
- Able to explain flames, flame height and air drag.
- Able to explain about indoor fires.
- Able to explain the relationship between temperature and time.
- Be able to explain chronologically the causes, effects, losses and wisdom ofexplosions and fires.

At the Design stage, the researcher designs a development flowchart and scenario for the storyline which will be used as a backdraft simulation and video learning media flowchart. Then at the Development stage, the researcher makes a backdraft and flowchart simulation video with reference to the scenario and also the material guide and studies that have been done previously.

RESULTS AND DISCUSSION

The target of the desired course learning achievement is that students can operate the Fire Dynamic Simulator program to determine the spread of smoke and fire from various points under several conditions. This will of course be influenced by ventilation, roomdensity, oxygen supply, the amount of smoke present and of course the material used as a burning simulation material. With FDS programming, it will provide visualization results to find out what level of risk is happening without having to simulate it manually.

Based on the results of the analysis above, it is found that the researcher has given a case based on the fact that the use of simulation using software that supports it based on its competence will increase a person's understanding of something to be tested. To develop this,of course, we need educators who master the FDS software. Because in its use FDS gives a disclaimer in the form of someone who can operate based on technical analysis, be it heat transfer, thermodynamics, and other related exact sciences.

Educators and students must also learn the science of coding properly. Different software versions will affect the operation of FDS. In addition, the emphasis given is on the backdraft and flowchart which of course will be the result in the operation of this FDS software. For this reason, the material and data provided must also be accurate and appropriate and meet the success of the "running" process in the FDS.

The result of this study is to assess the product which is intended to collect data about the quality of video-based learning media. This assessment stage is carried out before the product is used in general and this assessment is carried out by material experts and media experts.

The data needed in the research are qualitative and quantitative data. Qualitative data is the result of an assessment questionnaire in the form of a description of suggestions and input from the test subject while quantitative data is obtained from a test questionnaire in the form of category values namely 5, 4, 3, 2, and 1 then this category is changed to qualitative data as follows:

Material Expert Validation

Material expert validation carried out by competent lecturers in the Fire Dynamics Course. Material expert instruments in the form of a questionnaire are as follows:

Table 1. Material Expert Instrument Grid

No.	Aspect	Indicator
1.	Learning	Relevance of material with basic competence
		Systematics of Material Presentation
		The suitability of the material with the indicators of theclarity of the description of the material
		Adequacy of providing feedback on learning motivation
		Clarity of language use
2.	Truth of Content	Sufficient material weight for the achievement of goals
		Systematic presentation of material

	Truth of material
	The suitability of giving examples with the material
	Language is simple to understand
	The images presented support the material

These indicators are taken and used as a reference to assess the success of using backdraft simulations for learning media. This assessment instrument will then be used as evaluation material for both lecturers and students when successfully operating the FDS software. This observation is carried out in a structured manner because the 'running' process of coding made to open FDS will be open if it is made in a structured manner.

Material	Density [kg/m^3]	Conductivity [W/m/K]	Specific heat [kJ/kg/K]
Steel	7850	35	0.52
Concrete	2307	1.4	0.658

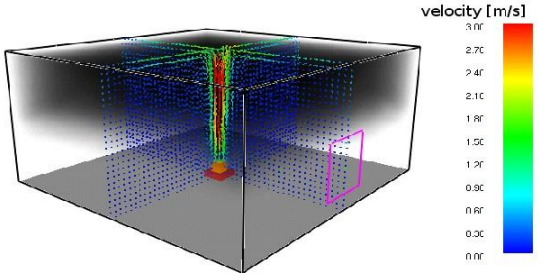

Figure 1. *CFD simulation of airflow velocity (0–3 m/s) in a steel–concrete compartment due to heat transfer.*

Increasing the density of a smoke also affects the intensity of the fire. Shown in the simulation above smoke trapped in the room. A range of velocity values is also given through the color differences in the burning room. The further away from the fire point, the smallerthe velocity and the color will turn blue.

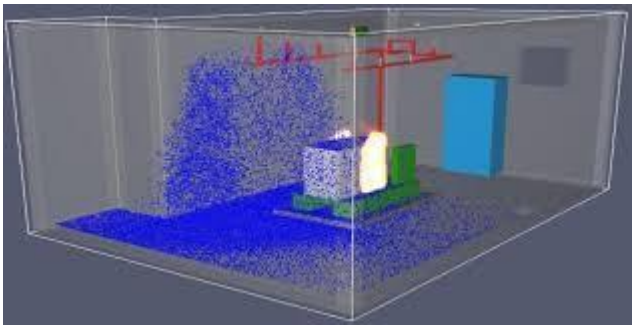

Figure 2. CFD simulation of sprinkler water spray distribution during a fire event in an enclosed room.

This Fire Dynamic Simulator program can also provide passive and active protection features, one of which is the sprinkler system. Simulation is needed to determine the effect of fire load on the structure of the passive and active building protection systems. The input of the simulation is the fire load.

Media Expert Validation

Validation of media experts is carried out by expert lecturers who are competent in learning media. The media expert instrument is in the form of a questionnaire which is described as follows:

Table 2. Media Expert Instrument Grid

No	Aspect	Indicator
1.	Appearance	Limitation of writing or text

		Accuracy of color selection and composition
		Image display quality
		Image serving
		Screen display
		Clarity of sound
		Language usage accuracy
		Background color with text
2.	Delivery	Text efficiency
		Image efficiency
		Media attraction

In the assessment using the indicators above as a complement and refinement of the backdraft simulation which will then be used as learning material, it must be made asinteresting and interactive as possible. Avoid errors and minimize failures that may occur dueto errors in operating the FDS software. In addition, always pay attention to the rules for running FDS software, don't let it be because the purpose of wanting to beautify will change the structure and purpose of the backdraft simulation that has been made.

The limitation of text and writing in question is that several versions of FDS will differ in programming language, so it is necessary to have the same version of FDS used by both educators and students. As with Autodesk software, colors are needed that provide information in it to distinguish between state A and state B. For the software itself, make surethat the educators have previously tried to run the software so that the screen display, voice clarity and others related to the display are needed. the software can run properly.

Submissions given by educators must also be convincing and provide a directed view of students so that they are motivated to learn FDS software, especially since this software is rarely used and often uses programming languages that have never been studied before.

Table 3. Calculation of Scale Conversion

Quantitative Data	Score		Criteria
	Formula	Average Score	
5	$X > \overline{Xi} + 1{,}8\ Sbi$	$X > 4{,}2$	Very good
4	$\overline{Xi} + 0{,}6\ Sbi < X \leq \overline{Xi} + 1{,}8\ Sbi$	$3{,}4 < X \leq 4{,}2$	Good
3	$\overline{Xi} - 0{,}6\ Sbi < X \leq \overline{Xi} + 0{,}6\ Sbi$	$2{,}6 < X \leq 3{,}4$	Enough
2	$\overline{Xi} - 1{,}8\ Sbi < X \leq \overline{Xi} - 0{,}6\ Sbi$	$1{,}8 < X \leq 2{,}6$	Not enough
1	$X \leq \overline{Xi} - 1{,}8\ Sbi$	$X \leq 1{,}8$	Very less

In this study, the product feasibility value was determined with a minimum of "3.4" with the "Good" category, so that the research results, both from material experts, media experts, had obtained the final assessment results with a minimum value, then the product developed was considered feasible. used.

Table 4. Material Expert Validation Results

No	Aspect	Indicator	Score	Category
1.	Learning	Relevance of material with Basic competence	5	Very good
		Systematic presentation of material	5	Very good
		Conformity of material with indicators Clarity of material description	4	Good
		Adequacy of providing feedback on learning motivation	4	Good
		Clarity of language use	5	Very good
2.	Content Truth	Sufficient material weight for the achievement of goals	4	Good
		Systematic presentation of material	5	Very good
		Material truth	5	Very good
		Compatibility of giving examples with the material	4	Good
		The use of language is easy to understand	5	Very good
		The images presented support the material	5	Very good
		Total	51	

Average	4,6	Very good

The number of validation scores for material experts on the content aspect is 51 out of11 indicators, so the average result of the material expert assessment is 4.6 with a very good category. Referring to the conversion table, the assessment of the content aspect is very good.

After the learning media has been created, the media expert validation is carried out. Media expert validation was used to assess the media that had been compiled in video-based learning media in the Fire Dynamics Course for backdraft and flashover materials. The mediaexpert who judged was Ms. Dra. Ratu Amilia Avianti, M.Pd. as an expert lecturer who is competent to carry out validation assessments. The results and validation analysis of media experts can be seen in the following table:

Table 5. Media Expert Validation Results

No	Aspect	Indicator	Score	Category
1.	Appearance	Text or writing limitations	4	Good
		Accuracy of color selection and composition	3	Enough
		Image display quality	4	Good
		Image serving	4	Good
		Layer view	3	Enough
		Voice clarity	4	Good
		Accuracy of language use	4	Good
		Background color with text	3	Enough
2.	Delivery	Text efficiency	4	Good
		Image efficiency	4	Good
		Media attraction	3	Enough
		Total	40	
		Average	3,7	Good

The number of validation scores for media experts on the content aspect is 40 out of 11 indicators, so the average result of the media expert's assessment is 3.7 with a good category. Referring to the conversion table, the assessment of the content aspect is good.

Through videos that have been assessed by material experts and media experts, the field results in this study showed positive results, namely making it easier and more interesting for students to learn about Flashover and Backdraft material.

CONCLUSION

Based on the research data, it can be concluded that learning with video-based simulation media can increase interest and increase students' understanding of backdraft and flashover. Learning with video-based simulation media aims to train students to think critically by making it easier for them to display the form of fire cases from the Fire Dynamic Simulator. Judging from these two aspects, namely the appearance and delivery, it can be shown in the average score of the validation results which can be categorized as good and feasible to use.

The purpose of this video-based learning using FDS is to increase student interest in Fire Safety Engineering where not everything can be done manually in simulating a fire and sometimes there are discrepancies or lack of accuracy in the manual practice process compared to the scientifically structured FDS program. and related to the exact sciences.

From the results of the assessment carried out on the validation of media experts, this development is urgently needed to improve learning efficiency and facilitate understanding ofthe operation of the software for students because actually Fire Engineer knowledge isneeded of course for engineering students who will deal with a building and produce zero mistakes.

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