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Designing a Web-Based Exposure Triangle Simulation for Audio and Video Processing Techniques Course at Vocational High School with a Constructivist Approach

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ABSTRACT

This research is motivated by the need for adequate instructional tools and learning media in photography course at Vocational High School in Surakarta. The objectives of this research are to (1) design learning media with a constructivist approach for the exposure triangle learning material and (2) produce a learning media design that aligns with the needs of teachers and students. The research utilizes the Research and Development (R&D) method with a prototype development model involving six stages: communication, quick plan, modeling quick design, construction of prototype, and deployment delivery & feedback. Data were collected through interviews to determine the needs for media design, and the results were used to design learning media for the subject of Audio and Video Processing Techniques. The design was subsequently validated by subject matter experts and media experts before being tested on 31 Multimedia students in grade 12 at Vocational High School. The testing results indicated positive percentages from subject matter experts (82%) and media experts (85%), with an average System Usability Scale (SUS) score of 75.73. This suggests that the learning media is suitable for use and well-received by users. The media addresses practical challenges, such as limited access to DSLR cameras, and provides interactive simulations to bridge theoretical understanding and practical application.

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Introduction

Video cameras are essential tools in the media and entertainment industry because their ability to capture and reproduce scenes with high quality (Chapman & Chapman, 2014). Kenworthy (2006)

explains that video cameras empower content creators by enabling them to efficiently capture visuals, record audio, and maintain full control over the production proces. Similarly, in educational settings, mastering video camera operation is a key skill, particularly in high school Audio and Video Processing Technical Subjects. Students are expected to apply practical camera operation techniques to meet industry standards, a skill that is becoming increasingly important in today's digital media landscape.

A fundamental concept in video camera operation is the exposure triangle, which consists of three elements: ISO, shutter speed, and aperture. Understanding how these elements work together is crucial for videographers to achieve optimal image quality. Christiansen (2013) emphasizes that a solid understanding of the exposure triangle is essential for anyone involved in video production. According to Murwonugroho (2020), mastering the exposure triangle is a balancing act, where the goal is to control light levels and exposure duration to produce the best image quality. Gunawan (2016) points out that mastering this skill requires both knowledge and experience and not all SLR camera owners can fully utilize its features due to a lack of understanding.

To address the complexity of mastering the exposure triangle, instructional media that supports student engagement is crucial. Muafa et al. (2014) define instructional media as a communication tool between teachers and students to achieve learning objectives. The purpose of using instructional media involves the effectiveness and efficiency of the teaching and learning process facilitating information delivery by teachers and helping students understand the material more easily (Sugi & Ambo, 2019). An innovation related to the exposure triangle material has been developed, for example, by Putra et al. (2024) who created a web-based learning media that incorporates video and quiz-based content for vocational high school student. The reliance on video and quizzes can restrict interactivity, preventing students from experimenting with the exposure triangle concepts directly.

It is essential to create a student centered learning experience. Students should be positioned as active learning subjects capable of accessing and analyzing information (Barry, 2012). In this regard the constructivist approach is considered suitable given that students not only receive information but also construct their knowledge through a constructive process (Piaget, 1952). Constructivist approach involves active learners in the learning process to address challenges they encounter, as it adheres to a system of discovery learning and meaningful learning (Masgumelar & Mustafa, 2021). By integrating the exposure triangle concept into interactive learning media, students can construct their knowledge through practical experiences, which is crucial in the digital age where media literacy is essential. The focus on the exposure triangle concept in learning media is highly relevant

for developing students' skills in the digital era, where visual content creation such as (Haqqu et al., 2020; Syahputra et al., 2023) plays a significant role in various industries. Mastering the exposure triangle—comprising ISO, shutter speed, and aperture—not only enhances technical proficiency in photography and videography but also problem-solving abilities essential for digital media production. As the creative industry increasingly demands skilled professionals with a deep understanding of camera operations and lighting techniques, integrating this concept into educational materials ensures that students are better prepared to meet these challenges. Furthermore, the application of constructivist principles in designing interactive learning media allows students to actively engage, experiment, and construct their knowledge, bridging the gap between theoretical understanding and practical application.

Therefore, this research aims to design instructional media as an alternative learning method that incorporates a constructivist approach. Through interactive tools and resources, this media provides students with opportunities to actively construct a deeper understanding of the exposure triangle, fostering critical skills essential for careers in digital media production.

Method

This research was conducted using the Research and Development (R&D) with the aim of creating a product and assessing its effectiveness (Sugiyono, 2011). As defined by Borg & Gall (1983), R&D in the educational context is a research model wherein the outcomes are utilized to design learning products systematically tested in practical settings. In this research, the Prototype Development Model (Lengkong et al., 2022) which involves six stages—communication, quick planning, quick design modeling, prototype construction, and deployment with delivery and feedback—is adopted to implement the development of learning media. In This method aligns with the research objective, which is to develop simulation-based learning media using a constructivist approach for exposure triangle content. Data were directly gathered from teachers of the Audio and Video Processing Technical Subject through interviews and the analysis of literature pertaining to exposure triangle teaching materials. This approach was chosen to comprehensively grasp the learning needs and ensure that the learning media design meets practical requirements in learning activities.

The Prototype Development Model involves six key stages: Communication, where data is gathered through interviews with teachers to identify learning barriers and material needs; Quick Plan, where user, material, and non-functional requirements are analyzed to address challenges like limited teaching aids. This stage aligns with the principles of constructivism, focusing on designing

a learning experience (Pribadi & Sjarif, 2010) that allows students to build knowledge actively. It involves formulating questions to promote exploration of the exposure triangle concept, explaining related phenomena, encouraging critical thinking, and providing problem-solving opportunities. Modeling Quick Design follows, where the system is designed using UML, including use case, activity, and sequence diagrams, as well as interface prototypes to ensure clarity and usability. Construction of Prototype is the stage where the agreed design is translated into a functional prototype using HTML, CSS, and JavaScript, and validated by experts to refine the prototype and ensure it meets educational goals. Finally, in the Deployment, Delivery & Feedback stage, the prototype is tested with students, and feedback is collected using System Usability Scale (SUS) questionnaires to guide further improvements. Each stage ensures that the final product meets user needs and enhances learning outcomes through interactive, student-centered experiences.

Data collection techniques included interviews with subject teachers, literature analysis related to the Discovery Triangle teaching materials, and the use of questionnaires such as the Educational Media Assessment Questionnaire and the Media and Content Expert Checklist. Both checklists were used to ensure that the developed learning media meets the necessary quality and effectiveness standards in terms of content and design. Likert scales were employed to assess respondent reactions to the created learning media. The validity of our research instrument was examined by testing its substance through expert validation, which served as the primary indicator of the instrument's quality. Validation of the learning media was carried out by material experts and media experts. The instrument used in this research was adopted from the learning media evaluation instrument designed by Chaeruman (2015). This instrument is used to assess various aspects of the learning media, including content, instructional design, learning media and communication, and implementability & user acceptance. The Likert scale used includes the following scores: 5 (Very Good), 4 (Good), 3 (Fair), 2 (Poor), and 1 (Very Poor). The suitability of the learning media was then determined based on the criteria values presented in Table 1.

Table 1. Criteria for interpretation scale

Percentage	Criteria
0% - 20%	Not Feasible
21% - 40%	Less Feasible
41% - 60%	Quite Feasible
61% - 80%	Feasible
81% - 100%	Very Feasible

Usability testing was also conducted using System Usability Scale (SUS) (Alam & Puji Rahayu Kurniasih, 2024; Blattgerste et al., 2022; Herawati & Azahra, 2024; Ratnawati & Anandito, 2024) in

form of Likert scale (ranged from 1 to 5 with 10 satetements) to evaluate the level of usability of this product. The SUS instrument used is an Indonesian-language version adopted from Sharfina & Santoso (2016) research, which has been tested for its reliability. This instrument is a translated version of the common English-language SUS. The purposive sampling method was used to select 31 students from a multimedia class in a vocational high school. These students were specifically chosen because they were learning the concept of light triangles in the context of audio and video processing techniques.

The SUS results were calculated to determine user satisfaction and the reliability of the learning media, including net interpretation through percentile ratings, feature recognition rates, and recommendation scores (NPS) using the SUS formula (Ratnawati & Anandito, 2024). Respondent scores are processed using the SUS method: for odd-numbered statements (generally reflect positive experiences), subtract 1 from the score; for even-numbered statements (generally reflect negative experiences), subtract the score obtained from 5. The final SUS score is the total of all adjusted scores multiplied by 2,5. The final score (average SUS score) is obtained by summing the SUS scores of all respondents and dividing the total by the number of respondents. This final score will be interpreted according to Figure 5. Additionally, a simple descriptive statistics approach was also employed to analyze the SUS instrument by calculating the average score for each statement obtained from the users.

Result and Discussion

User Needs Analysis

In creating learning media for the Sound and Video Processing Techniques course at a vocational high school, a client needs analysis was conducted through interviews with subject instructors. The results of the interviews identified several key issues, including:

a. Limitations in teaching aids, particularly the limited availability of DSLR cameras and concept.
b. Insufficient opportunities for students to practice the exposure triangle concept.
c. Limited access to learning materials on the exposure triangle.

Based on the obstacles encountered in learning, user needs are formulated by integrating constructivist learning approach (Pribadi & Sjarif, 2010) into the design of this learning media. The following requirements were identified:

a. Formulate questions

   Learning media must give students the freedom to actively formulate the questions they have when carrying out exposure triangle experiments.

b. Explaining the Phenomenon

Learning media must contain detailed explanations regarding the concept of the exposure triangle as well as the material that needs to be studied in the exposure triangle such as ISO, aperture, and shutter speed.

c. Critical Thinking

Learning media must make students think critically in carrying out exposure triangle experiments. In this case, the simulator is needed to train students in producing photos by paying attention to the aspects contained in the exposure triangle. Apart from that, feedback on the results of students' experiments is also needed to develop critical thinking skills and increase their understanding.

d. Troubleshooting

Learning media must be able to help students in overcoming problems that may occur when students operate learning media.

Table 2. Exposure Triangle Material

Table	***Header***
Exposure	• Understanding Exposure • Exposure Value (EV) • Various expsures (normal, over, and under)
Aperture	• Understanding aperture • Aperture value on the camera • Relationship between aperture and exposure • Aperture and focus space • Depth of Field
Shutter Speed	• Understanding shutter speed • Effects of shutter speed on object movement
ISO	• Understanding ISO • Effects of ISO on lighting

Aligning learning media with the teaching materials used by subject instructors is essential. An analysis of these materials identified the content requirements for the developed learning media, as detailed in Table 2.

Learning Media Design

The learning media design in Figure 1 aims to support the implementation of the learning media design for the triangle exposure simulation. This design was created to meet the expected functionality goals.

Users can access learning media home page and simulator. During initial access to the learning media the user is directed to the main page of the simulator and provided with a menu for direct access to the learning material. Users can simulate exposure triangulation by manually setting aperture, ISO, shutter speed, and EV in the simulator menu. Apart from these users can access the guide menu and video tutorials using the simulator.

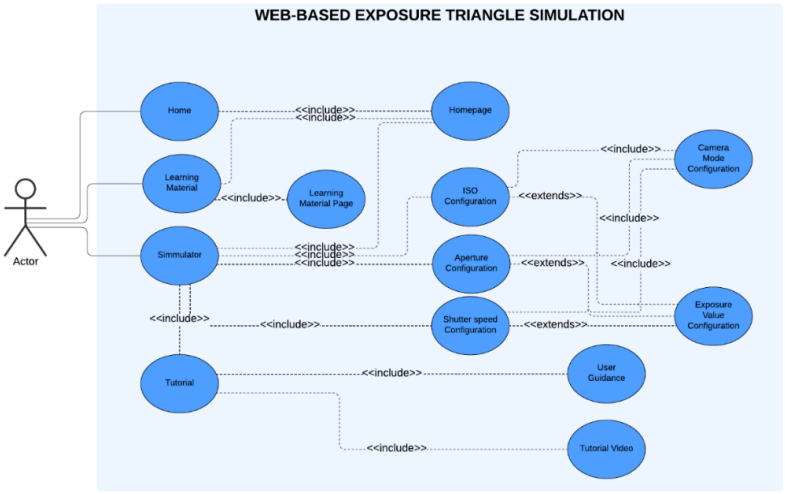

Fig 1: Use Case Diagram

Design Results

In this section, we present views of the learning media created based on the previously designed results. The implementation phase resulted in a system ready for testing and operation.

1. Homepage

The homepage serves as the starting page of the learning media. The implementation form of this main page can be seen as follows:

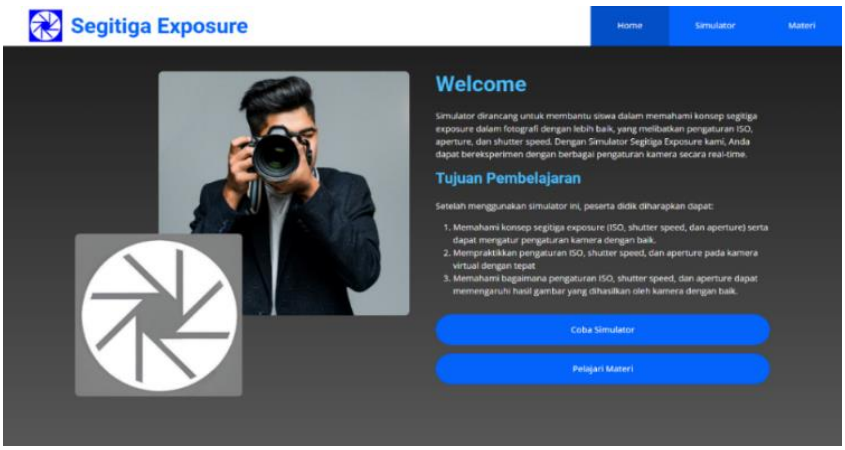

Fig 2: Homepage

2. Simulator Page

This page (Figure 3) will display various camera settings, ranging from camera mode selection to ISO, aperture, shutter speed, and EV settings. This page is created to allow users to simulate the exposure triangle. Additionally, this page provides a guide on using this simulator.

The simulator page aligns with the constructivist approach in design. It provides students with active learning, hands-on experimentation and critical thinking. Students are able to select a camera mode (A, Av, Tv, M) and adjust the ISO, aperture, and shutter speed by operating the sliders. As the exploration begins, they will be encouraged to ask about how these settings will affect the photos. For example, some questions such as "What happens when I adjust the shutter speed?", or "How does adjusting the aperture size influence the exposure?".

Adjusting and observing the resulting image helps students grasp how the exposure triangle works, connecting what they learn in theory with real-world application. This design is intended to stimulate the students' curiosity and encourage deeper exploration. In addition, by adjusting settings and analyzing the changes in the image may help the student to develop critical thinking, as the student will reflect on concepts, decisions and their impacts, practical experience, and problem-solving based on the learning process and results of exploration. The student will reflect on concepts, decisions and their impacts, practical experience, and problem-solving based on the process and results of exploration. The simulator also supports troubleshooting, as students can experiment with different settings and revise their choices until they achieve the desired result. The interactive nature of the simulator is expected to set up a learning environment that aligns with the constructivist approach.

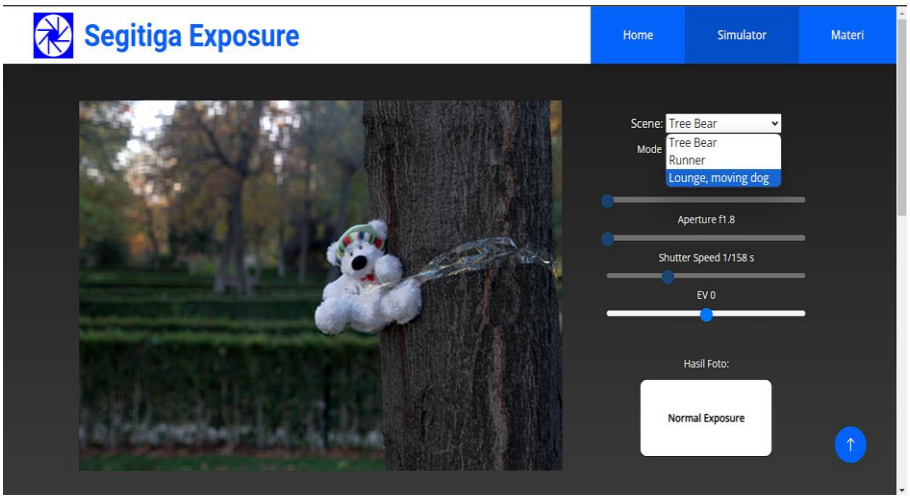

Fig 3: Simulator Page

3. Material Page

This page displays learning material menus on exposure triangle learning. The implementation form of the material page can be seen in Figure 4.

Fig 4: Material Page

The materials page is also designed to align with the constructivist approach. By navigating to the page and selecting topics such as Exposure, ISO, aperture, and shutter speed, students are encouraged to formulate questions about the concepts they are about to explore, thereby sparking curiosity and fostering active learning. As students click on a specific item, the media is expected to guide their understanding by explaining the phenomenon, helping them gain deeper insight into how each element of the exposure triangle impacts the resulting image. This process aims to help students build a strong foundation of knowledge.

This page is purposefully designed to provide students with specific information, enabling them to make informed decisions and think critically about how adjustments will impact the resulting image. It also offers guidance to help students troubleshoot any challenges they may encounter during the experiment. This type of setting is designed to create a learning environment that aligns with the constructivist approach, allowing students to navigate between the material and the simulator as needed.

Validation of Learning Media

The results of the validation of the learning media design are as follows:

1. Validation By Content Expert

Table 3. Results of content expert validation

	Criteria	Score
1.	The material presented in the learning media does not contain material or conceptual errors.	4
2.	The material presented in the learning media is very accurate and reliable.	3
3.	The material in the learning media remains relevant and is suitable for the latest developments in the context of the exposure triangle.	4
4.	The material presented in the learning media covers important aspects in learning the exposure triangle.	4
5.	The material presented has sufficient depth for students to learn the exposure triangle.	4
6.	Learning media is easy for students to use to learn the exposure triangle.	5
7.	Learning media increases students' interest and motivation in learning, both in the classroom and in independent learning.	4
8.	Learning media can be used by students as a tool for independent learning and by teachers as a tool in the teaching process in the classroom.	5
9.	Learning media encourages students to think critically in analyzing the relationships between exposure triangle aspects (ISO, aperture, and shutter speed).	4
10.	Learning media encourages students to develop problem-solving skills related to the exposure triangle through a simulation approach.	4
11.	Learning media helps students connect and apply exposure triangle concepts and its aspects (ISO, aperture, and shutter speed) in operating the camera.	4
12.	Learning media is effective in helping students quickly understand and master exposure triangle materials, concepts, and skills.	4
	Total Score	**49**

From the results of the expert content testing in Table 3, the feasibility percentage is obtained as follows:

$$Feasibility\ Score\ (\%) = \frac{Total\ Score}{Ideal\ Score} \times 100\%$$

$$= \frac{49}{60} \times 100\%$$

$$= 82\%$$

With a feasibility percentage of 82%, the material included in the learning media is categorized as highly feasible for use based on Table 1. Content expert validation further supports this, with item no. 2 receiving a score of 3/5. This suggests that while the material is deemed accurate and reliable to a considerable extent, there is still room for improvement to ensure the highest level of precision and dependability in the content.

2. Validation by Media Expert

Table 4. Results of media expert validation

	Criteria	Score
1.	The presentation of exposure triangle material in learning media is delivered in a way that is suitable for students	4
2.	The exposure triangle material in learning media is easy to understand.	5
3.	Learning media helps students practice critical thinking and solving problems related to the exposure triangle.	3
4.	Learning media assists students in connecting and applying exposure triangle concepts and its aspects (ISO, aperture, and shutter speed) in operating a camera.	5
5.	Simulations used in learning media help students better understand exposure triangle material.	5
6.	The use of graphics and visuals in learning media aligns with learning objectives and aids student understanding.	4
7.	The quality of graphics and visuals in learning media supports learning objectives and the content of exposure triangle material.	4
8.	The use of audio and narration in learning media aligns with learning objectives and aids student understanding.	4
9.	The quality of audio and narration in learning media supports learning objectives and the content of exposure triangle material.	5
10.	The use of video in learning media aligns with learning objectives and aids student understanding.	5
11.	The quality of video in learning media supports learning objectives and the content of exposure triangle material.	5
12.	The use of animation and simulation in learning media aligns with learning objectives and aids student understanding.	3
13.	The quality of animation and simulation in learning media supports learning objectives and the content of exposure triangle material.	4
14.	The use of language in learning media is easily understood in conveying exposure triangle material.	4
15.	Users can interact directly with learning media and it is easy to operate.	5
16.	Learning media has an attractive appearance for students overall, including typography, colour, illustrations, icons, and layout.	3
	Total Score	**68**

From the results of the expert media testing in Table 4, the feasibility percentage is obtained as follows:

$$Feasibility\ Score(\%) = \frac{Total\ Score}{Ideal\ Score} \times 100\%$$

$$= \frac{68}{80} \times 100\%$$

$$= 85\%$$

With a percentage of 85%, learning media can be stated as very feasible for use based on Table 1. Validation from media experts highlights several key insights: Item 2 scored 5/5 for the exposure triangle material being easy to understand, Item 4 scored 5/5 for helping students connect and apply exposure triangle concepts in camera operation, and Item 14 scored 5/5 for interactivity and

ease of use. However, areas requiring improvement were noted: Item 3 scored 3/5 for problem-solving enhancement, and Item 16 scored 3/5 for the visual appeal of the learning media.

Testing the Learning media Design

After respondents filled out the questionnaire, the next step involved calculating for each questionnaire dataset collected from each participant. The results were then summarized in Table 5.

Table 5. System Usability Scale (SUS)

No	Resp	Raw Score Per-Statement										Conversion Score Per-Statement										Total	SUS Score
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10		
1	R01	5	2	5	2	5	3	5	2	5	2	4	3	4	3	4	2	4	3	4	3	34	85
2	R02	4	2	5	2	5	3	4	2	5	2	3	3	4	3	4	2	3	3	4	3	32	80
3	R03	5	2	5	2	5	2	5	2	4	3	4	3	4	3	4	3	4	3	3	2	33	82.5
4	R04	5	2	2	2	5	2	5	2	5	2	4	3	4	3	4	3	4	3	3	2	33	82.5
5	R05	5	2	5	2	5	2	5	1	5	3	4	3	4	3	4	3	4	4	4	2	35	87.5
6	R06	4	3	5	3	4	3	5	3	5	2	3	2	4	2	3	2	4	2	4	3	29	72.5
7	R07	4	2	5	3	5	2	4	2	5	3	3	3	4	2	4	3	3	3	4	2	31	77.5
8	R08	5	2	5	3	5	2	5	2	5	4	4	3	4	2	4	3	4	3	4	1	32	80
9	R09	4	3	4	4	4	3	4	3	4	4	3	2	3	1	3	2	3	2	3	1	23	57.5
10	R10	4	4	4	1	5	3	5	2	4	4	3	1	3	4	4	2	4	3	3	1	28	70
11	R11	4	3	5	4	4	3	5	4	5	4	3	2	4	1	3	2	4	1	4	1	25	62.5
12	R12	5	2	5	1	5	3	5	2	5	4	4	3	4	4	4	2	4	3	4	1	33	82.5
13	R13	5	2	5	2	5	2	5	2	5	2	4	3	4	3	4	3	4	3	4	3	35	87.5
14	R14	5	2	5	3	4	2	5	2	5	3	4	3	4	3	4	3	4	3	4	3	35	87.5
15	R15	4	2	5	3	5	2	5	2	5	2	3	3	4	2	4	3	4	3	4	3	33	82.5
16	R16	5	2	5	2	5	3	5	3	4	3	4	3	4	3	4	2	4	2	3	2	31	77.5
17	R17	5	3	5	1	5	1	5	2	5	5	4	2	4	4	4	4	4	3	4	0	33	82.5
18	R18	5	3	4	3	4	3	4	3	3	3	4	2	3	2	3	2	3	2	2	2	25	62.5
19	R19	5	2	5	3	5	3	5	2	5	4	4	3	4	2	4	2	4	3	4	1	31	77.5
20	R20	5	2	5	2	5	2	5	2	5	3	4	3	4	3	4	3	4	3	4	2	34	85
21	R21	5	1	5	2	5	2	5	2	5	3	4	4	4	3	4	3	4	3	4	2	35	87.5
22	R22	5	1	5	2	5	2	5	2	5	3	4	4	4	3	4	3	4	3	4	2	35	87.5
23	R23	5	3	5	3	5	3	4	3	5	4	4	2	4	2	4	2	3	2	4	1	28	70
24	R24	4	2	5	2	5	3	5	2	4	5	4	2	4	2	4	2	3	2	4	1	28	70
25	R25	4	4	3	2	4	2	5	2	3	4	3	1	2	3	3	3	4	3	2	1	25	62.5
26	R26	5	3	5	3	5	2	5	3	5	4	4	2	4	2	4	3	4	2	4	1	30	75
27	R27	5	3	5	3	4	3	5	3	4	3	4	2	4	2	3	2	4	2	3	2	28	70
28	R28	4	4	4	3	4	3	3	3	4	4	3	1	3	2	3	2	2	2	3	1	22	55
29	R29	4	3	5	5	5	3	5	2	5	5	3	2	4	0	4	2	4	3	4	0	26	65
30	R30	4	4	4	2	5	3	5	3	4	4	3	1	3	3	4	2	4	2	3	1	26	65
31	R31	5	2	5	3	5	3	5	2	5	4	4	3	4	2	4	2	4	3	4	1	31	77.5
																	Average						**75.73**

The results show that the learning media achieved an average SUS score of 75.73. To interpret this average score, we refer to the SUS score interpretation scale by Bangor, as shown in Figure 5.

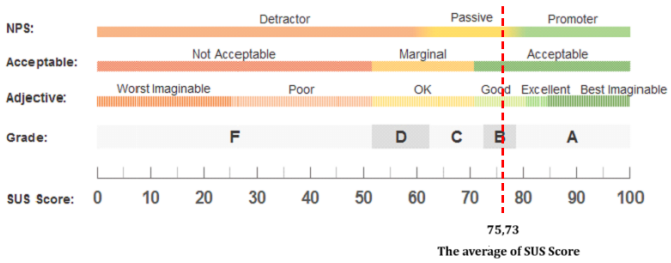

Fig 5: Interpretation of SUS Scores for Exposure Triangle Simulation

By looking at the Sauro curve (Figure 6) in the graph, we can see that the SUS evaluation results for the exposure triangle simulation learning media are between 70% and 79%.

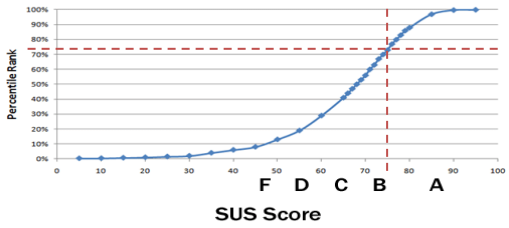

Fig 6: Percentile SUS Score

The detailed interpretation results are shown in Table 6. The web-based exposure triangle learning tool got a B rating for how easy it is to use, with a score of 75. 73 out of 100. This result is above the standard set at 68, with a percentile ranking between 70% and 79%, indicating performance above average. From an “Adjective” perspective, this learning medium is considered as “Good” category, and and its acceptance level falls into the "Acceptable" category, reflecting general approval by students. In NPS based interpretation, the outcomes are “Passive”. This means that even if people think learning media is helpful, they might not feel very excited about telling others to use it. In general, the students thought the web-based exposure triangle simulation was okay after trying it out in this study that shown on table 6.

Table 6. Interpretation Results of SUS Scores for Exposure Triangle Simulation

Grade	SUS	Percentile Range	Adjective	Acceptable	NPS
A+	84.1 – 100	96 – 100	Best Imaginable	Acceptable	Promoter
A	80.8 – 84.0	90 – 95	Excellent	Acceptable	Promoter
A-	78.9 – 80.7	85 – 89	Good	Acceptable	Promoter
B+	77.2 – 78.8	80 – 84	Good	Acceptable	Passive
B	74.1 – 77.1	70 – 79	Good	Acceptable	Passive
D	51.7 – 62.6	15 – 34	OK	Marginal	Detractor

In this research, descriptive statistical analysis was also carried out from the results of questionnaires distributed to 31 students after trying out the results of a web-based exposure triangle simulation design. The following are the results of descriptive statistical analysis based on the results of the System Usability Scale (SUS) questionnaire after students tested the results of designing exposure triangle simulation learning media that shown on table 7.

Table 7. Descriptive analysis

	Item	N	Mean	Std. Deviation
1.	I think that I would like to use this system.	31	4.61	.495
2.	I found the system unnecessarily complex.	31	2.48	.811
3.	I thought the system was easy to use.	31	4.68	.702
4.	I think that I would need the support of a technical person to be able to use this system.	31	2.52	.890
5.	I found the various functions in this system were well integrated.	31	4.74	.445
6.	I thought there was too much inconsistency in this system.	31	2.52	.570
7.	I would imagine that most people would learn to use this system very quickly.	31	4.77	.497
8.	I found the system very cumbersome to use.	31	2.32	.599
9.	I felt very confident using the system.	31	4.61	.615
10.	I needed to learn a lot of things before I could get going with this system.	31	3.39	.919
	Valid N (listwise)	**31**		

The findings from the System Usability Scale (SUS) questionnaire align well with a constructivist approach to learning, which emphasizes active, learner-centered experiences and building knowledge through interaction with the environment. The high scores on the odd-numbered items (such as Item 3 with a score of 4.68, Item 5 with a score of 4.74, and Item 7 with a score of 4.77) indicate that students found the web-based exposure triangle simulation easy to use, well-integrated, and intuitive. These positive outcomes are consistent with the constructivist approach, which values the ability for students to engage with learning tools in a way that facilitates exploration and self-directed learning (Ziani & Aoumeur, 2022). In a constructivist framework, the system's user-friendliness supports students' autonomy and encourages them to explore and learn by doing, which is evident in the feedback that users felt confident (Item 9, score 4.61) and believed that others would quickly learn to use the system (Item 7, score 4.77).

However, some challenges were noted, particularly from the even-numbered items (such as Item 2 with a score of 2.48, Item 8 with a score of 2.32, and Item 6 with a score of 2.52), which suggest that parts of the system were perceived as confusing or inconsistent. In the context of constructivist learning, these challenges point to the need for more effective scaffolding. Scaffolding is a critical component of constructivism, where learners are supported as they build new knowledge. The

feedback indicating confusion and the need for time to adjust (Item 10, score 3.39) suggests that the system might not provide enough immediate support for students to make meaning from the learning material without additional guidance. This aligns with Vygotsky's theory of the Zone of Proximal Development (ZPD), where learners need to be provided with the appropriate amount of support to move beyond their current understanding (Abtahi, 2021; Wei, 2024). Therefore, the tool might benefit from clearer instructions or enhanced guidance to help students bridge the gap between their existing knowledge and the new concepts introduced by the simulation. Future development should focus on enhancing motivation and engagement through Gamified Learning (Jiang et al., 2023) as a means of implementing scaffolding. This approach has the potential to address challenges related to the need for effective scaffolding.

Conclusion

Based on the results of research and descriptive statistical analysis of web-based exposure triangle learning media, there are several findings which can be described. The service was rated B for usability with a score of 75. 73 on the System Usability Scale (SUS). This learning media can be categorized as "Good", and the level of acceptance is in the "Acceptable" category, indicating general acceptance by students. However, through an interpretation approach based on the Net Promoter Score (NPS), the results show the "Passive" category, suggesting a lack of strong motivation among users to recommend the product to others. This reflects the need for further refinement to enhance user engagement and satisfaction. The media effectively supports a constructivist learning approach by enabling self-directed exploration and critical thinking, yet improvements in scaffolding and instructional clarity are essential to optimize its potential.

The media's ability to address practical limitations, such as the lack of DSLR cameras in vocational schools, higlight its value as a supplementary tool for learning activitites. By providing interactive simulations, the media helps bridge the gap between theoretical understanding and practical application. Furthermore, the media holds potential as a strategic contribution to vocational education curricula, aligning student competencies with industry standards. Future development should focus on enhancing motivation and engagement through elements like gamification and feedback mechanisms, ensuring the media can provide an even more comprehensive and impactful learning experience.

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