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Interactive Video-Supported Worksheet to Enhance Conceptual Understanding and Practical Skills in Aircraft Composite Engineering

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ABSTRACT

Composite engineering is an important component in aviation vocational education, requiring both strong conceptual knowledge and precise practical skills. However, practical training in this field often faces challenges, including limited access to materials, expensive equipment, and high safety requirements. This study aims to design and evaluate the effectiveness of an Interactive Video-Supported Worksheet (IVSW) as a low-fidelity simulation-based learning medium to enhance cadets' conceptual understanding and practical competence in composite engineering, using the ADDIE model and a quasi-experimental one-group pretest–posttest design. Participants consisted of cadets enrolled in the Aircraft Composite Engineering course at Makassar Aviation Polytechnic. IVSW provides structured guidance through worksheets accompanied by instructional videos that demonstrate the procedures for fabrication and repair. Data were collected through pretest–posttest conceptual tests, observation rubrics for practical performance, and student perception questionnaires. Quantitative data were analyzed using paired sample t-tests and descriptive statistics. The results of this study indicate that combining structured worksheets with embedded instructional videos can serve as a low-impact yet highly effective simulation-based learning approach. This approach provides cognitive support and procedural modeling, enabling cadets to better integrate theory with practice. The findings show that cadets who used IVSW demonstrated improvements in theoretical knowledge (sig (2-tailed) = 0.012), as well as procedural accuracy, time efficiency, and the quality of composite fabrication and repair. However, alternative learning models are needed to enhance conceptual understanding, such as quizzes within videos, structured discussions, and clear learning instructions to improve a more significant understanding of concepts.

I. Introduction

Composite materials improve fuel efficiency, reduce aircraft weight, and enhance structural performance (Parveez et al., 2022). The increasing use of composite aircraft structures requires aviation maintenance technicians to possess specialized composite repair and inspection competencies (Wang & Zimmermann, 2021). Aircraft maintenance technicians are required to possess competencies in non-destructive testing (NDT) for composite structure inspection. However, teaching and learning composite engineering faces several challenges. Practical training in composite fabrication and repair often requires expensive materials, specialized equipment, and stringent safety procedures (Katunin et al., 2021). These constraints limit the frequency and intensity of student practice, resulting in a persistent gap between theoretical understanding and practical skills in vocational training environments (Metrey, 2021).

Various studies in engineering education have explored the use of interactive media such as virtual reality (VR), augmented reality (AR), and computer-based simulations to enhance learning outcomes (Chan, 2022). These approaches have demonstrated significant benefits in terms of conceptual understanding, motivation, and learner engagement (Spangenberger, 2022). However, the implementation of such high-fidelity technologies remains expensive and technologically demanding, especially in vocational institutions with limited resources (Nurlaela, 2025). Furthermore, most existing studies primarily emphasize cognitive outcomes, with fewer addressing the development of psychomotor skills that are essential in the maintenance and repair of composites.

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In vocational education, structured learning tools such as worksheets play a crucial role as scaffolds, guiding students step-by-step from theoretical knowledge to practical application (Yusuf, 2024). When combined with multimedia elements such as instructional videos, worksheets can serve as interactive media that simulate real-world tasks in a cost-effective manner (Priciliya, 2022). Previous research has shown that video demonstrations support procedural learning by providing visual representations of complex processes, thereby reducing errors during practice (Yoosoof, 2022). This integration of worksheets and videos creates a form of low-fidelity simulation-based learning that, while not as fully immersive as VR or AR, still provides interactivity, guided practice, and contextual learning aligned with the needs of vocational training (Omarchevska et al., 2022). Low-fidelity simulation refers to learning media that simulate real-world processes in a limited way, with simple representations of procedures and work steps, allowing students to observe, process, and practice conceptually before actual practice (Hontvedt & Øvergård, 2020). In the context of composite engineering, the use of worksheets + videos can be seen as an effective form of low-fidelity simulation in building conceptual understanding and practice readiness.

This study introduces a Video-Supported Interactive Worksheet designed for a Composites Engineering course in aviation vocational education. However, no studies have examined the effectiveness of IVSW specifically on composite engineering in aviation vocational education. The worksheet provides structured guidance for cadets in performing composites practices, from fabricating simple composite objects to repairing damaged structures, with embedded video links at each stage of the practice. The objective of this study is to investigate the effectiveness of this medium in enhancing conceptual understanding and practical skills (Prastyo, 2020). Thus, this study contributes to the growing literature on educational technology in vocational engineering by offering a cost-effective, scalable, and context-specific simulation-based learning approach to develop cognitive and psychomotor skills.

The development of the Interactive Video-Supported Worksheet (IVSW) was motivated by the need for accessible and effective learning media that can bridge theoretical knowledge and practical application in aviation composite engineering education. While previous studies have reported the benefits of instructional videos and worksheet-based learning in various educational contexts, limited research has explored their integrated use within composite engineering training in aviation vocational institutions (Alobaidi, 2020). To address this gap, the IVSW was designed to provide step-by-step procedural guidance accompanied by embedded instructional videos that learners can access directly during practical activities. This integration enables cadets to review procedures, visualize technical processes, and reinforce learning independently before and during laboratory sessions. By combining structured learning support with multimedia resources, the IVSW aims to improve learning efficiency, enhance procedural accuracy, and promote greater learner engagement. As a result, this study offers a practical contribution to aviation vocational education by demonstrating how a low-cost and easily implemented digital learning tool can support the development of both conceptual understanding and hands-on competencies required in composite engineering practice.

II. Method

A. Research Design

This study employed a one-group pretest–posttest quasi-experimental design. Since no control group was included, several threats to internal validity such as testing effects, maturation, and prior exposure to instructional materials may have influenced the results. Therefore, the findings should be interpreted cautiously as preliminary evidence of the effectiveness of the Interactive Video-Supported Worksheet (IVSW). Future studies are recommended to employ randomized or controlled experimental designs to strengthen causal inference. This study employs a design development approach combined with a quasi-experimental method to evaluate the effectiveness of the developed learning media. This study was conducted in two main stages: (1) development of a Video-Supported Interactive Worksheet for composite engineering practice, and (2) implementation of the worksheet in class and laboratory sessions to measure its impact on students' conceptual understanding and practical skills (Reeves & Hedberg, 2003).

B. Participants

The participants of this study were cadets enrolled in the fifth semester of the Diploma III program in Aircraft Maintenance Technology at the Makassar Aviation Polytechnic. A total of 14 cadets participated in this study, consisting of 10 males and 4 females, aged between 19 and 21 years. The sample size consisted of one intact class of 14 cadets enrolled in the Aircraft Composite Engineering course (Davis, 1989). The use of a small sample was due to the limited number of cadets registered in the course during the semester in which the study was conducted. Therefore, purposive sampling was applied, considering that all participants had relatively homogeneous academic backgrounds and had completed prerequisite theoretical instruction related to composite materials. Although the sample size limits the generalizability of the findings, the study was intended as an exploratory implementation study within a vocational aviation training context. The cadets were in their fifth semester/third year and had previously received theoretical instruction in composite materials but had limited hands-on experience.

C. Development of Learning Media

The developed IVSW consisted of several integrated learning features designed to support procedural understanding during laboratory practice. Each worksheet section contained step-by-step procedural guidance, QR codes linked to instructional videos, laboratory safety reminders, required tools and materials, and reflective practice notes.

The embedded instructional videos demonstrated critical procedures such as resin preparation, fiber placement, vacuum bagging preparation, and composite repair techniques. The videos were intentionally designed in short segments to allow cadets to repeatedly access specific procedures during practice activities. In addition, the worksheets provided structured checkpoints to help learners monitor procedural completion and reduce operational errors during laboratory sessions.

The Interactive Video-Supported Worksheet (IVSW) was developed using the ADDIE instructional design model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Wulandari et al., 2021).

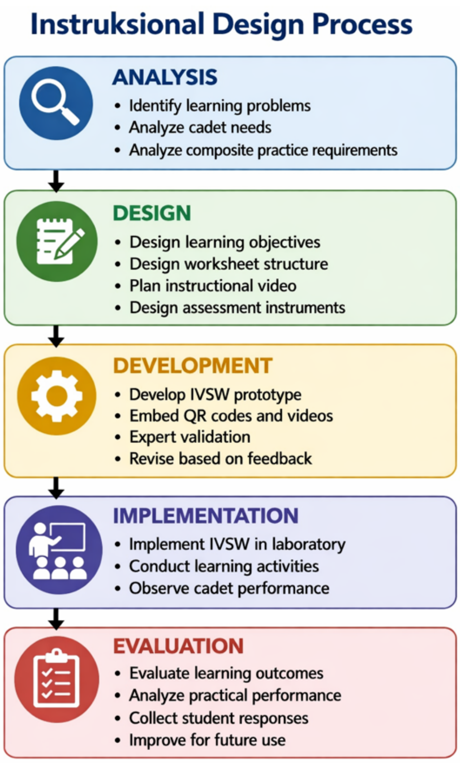

Fig. 1. ADDIE Instructional Design

Figure 1 illustrates the d evelopment stages of IVSW using the ADDIE instructional design model. Each stage was conducted systematically to ensure that the developed media aligned with the learning objectives, laboratory procedures, and vocational competency requirements in composite engineering practice.

During the analysis stage, the researchers identified learning difficulties experienced by cadets in composite engineering practice, particularly related to procedural understanding, laboratory safety, and limited access to repeated demonstrations. In the design stage, the structure of the worksheet, learning objectives, practice sequences, and integration of instructional videos were planned systematically.

The development stage involved producing the worksheet content, embedding QR codes and YouTube video links, preparing laboratory practice instructions, and conducting expert validation. Revisions were carried out based on feedback from media and subject-matter experts. The implementation stage involved applying the IVSW during four weeks of laboratory practice sessions in the Aircraft Composite Engineering course. Finally, the evaluation stage assessed the effectiveness, usability, and student responses toward the developed media through conceptual tests, observation rubrics, and questionnaires.

D. Implementation Procedure

This research was conducted during the Composite Engineering course over a 4-week laboratory session. The procedure followed four phases: (1) Preparation - Cadets are introduced to the worksheet and given an overview of the objectives and tasks, (2) video simulation - Before each practical, cadets access a video demonstration contained in the worksheet to visualize the correct steps, (3) hands-on practice - Cadets perform practical work in the workshop following the worksheet guidelines, including fabrication of composite specimens and repair of damaged structures, (4) reflection and feedback - Cadets complete reflection tasks in the worksheet, while the instructor provides formative feedback based on the practical results.

E. Instruments and Data Collection

Three types of data were collected: (1) conceptual understanding - measured through pre-test and post-test assessments consisting of multiple-choice and short-answer questions covering composite structures, materials, and repair principles, (2) practical skills - assessed using an observation rubric focusing on procedural accuracy, safety compliance, tool use, composite work quality, and total processing time, (3) student responses - collected through a questionnaire measuring perceptions of usefulness, ease of use, engagement, relevance, and satisfaction with the learning media.

Before implementation, the research instruments were validated by three experts in aviation vocational education and composite engineering. The validation process focused on content relevance, clarity of instructions, alignment with course learning outcomes, and suitability for vocational laboratory learning. Several revisions were made based on the experts' suggestions before the instruments were used in the study.

Table 1. Expert Validation Table

Aspect	Mean Score	Category
Content Relevance	4.67	Very Valid
Instruction Clarity	4.50	Very Valid
Media Design	4.75	Very Valid
Practical Applicability	4.58	Very Valid
Overall	4.63	Very Valid

To ensure reliability, the instruments were tested using Cronbach's alpha coefficient. The conceptual understanding test achieved a Cronbach's alpha value of 0.82, while the student response questionnaire obtained a reliability coefficient of 0.86. These values indicate that the instruments had good internal consistency and were considered reliable for data collection.

F. Data analysis

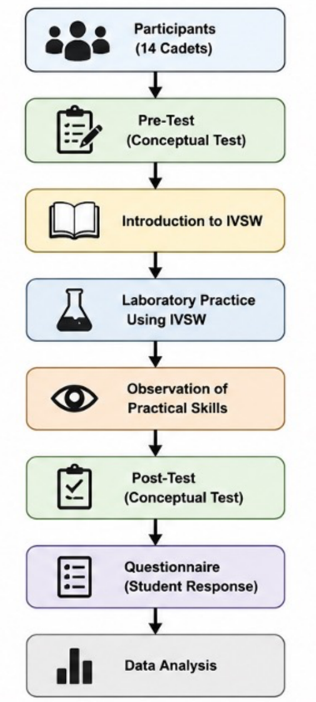

Fig. 2. Research Procedure

The research procedure began with administering a pre-test to measure cadets' initial conceptual understanding. Subsequently, the cadets participated in laboratory activities using IVSW during composite engineering practice sessions. Observations of procedural performance and safety compliance were conducted throughout the implementation phase. At the end of the intervention, post-tests and student response questionnaires were administered to evaluate conceptual understanding and user perceptions toward the developed learning media.

Quantitative data from the pretest and posttest were analyzed using paired-samples t-tests to determine significant differences in conceptual understanding before and after the intervention. Skill performance was practically analyzed in a descriptive use score rubric.

Practical skills assessment combined the psychomotor levels of Dave's taxonomy with performance-based indicators adapted from vocational training standards (Gorbunova et al., 2023). The rubric consisted of five observable aspects-procedure accuracy, safety compliance, tool handling, time efficiency, and quality of repair work-each rated on a five-level scale (1 = imitation, 5 = naturalization). This integrated assessment approach ensured that both technical execution and psychomotor mastery were objectively evaluated during the composite workshop sessions.

Meanwhile, student responses were analyzed using descriptive statistics (mean and percentage) to evaluate the appropriateness and acceptability of the media. The students' responses toward the interactive learning media were measured using a Likert-scale questionnaire adapted from Kemp and Dayton's media evaluation framework (1985) and the Technology Acceptance Model (Davis, 1989) (Reeves & Hedberg, 2003). The interpretation of the mean scores followed a five-category range (1.00-1.80 = very negative; 1.81-2.60 = negative; 2.61-3.40 = neutral; 3.41-4.20 = positive; 4.21-5.00 = very positive).

III. Results and Discussion

A. Development of Video-Supported Interactive Worksheets for composite engineering practice.

Video-supported interactive Worksheets are developed with reference to the ADDIE Model. The Lab Module is designed for 4 face-to-face sessions with the following topics: (1) Resin Lamination, (2) Room Temperature Wet Lay Up, (3) Reinforced Composites, (4) Wet Lay Up with Hot Bonder. Each topic contains: (1) Conceptual introduction a brief explanation of relevant theory (e.g., composite structures, their properties, and repair techniques), (2) Embedded multimedia links – QR codes or hyperlinks that direct cadets to instructional videos that visually demonstrate procedures, safety considerations, and expected results, (3) Practical instructions – detailed and structured guides for hands-on laboratory activities such as composite fabrication, defect identification, and structural repair, (4) Reflection, discussion, and analysis tasks, space for cadets to document cognitive and psychomotor experiences in the form of conclusions about understanding concepts and theories and skills improvements obtained from learning experiences in laboratory practices and compare them with the instructional videos and answer guiding questions.

B. Implementation of worksheets in class and laboratory sessions to measure their impact on students' conceptual understanding and practical skills

1) Improved Conceptual Understanding

The pretest and posttest results on the composite engineering material are summarized in Table 1. The

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cadets' average scores increased after using the Interactive Video-Supported Worksheet (IVSW)

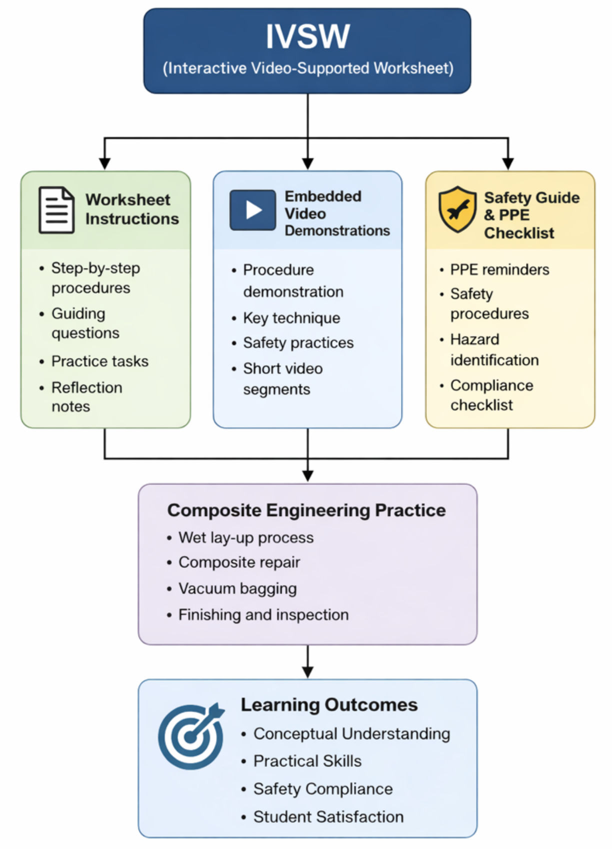

Fig. 3. Architecture of IVSW

Table 2. Conceptual Understanding Test Results

Roll call	Pre-test score	Post-test score
1	78	80
2	75	77
3	80	78
4	77	79
5	78	81
6	76	83
7	80	80
8	78	77
9	75	75
10	75	79
11	76	78
12	79	82
13	77	78
14	70	79

Quantitative data from the pretest–posttest were analyzed using a paired sample t-test to determine significant differences in conceptual understanding before and after the intervention.

As is common with parametric statistics, a normality test is performed before conducting the paired sample t-test as a prerequisite for parametric statistics. The data normality test is used to determine whether the data is normally distributed. The results of the normality test using SPSS 22 are shown in Table 3.

The Shapiro-Wilk normality test revealed a pre-test significance value of 0.103, greater than the alpha significance value of 0.05. This value indicates that the pre-test results were normally distributed. Meanwhile, the post-test data using the Shapiro-Wilk test showed a significance value of 0.946, greater than the alpha significance value of 0.05. show distribution of post- test data results, which are normally distributed.

After it is proven that the data is normally distributed, then a paired sample t-test was conducted. This test was done for known significance difference results in class TPPU XIV after the given treatment in the matter. This use of the Interactive Video-Supported Worksheet (IVSW) learning media

Table 3. Paired sample statistics

Pair	Variable	Mean	N	Standard Deviation	Std. Error Mean
1	Pre-Test	76.7143	14	2.58482	0.69082
Post-Test	79.0000	14	2.11224	0.56452	

The statistical table above shows that the average pre-test score was 76.71, while the average post-test score was 79.00. This indicates a significant difference after using the Interactive Video-Supported Worksheet (IVSW) media device. To ensure a significant difference between the pre-test and post-test scores, we looked at the sig (2-tailed) paired samples test results.

Table 4. Paired Sample Test

Pair	Mean Difference	t	df	Sig. (2-tailed)
Pre-Test – Post Test	-2.286	-3.828	13	0.012

Table 5 shows that the significance value (Sig. 2-tailed) was 0.012, which is lower than 0.05. Therefore, there was a statistically significant difference between pre-test and post-test scores following implementation of the Interactive Video-Supported Worksheet (IVSW). The findings indicate that IVSW contributed to improving cadets' conceptual understanding of composite engineering (Ekayanti et al., 2023).

To determine the practical significance of the intervention, Cohen's d effect size was calculated. The obtained effect size indicated a small-to-moderate practical impact of IVSW on conceptual understanding. This finding suggests that although the statistical difference was significant, the educational effect on conceptual mastery remained limited.

The table data shows a sig value (2-tailed) of 0.012. This value is smaller than the alpha value of 0.050. This

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indicates a statistically significant difference between the pre-test and post-test scores. However, the magnitude of the improvement was relatively small in practical terms, with the average score increasing from 76.71 to 79.00. Therefore, the findings should be interpreted as preliminary evidence that IVSW may provide limited support for conceptual understanding, while showing stronger potential in facilitating procedural comprehension and laboratory performance. However, the increase in post-test scores was relatively modest, indicating that the media was more effective in supporting procedural and practical comprehension rather than deep conceptual mastery (Ningrum, 2023).

2) Practical Skills Performance

Cadet practical performance was evaluated using an observation rubric. The rubric covered aspects such as procedural accuracy, safety compliance, tool handling, processing time, and composite repair quality. Each cadet was given a score for each aspect on a scale of 1-5, with skill mastery criteria as outlined in the following table (Gunawan et al., 2020).

Table 5. Score and Criteria

Level	Description	Range
1 – Novice	Need help full	1.0–1.9
2 – Beginner	Able to follow instructions with minor errors	2.0–2.9
3 – Competent	Perform procedures correctly and safely	3.0–3.9
4 – Proficient	Efficient, independent, and consistent work results	4.0–4.4
5 – Expert	Automatic , adaptive , and creative	4.5–5.0

After assessing each cadet in each aspect, the average score was obtained as shown in the following table.

Table 6. Practical Skills Performance

Practicum Assessment Aspects	Mean Score	Level	Description
Procedure Accuracy	4.29	Proficient	Efficient, independent, and consistent work results
Compliance with Work Safety (Safety Compliance)	4.50	Expert	Automatic, adaptive, and creative
Tool Handling and Maintenance	3.57	Competent	Performing procedures correctly and safely
Work Quality / Repair Results	3.36	Competent	Performing procedures correctly and safely
Total Time	4.71	Expert	Automatic, adaptive, and creative

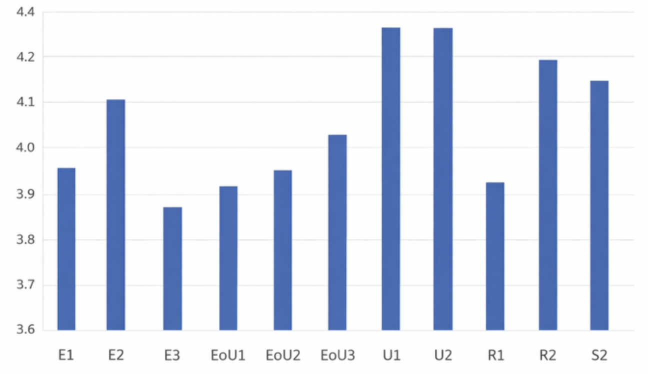

Fig. 4. Performance Aspect Graph

3) Student Responses to Media

Media suitability was assessed based on cadet responses, which were analyzed using descriptive statistics (averages and percentages) (Marjuki, 2021). Thirteen questions were used to evaluate the media's suitability and acceptability. The thirteen questions were grouped into five categories: usefulness, ease of use, engagement, relevance, and satisfaction (Kohler & Dietrich, 2021).

The cadets provide an assessment by giving a score between 1 and 5 with the following assessment categories.

Table 7. Assessment Categories.

Average Score Range	Category Perception	Theoretical Interpretation (based on Kemp & Dayton + TAM)
4.21– 5.00	Very Positive	The media is very useful, easy to use, and increases learning motivation.
3.41 – 4.20	Positive	The media is effective, engaging, and worth using with a few improvements.
2.61 – 3.40	Neutral	The media is quite helpful, but does not fully support learning engagement.
1.81 – 2.60	Negative	The media is less relevant or difficult for students to use.
1.00 – 1.80	Very Negative	The media is ineffective and not accepted by students.

Table 8. Assessment of Cadet Respon to Media

No	Aspect	Perception					Score Average
		1	2	3	4	5	
		1. (Usefulness)					3,98
1	U1	0%	0%	29%	50%	21%	3,93
2	U2	0%	0%	14%	57%	29%	4,14
3	U3	0%	0%	29%	57%	36%	3,86
		2. (Ease of Use)					3,98
4	EoU1	0%	0%	29%	50%	21%	3,93
5	EoU2	0%	0%	29%	43%	29%	4,00
6	EoU3	0%	0%	29%	43%	29%	4,00
		3. (Engagement)					4,26
7	E1	0%	0%	29%	36%	36%	4,07
8	E2	0%	0%	7%	50%	43%	4,36
9	E3	0%	0%	7%	50%	43%	4,36

No	Aspect	Perception					Score Average
		1	*2*	*3*	*4*	*5*	
		4. (Relevance)					4,11
10	R1	0%	0%	21%	64%	14%	3,93
11	R2	0%	0%	7%	57%	36%	4,29
		5. (Satisfaction)					4,11
12	S1	0%	0%	7%	64%	29%	4,21
13	S2	0%	0%	29%	43%	29%	4,00

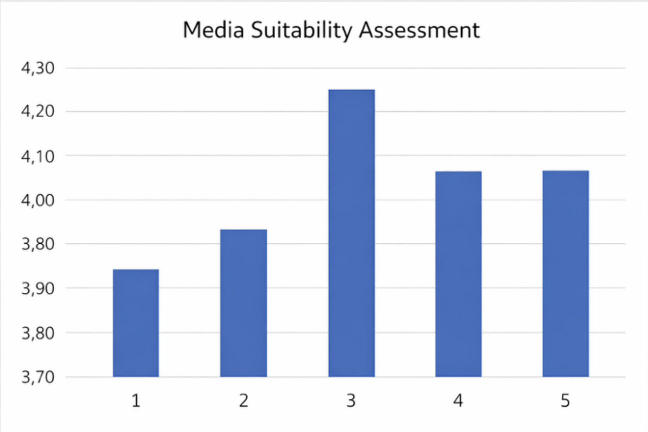

Fig. 5. The Average Respon of Five Categories

Of the five categories, the average cadet response was positive. Regarding the usefulness aspect, the average cadet assessment was very positive. Especially in the aspect, the accompanying video clarifies the lab steps, and the worksheet makes you more confident in doing the lab, with 7% neutral, 50% positive, and 43% very positive.

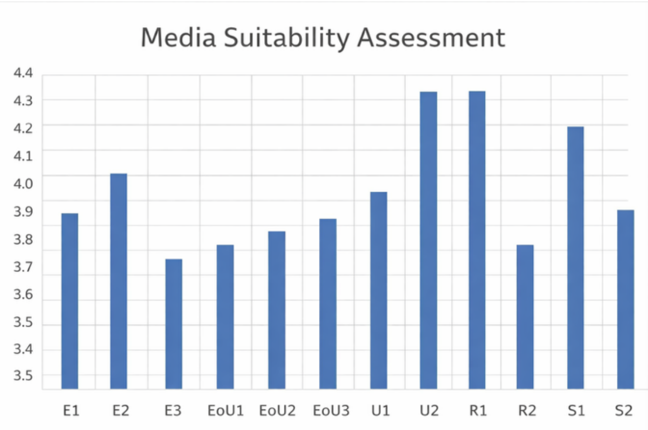

Fig. 6. The Average Respon of Five Categories

From the graph above, we can see that the cadets' responses were very positive for four statements, namely aspects U2, U3, R2, and S1. The accompanying video clarifies the lab steps; this worksheet makes them more confident in doing the lab; media meets the learning needs in the laboratory composite; and they are satisfied with using this media in learning composite practices (Wu, 2024).

On the other hand, the two statements with the lowest average response values were E3 and R1 (Onyeaka et al., 2023). This indicates that the combination of LKT and video makes learning more engaging, and cadets felt the material and examples in the videos aligned with actual composite practice activities (Park et al., 2023). However, these two statements were still in the positive response category above 3.40.

Most cadets agreed that the combination of worksheet guidance and video demonstrations made the learning process clearer, more engaging, and less intimidating than traditional methods (Resendiz-Calderón et al., 2024).

The aviation vocational education context presents unique instructional challenges compared to general engineering education (Utaminingsih et al., 2024). Composite engineering training requires high levels of procedural precision, safety awareness, and compliance with technical maintenance standards. Errors in procedural execution may directly affect material integrity and operational safety. Therefore, instructional media in this context must not only support conceptual learning but also reinforce procedural discipline, operational consistency, and safety-oriented behavior during laboratory practice (Hwang et al., 2022).

The findings should be interpreted cautiously because the study employed a one-group pretest-posttest design without a comparison group. Consequently, factors such as testing effects, maturation, and prior learning experiences may have partially contributed to the observed improvement. Future studies using randomized controlled designs are needed to strengthen causal interpretation (Sevim-Cirak & Yıldırım, 2020).

The findings of this study highlight the effectiveness of Video-Supported Interactive Worksheets (IVSW) in enhancing conceptual understanding and practical competency in composite engineering. The findings can also be interpreted through several learning theories relevant to multimedia and vocational learning (Anyan & Setyawan, 2022). From the perspective of Mayer's Cognitive Theory of Multimedia Learning, the combination of visual demonstrations through video and written procedural guidance through worksheets may reduce cognitive overload and support dual-channel information processing (Zhu et al., 2022). The videos provide visual and auditory representations of composite procedures, while the worksheets organize procedural steps systematically, enabling cadets to process information more effectively (Koh & Ahn, 2023).

This finding indicates that the primary contribution of IVSW may not lie in significantly increasing abstract conceptual understanding, but rather in supporting procedural readiness and reducing uncertainty during laboratory practice (Alharbi et al., 2024). In aviation vocational education, procedural confidence and operational accuracy are critical components of competency development. Therefore, even modest conceptual gains may still have practical educational value when accompanied by improvements in procedural performance, safety compliance, and task efficiency.

Furthermore, the IVSW design reflects the concept of scaffolding, in which learners receive structured support during complex procedural tasks. The worksheet functions as step-by-step guidance, while the videos model correct procedures and expected outcomes. This approach is also aligned with cognitive apprenticeship theory, particularly in the aspects of modeling and guided practice, where learners observe expert demonstrations before independently performing technical procedures in the laboratory (Delcker & Ifenthaler, 2022).

First, the increase in posttest scores indicates that the integration of guided worksheets with video simulations can bridge the gap between theory and practice. Several studies have demonstrated the effectiveness of this approach. Wulandari's (2021) research results show that the integration of augmented reality with teaching materials and learning models can support student learning processes and outcomes. It was also found that problem-based augmented reality makes learning more meaningful (Wulandari et al., 2021). Gorbunova et al. suggested that instead of comparing inductive and deductive methods, future research should also include inductive methods that use various types of supported problem solving, combined with expository and investigative instruction (Gorbunova et al., 2023). Interactive video interventions have shown significant positive effects on cognitive learning outcomes across studies. D. Gunawan et al., 2020 found that interactive video increased the mean score from 71.59 to 79.54 (t=3.252, p=0.02) (Gunawan et al., 2020). Bayu Ahsani Marjuki et al., 2021 reported a dramatic increase from 26.08 to 80.33 (t=15.708) (Marjuki, 2021). This is in line with the model developed in this study, which states that worksheets supported by video tutorials have been shown to improve conceptual understanding from an average pre-test score of 76.71 to 79.00 in the post-test.

However, the change in conceptual mastery learning outcomes in the post-test of 2.29 did not indicate a significant increase. This occurred because the addition of video to the worksheet was more beneficial in improving practical understanding, not conceptual understanding. This is in line with research by S. Kohler (2021) that media designs that combine worksheets and videos are indeed effective for procedural demonstrations and practical preparation, but recent evidence shows that video alone is often insufficient to promote deep conceptual understanding. This study reported that the effectiveness of video is highly dependent on the presence of active learning prompts, scaffolding, or integration in a blended/interactive learning model. Without it, conceptual improvement tends to be minimal or only occurs in participants who already have prior knowledge (Kohler & Dietrich, 2021). Other research confirms that strategies such as inserting interactive questions, annotations, structured discussions, or the use of simulations/AR that complement videos can enhance deep processing and knowledge transfer. Therefore, a multimodal approach that combines worksheets and videos with active methods (e.g., in-video quizzes, reflective pit stops, peer instruction, or simulated practice) is more effective in building stable concepts than passive video alone (Kohler & Dietrich, 2021). Therefore, the findings of this study suggest that IVSW may provide limited support for conceptual understanding, particularly in helping cadets connect procedural demonstrations with theoretical content. However, the relatively small increase in post-test scores indicates that additional active learning strategies such as in-video quizzes, guided discussions, reflective prompts, or simulation-based interaction may still be necessary to achieve deeper conceptual mastery.

Second, media design that combines directed worksheets with video demonstrations has been proven to improve performance in terms of time usage, meaning that with IVSW cadets will more easily understand and comprehend a series of experiments so that it will shorten learning time. The aspect with the second highest value is Safety Compliance, this provides evidence that with IVSW cadets will be more concerned and implement safety procedures properly and correctly.

Overall, the results showed that IVSW enabled cadets to perform laboratory activities with greater precision and reduced errors compared to conventional instruction. This is in line with the research of Onyeanka et al. that pre-practical videos allow students to visually observe technical steps and internalize the work sequence before direct practice, thereby reducing procedural errors during execution (Wu, 2024). In addition, the integration of videos with written guidance supports compliance with occupational safety, use of PPE, handling of hazardous materials, and critical points of K3 so that participants are better prepared and consistently comply with safety protocols during laboratory practice (Onyeaka et al., 2023). Finally, the combination of worksheets and videos also contributes to time efficiency (reducing total task execution time), because cognitive preparation through videos reduces trial-and-error time in the workshop and accelerates the implementation of operational steps with more direction (Park et al., 2023).

However, no studies have directly examined the application of IVSW in composite engineering specifically, so the conclusion of this study provides a reference that the improvement in practical performance indicates that IVSW provides procedural clarity and reduces trial-and-error errors. By watching video demonstrations before practice, cadets are able to mentally simulate the steps and anticipate potential challenges. This aligns with cognitive apprenticeship theory, which emphasizes the importance of modeling, scaffolding, and guided practice in skill development.

The positive responses of the cadets indicate that the media design is not only pedagogically effective but also motivationally engaging. Previous studies have demonstrated that interactive simulation media and learning videos effectively enhance conceptual understanding and practical skills among engineering students, with significant improvements in conceptual understanding scores, procedural accuracy, work safety, and positive student responses averaging above 4 through visualization and active engagement (Utaminingsih et al., 2024). Ekayanti et al. (2023) developed a STEM-based student worksheet equipped with a video simulation component, with validation results showing good feasibility based on evaluations by material and media experts. Similarly, Saputri and Jasuri (2023) reported a moderate increase in material comprehension (gain score = 0.53) through video-based practical training. Ningrum (2023) found that worksheets assisted by animated videos achieved a validity level of 88.13% and practicality of 91.05%. Hwang et al. (2022) demonstrated that integrating simulation-based and augmented reality (AR) learning environments significantly improves both conceptual understanding and procedural skills in engineering education. Students exposed to AR-supported simulations exhibited higher motivation, engagement, and accuracy in performing practical tasks compared to those taught using conventional methods. These findings affirm the pedagogical value of interactive and visually rich learning media that connect theoretical concepts with real-world applications. Furthermore, Sevim-Cirak and Yıldırım (2019, 2020) examined the educational and motivational effects of game-based simulations and found that such media effectively enhance conceptual visualization, procedural understanding, and student motivation. Their phenomenological study revealed that interactive and challenging simulation environments foster curiosity, engagement, and self-confidence while supporting experiential learning processes such as observation, hypothesis testing, and decision-making. Collectively, these studies confirm the pedagogical potential of interactive simulation tools in facilitating experience-based learning without the risks inherent in real practice.

Regarding motivational appeal, (Anyan Anyan et al., 2022) found that interactive learning videos effectively increase student motivation, making learning "less monotonous and more engaging." (Anyan & Setyawan, 2022). Learning designs that combine structured worksheets with short videos have been shown to improve cognitive engagement and learning outcomes for example, studies have shown that the use of short videos significantly increases student engagement and final exam scores (Zhu et al., 2022). Furthermore, videos designed to encourage participation (student-engaged videos) increase learning motivation and instructional appeal, making students more motivated to repeat and practice technical procedures (Koh & Ahn, 2023). Consistent evidence from systematic reviews also confirms the effectiveness of simulation-based learning (including low-fidelity approaches) in strengthening procedural skills and retention of practical skills (Alharbi et al., 2024). In the context of vocational education, the combination of worksheets and videos has been widely used during distance learning and has been shown to maintain the quality of practical learning and reduce barriers to access to laboratory facilities (Delcker & Ifenthaler, 2022). In general, the engineering and health education literature suggests that the integration of interactive visual media and practical scenarios (even low fidelity) helps students map abstract concepts to concrete actions, while increasing motivation, confidence, and procedural adherence (Elendu et al., 2024).

In summary, this study confirms that integrating worksheets with videos can be an effective, low-cost, and scalable alternative to high-fidelity simulators, especially in vocational education contexts such as aviation polytechnics. The interactive format allows cadets to take more responsibility for their learning process, while the embedded videos support a variety of learning styles, particularly for visual and kinesthetic learners.

Despite the advantages of using YouTube-based instructional videos as accessible learning resources, several limitations should be acknowledged. Online video content may change, become unavailable, or vary in pedagogical quality over time (Suhanto et al., 2024). To minimize this issue, the selected videos were carefully reviewed by the researchers based on relevance to course objectives, procedural accuracy, and safety compliance before being integrated into the worksheet. Nevertheless, future development is recommended to produce institutionally controlled instructional videos to ensure long-term accessibility, content consistency, and pedagogical standardization.

Regarding motivational appeal, previous studies have consistently demonstrated that the integration of interactive multimedia elements can positively influence students' motivation, engagement, and learning outcomes. For example, (Anyan Anyan et al., 2022) found that interactive learning videos effectively increase student motivation by making learning activities less monotonous and more engaging (Anyan & Setyawan, 2022). The visual and auditory features of video-based learning provide learners with opportunities to observe procedures repeatedly, thereby reducing cognitive barriers associated with complex technical content. Similarly, learning designs that combine structured worksheets with short instructional videos have been reported to enhance cognitive engagement and improve academic achievement, with several studies indicating significant increases in student participation, knowledge retention, and final examination performance (Zhu et al., 2022). Furthermore, videos designed to actively involve learners through observation, reflection, and guided participation have been shown to increase learning motivation and instructional attractiveness, encouraging students to repeatedly review and practice technical procedures until mastery is achieved (Koh & Ahn, 2023).

The positive outcomes observed in this study are also consistent with the broader literature on simulation-based learning. Numerous systematic reviews have concluded that simulation-based educational approaches, including low-fidelity simulations, are effective in strengthening procedural competence, improving skill retention, and enhancing learner confidence in performing practical tasks (Alharbi et al., 2024). Although high-fidelity simulators offer highly realistic training environments, they often require substantial financial investment, specialized facilities, and ongoing maintenance. Consequently, many vocational institutions face challenges in implementing such technologies on a large scale. In contrast, low-fidelity learning environments supported by instructional media such as worksheets and videos can provide meaningful learning experiences while remaining affordable and accessible. The present study demonstrates that IVSW can serve as a practical alternative by enabling cadets to visualize procedures, understand operational sequences, and mentally rehearse practical activities before entering laboratory sessions.

From a cognitive learning perspective, the integration of worksheets and videos may support learning through multiple mechanisms. The worksheet functions as a structured guide that organizes learning activities, directs attention to key concepts, and promotes active information processing. Meanwhile, embedded videos provide visual demonstrations that help learners connect theoretical explanations with practical actions. This combination aligns with multimedia learning theory, which suggests that students learn more effectively when information is presented through both verbal and visual channels. By simultaneously engaging multiple cognitive pathways, learners may develop more accurate mental models of composite engineering procedures and materials. In aviation composite engineering, where learners must understand complex repair techniques, material properties, and safety requirements, such multimodal learning support is particularly valuable.

The findings are also relevant to vocational education, where learning outcomes depend not only on conceptual understanding but also on the ability to perform technical procedures accurately and safely. During practical sessions, learners are often required to remember multiple sequential steps while adhering to strict operational standards. Embedded instructional videos provide immediate procedural references that can be revisited whenever necessary, thereby reducing uncertainty and supporting independent learning. As a result, cadets can spend more time focusing on skill development rather than attempting to recall procedural instructions from memory alone. This feature may contribute to greater learning autonomy, self-regulation, and confidence during laboratory activities.

In the context of vocational and technical education, the combination of worksheets and videos gained significant attention during periods of distance learning and restricted laboratory access. Previous studies have reported that such learning media can maintain the quality of practical instruction, facilitate self-paced learning, and reduce barriers related to equipment availability and laboratory scheduling (Delcker & Ifenthaler, 2022). Even after the return of face-to-face instruction, these tools continue to offer substantial benefits by extending learning opportunities beyond the classroom and supporting preparation before practical sessions. For aviation vocational institutions that frequently face constraints related to equipment costs, laboratory capacity, and instructor availability, scalable digital learning resources represent an important complement to conventional teaching methods.

More broadly, evidence from engineering, health sciences, and vocational education suggests that the integration of interactive visual media with practical learning scenarios can help students translate abstract concepts into concrete actions (Elendu et al., 2024). By observing real procedures and immediately applying them through guided activities, learners can strengthen the connection between conceptual knowledge and psychomotor performance. Such learning experiences have been associated with increased motivation, greater confidence, improved procedural adherence, and reduced errors during skill execution. These benefits are particularly important in safety-critical disciplines such as aviation maintenance, where procedural accuracy and compliance with technical standards directly influence operational safety.

In summary, this study supports the growing body of evidence indicating that the integration of structured worksheets and instructional videos can serve as an effective, low-cost, and scalable alternative to more resource-intensive simulation technologies. The IVSW developed in this study enables cadets to engage actively in the learning process, encourages self-directed learning behaviors, and accommodates diverse learning preferences, particularly among visual and kinesthetic learners. By combining procedural guidance with multimedia demonstrations, the learning media not only supports conceptual understanding but also enhances readiness for practical performance in aviation composite engineering training.

Despite these advantages, several limitations associated with the use of YouTube-based instructional videos should be acknowledged. Online video content may change, become unavailable, be removed by content creators, or vary considerably in pedagogical quality over time (Suhanto et al., 2024). Differences in production standards, instructional clarity, and technical accuracy may influence the consistency of learning experiences across cohorts. To mitigate these risks, all videos included in the IVSW were carefully reviewed and selected by the researchers based on their alignment with course learning outcomes, procedural accuracy, technical relevance, and compliance with aviation safety requirements before being integrated into the worksheet. Nevertheless, reliance on external video platforms remains a potential limitation for long-term implementation. Therefore, future development should focus on producing institutionally controlled instructional videos that are specifically tailored to course objectives and local training requirements. Such an approach would improve content consistency, ensure long-term accessibility, facilitate periodic updates, and provide greater quality assurance. Future versions of IVSW could also incorporate interactive features such as embedded quizzes, branching scenarios, adaptive feedback mechanisms, augmented reality visualizations, and virtual simulation components to further enhance learner engagement, conceptual understanding, and practical skill acquisition in aviation vocational education.

IV. Conclusion

In summary, this study developed and evaluated the Interactive Video-Supported Worksheet (IVSW) as an innovative learning medium for aviation composite engineering education. The findings indicate that combining structured worksheets with embedded instructional videos effectively enhances conceptual understanding and practical skills, functioning as a low-fidelity simulation tool that supports procedural training and laboratory readiness. Cadets reported high satisfaction with IVSW's clarity, usability, and relevance to real-world practice, highlighting its potential as a cost-effective and scalable solution for vocational institutions. However, limitations such as small sample size, short intervention duration, and the absence of a control group restrict the generalizability of the results. Future research should employ larger samples, extended intervention periods, and controlled experimental designs to strengthen evidence of IVSW's effectiveness. Further development is recommended through the integration of advanced technologies such as augmented reality (AR), virtual simulation environments, in-video quizzes, and adaptive feedback systems to foster active learning, procedural accuracy, and long-term retention. Multi-institutional and longitudinal studies are also needed to examine IVSW's impact on conceptual mastery, skill transfer, motivation, and professional competency across diverse aviation training contexts, ensuring sustainable learning outcomes and workforce readiness in safety-critical environments.

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