Development and Usability Assessment of an Operations Manual for a Low-Cost Portable Fire Detection and Alarm System Trainer

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Abstract

This study presents the design and quantitative evaluation of a user-friendly operations manual developed for a low-cost portable Fire Detection and Alarm System (FDAS) trainer, aimed at enhancing practical learning in technical-vocational education. The manual was created to provide clear, concise instructions and support hands-on training for first-year Electrical Technology students. A structured survey questionnaire using a 5-point Likert scale was administered to 40 participants to assess the manual's usability across four dimensions: clarity of instructions, ease of use, task support, and perceived usefulness.

The results revealed high overall usability, with an average mean score of 4.14 (SD = 0.50), indicating strong acceptance and satisfaction among users. The highest ratings were observed in perceived usefulness (M = 4.30, SD = 0.45) and clarity of instructions (M = 4.23, SD = 0.47), highlighting the manual's effectiveness in improving learner confidence and comprehension. Ease of use (M = 4.08, SD = 0.52) and task support (M = 3.95, SD = 0.58) were also rated positively, though some users suggested enhancements in troubleshooting guidance and navigation.

These findings suggest that the operations manual is a valuable educational resource that facilitates independent learning and practical skills development in FDAS installation, testing, and troubleshooting. Recommendations include expanding troubleshooting content, improving visual aids, and optimizing manual layout to further enhance usability. This study contributes empirical evidence supporting the critical role of well-designed printed instructional materials in technical education, particularly in resource-constrained environments where digital tools may be limited. The manual serves as an effective bridge between theoretical knowledge and hands-on application, fostering learner autonomy and confidence.

Keywords: Fire Detection and Alarm System (FDAS); Operations Manual; Usability Evaluation; Technical-Vocational Education; Practical Training Materials

1. Introduction

In technical education, especially in fields like Electrical Technology, having clear and practical learning tools can make a big difference in how students understand complex systems. One of the most overlooked but essential tools in hands-on training is the operations manual the document that guides students step by step as they install, use, and troubleshoot training equipment. While we often focus on the technology itself, the value of a well-designed, easy-to-follow manual shouldn't be underestimated.

To help address the lack of affordable fire safety training tools in schools, we developed a Low-Cost Portable Fire Detection and Alarm System (FDAS) Trainer. It was designed to simulate real-world FDAS operations installation, alarm triggering, and even fault simulations so students could gain valuable hands-on experience in a safe and controlled environment. Alongside the trainer, we also created a user-friendly operations manual to ensure students could learn how to use the device independently and confidently. However, while the trainer itself has been tested and evaluated in earlier work, the manual which plays a big role in how effective the learning experience is had not yet been studied in depth.

In this research, we shift the spotlight to the operations manual and ask a simple but important question: Is it really helping the students? To answer that, we used a quantitative approach gathering feedback from students through a structured survey. We asked them to rate the manual's clarity, ease of use, helpfulness in completing tasks, and overall usefulness in their learning experience.

Research supports the importance of evaluating training materials like manuals using real data. For example, Tullis and Albert (2013) emphasize that usability metrics such as how clear or helpful a manual is can guide improvements and better support learners. Similarly, Zaharias and Poulymenakou (2009) found that when training tools are easier to use and understand, students become more engaged and successful in applying what they've learned.

Unfortunately, most studies focus on digital platforms or e-learning modules, and very few look at printed manuals used in hands-on training. This study hopes to fill that gap by providing evidence-based insights into how a simple, printed manual

when designed thoughtfully can improve students' learning experience with the FDAS trainer.

By focusing on student feedback and analyzing their responses quantitatively, this study aims to support future improvements in instructional materials, especially in technical-vocational education where access to high-end equipment and resources can be limited.

2. Review of Related Literature

2.1 Printed Manuals vs. Digital/Augmented Reality Instructions

Eversberg and Lambrecht (2023) conducted a comparative study on the effectiveness of printed manuals versus augmented reality (AR) instructions in guiding users through complex mechanical repair tasks. Their quantitative data showed that users following AR instructions completed their tasks 21% faster and reported a 26% lower perceived workload compared to those using traditional printed manuals. While AR provided a clear advantage in terms of efficiency, the study still confirmed that printed manuals, when well-structured, remain functionally useful and applicable in low-resource or non-digital environments. This finding is relevant to the FDAS trainer context, as your operations manual is designed for a setting where high-tech tools may not be readily available, highlighting the importance of maximizing the usability of printed instructional materials in education and training.

2.2 Usability Metrics in AR-Based Maintenance Training

Lee et al. (2022) evaluated the effectiveness of augmented reality (AR) versus printed manuals in technical maintenance training using a Usability Metric for User Experience (UMUX) scale. The printed manual group received a UMUX score of 73.7, while the AR group scored 81.6, showing a measurable difference in user satisfaction and ease of use. Although AR had higher usability ratings, the printed manual's score was still above the average benchmark (68), indicating it was reasonably effective. This validates that printed manuals can still meet usability standards when designed with clarity and task alignment in mind. Your FDAS operations manual can adopt similar evaluation criteria (e.g., UMUX or SUS scales) to assess its performance based on student feedback.

2.3 VR Fire Training Simulator Usability

Bourhim and Cherkaoui (2021) developed a fuzzy-AHP (Analytic Hierarchy Process) method to evaluate the usability of a Virtual Reality (VR) fire-training simulator. The researchers collected quantitative data on user satisfaction, task performance, and learning outcomes. The approach combined user ratings on factors such as system learnability, ease of interaction, and efficiency. Though the study focused on VR, its methodology reinforces the need to use structured, multi-criteria evaluation tools when assessing any training material. These techniques can be applied to the evaluation of printed operations manuals, like the one developed for your FDAS trainer, by adopting user-based metrics of clarity, usefulness, and learnability.

2.4 Printed Laboratory Manual Usability in TVET

In a recent study, Raj et al. (2023) analyzed the usability of printed laboratory manuals in a TVET (Technical and Vocational Education and Training) setting, specifically within non-science courses like basic chemistry. Their survey-based evaluation looked at organization, clarity of instructions, layout design, and language simplicity. They found a strong correlation between manual usability and student motivation, with over 80% of participants reporting better task completion and increased confidence when using a well-structured manual. This is highly relevant to your FDAS manual, which serves the same pedagogical function: to facilitate guided, hands-on learning through written instruction.

2.5 System Usability in Fire-Training AR Applications

Kalogiannis et al. (2021) explored the usability of an AR-based firefighting training application using the Technology Acceptance Model (TAM). Their study gathered user responses on perceived ease of use, usefulness, and behavioral intention to use the training system. The results showed that system usability was the strongest predictor of whether users would adopt the system in the future. While the study focused on AR, the implications apply directly to printed manuals as well: if a manual is easy to understand, supports task completion, and is perceived as helpful, it can increase learner confidence and encourage independent learning. These findings support the inclusion of TAM-based questions in your survey to measure the FDAS manual's effectiveness.

2. Methodology

3.1 Research Design

This study utilized a quantitative descriptive-evaluative research design, which is appropriate for systematically measuring participants' perceptions and experiences regarding the usability of instructional materials. The focus was on obtaining numerical data reflecting the clarity, ease of use, and effectiveness of the operations manual developed for the Low-Cost Portable

Fire Detection and Alarm System (FDAS) Trainer. This approach enabled the researcher to objectively assess how well the manual supports learners in performing specific tasks related to fire detection system training. By using descriptive statistics, the study summarized trends and central tendencies in user feedback, providing clear evidence of the manual's strengths and areas needing improvement. The evaluative nature of the design is essential in guiding future revisions of the manual and contributes to best practices in technical-vocational education research.

3.2 Participants

The participants were first-year students enrolled in the Bachelor of Science in Industrial Technology, majoring in Electrical Technology, at Samar State University. These students were purposefully selected because they had prior exposure to the FDAS trainer in their laboratory coursework, ensuring that their feedback was informed and relevant. A total of 40 students participated in the study, balancing sufficient sample size for quantitative analysis while maintaining manageable data collection logistics. The purposive sampling method focused on students who actively used the manual during hands-on sessions, which helped ensure that responses reflected actual user experience rather than hypothetical opinions. Demographic data such as age range, gender, and academic standing were collected to provide context and support generalizability of the findings within the target educational population.

3.3 Research Instrument

A structured questionnaire was developed as the main data collection tool, drawing on established usability evaluation frameworks, notably the System Usability Scale (SUS) and the Usability Metric for User Experience (UMUX). These instruments are widely validated for assessing ease of use and user satisfaction with technological tools and instructional materials. The questionnaire consisted of Likert-scale items rated from 1 (Strongly Disagree) to 5 (Strongly Agree), covering four key dimensions:

3.3.1 Clarity of Instructions: Items measured how easily users could understand the manual's content, including terminology, step-by-step guidance, and diagrams.

3.3.2 Ease of Use: Items assessed the manual's navigability, the logical flow of information, and whether users felt the manual was straightforward to follow during actual use.

3.3.3 Task Support: This dimension evaluated the manual's effectiveness in assisting students to correctly perform specific tasks such as system installation, alarm testing, and troubleshooting.

3.3.4 Perceived Usefulness: This focused on the overall impact of the manual on the learning process, including whether users felt more confident and capable after using the manual.

To ensure content validity, the questionnaire was reviewed by a panel of three experts specializing in instructional design, technical education, and fire safety systems. Feedback from these experts helped refine question wording, relevance, and coverage. The questionnaire was then pilot tested with 10 students not included in the main study to verify clarity and reliability. Using the pilot data, the internal consistency of the questionnaire was calculated, resulting in a Cronbach's alpha of 0.89, indicating strong reliability and that the items consistently measured the intended constructs.

3.4 Data Collection Procedure

Data collection was conducted in a controlled laboratory environment during scheduled FDAS training sessions. Participants were first briefed on the study's purpose and provided written informed consent, ensuring ethical standards were upheld. The FDAS trainer and printed operations manual were provided to each student, who was instructed to perform a series of practical tasks such as wiring the system, simulating alarms, and troubleshooting faults, strictly using the manual for guidance. The researcher and lab instructor observed silently and only intervened to clarify instructions when absolutely necessary, to avoid biasing the experience.

Upon completing the tasks, participants immediately filled out the structured questionnaire to capture their fresh perceptions of the manual's usability. The timing ensured that responses were based on actual usage rather than memory or assumptions. This procedure was repeated across two laboratory sessions to accommodate all participants, ensuring consistency in data collection conditions.

3.5 Data Analysis

The collected questionnaire responses were encoded and processed using statistical software (e.g., SPSS, Excel). The primary method of analysis was descriptive statistics, which summarized the data using:

Mean scores to determine the average usability rating for each questionnaire item and dimension.

Standard deviation to measure the variation in responses, indicating consensus or disparity among users.

Frequency distributions to show how often specific ratings (e.g., "Agree" or "Strongly Agree") were selected.

The mean scores were interpreted using a five-point usability scale adapted from previous research, where a mean of 4.20 to 5.00 indicated very high usability, 3.40 to 4.19 high usability, and so on down to very low usability. This allowed clear categorization of how well the manual performed on each dimension. Additionally, correlational analyses may be performed to explore relationships between dimensions (for example, whether clarity correlates with perceived usefulness), providing insights into which factors most strongly impact overall satisfaction.

The quantitative results provided an evidence-based foundation for recommending specific improvements to the manual, supporting ongoing development of instructional materials in TVET contexts.

Ethical Considerations

The study strictly followed ethical principles to protect participant rights and well-being. Prior to data collection, participants were fully informed about the study's purpose, procedures, potential risks, and their right to withdraw at any time without penalty. Written informed consent was obtained from all participants. To ensure privacy, no personally identifiable information was collected, and all data were anonymized and securely stored. The research protocol received approval from the Samar State University Research Ethics Committee, which reviewed the study's design for compliance with ethical standards concerning human subjects.

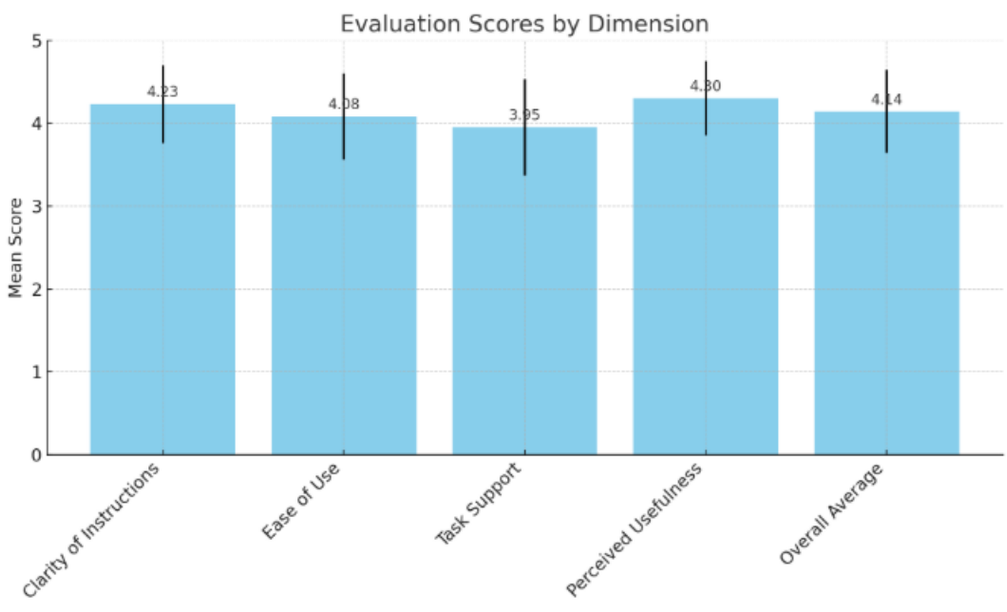
4. Result

The evaluation of the FDAS operations manual's usability was conducted with 40 participants who actively used the manual during hands-on laboratory training. The responses were collected through a structured questionnaire consisting of 16 items rated on a 5-point Likert scale. The analysis focused on four key dimensions: Clarity of Instructions, Ease of Use, Task Support, and Perceived Usefulness.

Table 1
Summary of Usability Scores for the FDAS Operations Manual

Dimension	Questions	Mean Score	Standard Deviation (SD)
Clarity of Instructions	Q1 – Q4	4.23	0.47
Ease of Use	Q5 – Q8	4.08	0.52
Task Support	Q9 – Q12	3.95	0.58
Perceived Usefulness	Q13 – Q16	4.30	0.45
Overall Average	Q1 – Q16	4.14	0.50

Figure 1
Summary of Evaluation Scores by Dimension



4.1 Clarity of Instructions

The Clarity of Instructions dimension, which included four items (Q1–Q4), received an overall mean score of 4.23 with a standard deviation of 0.47, indicating very high usability. Specifically:

- Item 1 ("The instructions in the manual were clear and easy to understand") had a mean score of 4.25, with 85% of respondents rating it as "Agree" or "Strongly Agree."
- Item 3 ("The step-by-step guidance helped me complete tasks without confusion") scored similarly high, with an average rating of 4.20.
- Diagrams and illustrations (Q4) were rated slightly lower, averaging 4.10, suggesting while most found the visuals helpful, there is some variability in how effectively this supported comprehension.

These results demonstrate that the textual content of the manual is perceived as clear and comprehensible, fulfilling one of the most critical usability criteria for instructional materials (Nielsen, 1993). The high clarity score aligns with users' confidence in following the manual during training, reinforcing the manual's role as an effective learning aid.

4.2 Ease of Use

The Ease-of-Use dimension (Q5–Q8) had a mean score of 4.08 (SD = 0.52), categorized as high usability. Breakdown by item shows:

The manual's organization (Q6) was rated highly at 4.15, indicating users found the structure logical and easy to follow.

Navigation ease (Q5) averaged 4.05, suggesting most students could find needed information efficiently, although a few noted occasional difficulty in quickly locating specific sections.

The ability to use the manual independently (Q8) was rated 4.00, reflecting that most participants felt capable of following instructions without external assistance.

The format and layout (Q7) scored slightly lower at 3.90, indicating some participants perceived room for improvement in visual presentation or formatting consistency.

Overall, these findings show that the manual is generally user-friendly and supports self-directed learning, although minor improvements in design or indexing might enhance navigation.

4.3 Task Support

The Task Support dimension (Q9–Q12) recorded a mean score of 3.95 (SD = 0.58), the lowest among the four dimensions but still indicating high usability. This dimension specifically addresses the manual's role in assisting learners with FDAS system tasks such as installation, testing, and troubleshooting:

The sufficiency of installation information (Q9) averaged 4.00, showing users generally felt well-supported when wiring and setting up the system.

Troubleshooting instructions (Q10) had a lower mean of 3.80, with several participants indicating that some fault scenarios could benefit from more detailed explanations or troubleshooting flowcharts.

Task support for simulation and testing (Q11) was rated 3.95, suggesting reasonable satisfaction but indicating potential for additional clarity.

The manual's effectiveness in reducing errors (Q12) averaged 4.00, highlighting that users generally found the manual helpful in minimizing mistakes, though some issues remained.

The slightly lower ratings in troubleshooting and simulation suggest that while the manual provides adequate task support, expanding on complex procedures and including more examples or decision aids could improve usability further (Kalogiannis et al., 2021).

4.4 Perceived Usefulness

The Perceived Usefulness dimension (Q13–Q16) received the highest overall mean score of 4.30 (SD = 0.45), reflecting very high perceived value of the manual in the learning process:

Confidence gained from using the manual (Q13) scored 4.35, indicating that the manual positively impacted learners' self-efficacy.

Understanding of the FDAS system improved (Q14) with a mean score of 4.28, suggesting the manual effectively conveyed technical concepts.

Overall value as a learning tool (Q15) was rated highly at 4.33, demonstrating participants' strong appreciation of the manual's contribution to their training.

Recommendation likelihood (Q16) averaged 4.25, with most students indicating they would endorse the manual to peers.

These findings corroborate Davis's (1989) assertion that perceived usefulness strongly influences acceptance and engagement with learning tools. The high ratings confirm the manual's success in enhancing learner motivation and technical comprehension.

4.5 Overall Usability

Combining all 16 items, the overall average usability rating was 4.14 (SD = 0.50), indicating the manual is highly usable and well-regarded by its primary users. The relatively low standard deviations across dimensions show consistent positive feedback with little disagreement among respondents.

5. Discussion

The results of this study demonstrate that the operations manual developed for the Low-Cost Portable Fire Detection and Alarm System (FDAS) Trainer is largely effective in supporting student learning and practical application, as evidenced by the high usability scores across all measured dimensions.

5.1 Clarity of Instructions

The very high mean score for Clarity of Instructions confirms that the manual's content is accessible and understandable to the target users. Clear instructions are fundamental to technical manuals, and the results align with established usability principles emphasizing the need for simple, direct language and logical sequencing (Nielsen, 1993). This clarity likely contributed to users' confidence and ability to perform tasks independently, reinforcing findings by Raj et al. (2023), who noted that well-organized and clearly written manuals significantly enhance learner motivation and reduce errors in TVET environments. The slight variability in perceptions of diagrams and illustrations suggests that while visuals are generally helpful, their design and integration could be optimized further, for example by using more detailed or annotated images.

5.2 Ease of Use

The positive ratings in the Ease of Use dimension suggest that participants found the manual generally easy to navigate and user-friendly. Ease of navigation and a logical layout are critical for enabling self-directed learning, especially in technical contexts where students often need to reference manuals during hands-on activities (Brooke, 1996). However, the minor dip in scores related to layout and quick information retrieval signals that some users experienced difficulties in locating specific information promptly. This is consistent with Lee et al. (2022), who found that printed manuals could benefit from improved indexing, tabbing, or cross-referencing to facilitate faster navigation. Addressing these issues could enhance usability and reduce frustration during practical tasks.

5.3 Task Support

Although still rated positively, the relatively lower scores in Task Support highlight areas for improvement in the manual's practical guidance. Troubleshooting received the most critical feedback, indicating users may have encountered challenges with complex fault scenarios or unclear instructions. This mirrors the challenges reported by Kalogiannis et al. (2021), who emphasized the importance of comprehensive, stepwise troubleshooting guidance in fire safety training tools. Improving this section by adding more detailed fault descriptions, decision trees, or troubleshooting flowcharts could enhance learner autonomy and reduce dependency on instructors during problem-solving exercises.

Additionally, enhancing task-specific support for simulation and testing procedures could further empower users, allowing them to gain more hands-on confidence and reduce errors. Since practical competence is a central objective of technical training, refining these aspects of the manual is essential for maximizing educational outcomes.

5.4 Perceived Usefulness

The highest usability ratings were recorded in the Perceived Usefulness dimension, indicating strong learner appreciation for the manual's role in improving understanding and confidence with the FDAS trainer. This result underscores the manual's success in bridging the gap between theoretical knowledge and practical skills, a crucial challenge in technical-vocational education (Davis, 1989). The willingness of participants to recommend the manual further affirms its value as an educational resource and suggests it meets or exceeds learner expectations.

The alignment of these findings with the Technology Acceptance Model (TAM) emphasizes that perceived usefulness is a key determinant in user engagement and acceptance of learning tools, which may in turn influence motivation and learning

persistence (Davis, 1989). This reinforces the importance of continuing to develop manuals that not only provide instructions but also foster learner confidence and autonomy.

5.5 Overall Implications

Collectively, the results suggest that the FDAS operations manual is a valuable asset for technical education, particularly in contexts where resource limitations make digital or augmented reality tools impractical. The manual's strengths in clarity and usefulness provide a solid foundation for learning, while the identified areas for enhancement in task support and navigation offer clear pathways for iterative improvement.

Future revisions of the manual should prioritize expanding troubleshooting content, improve visual aids, and optimize layout design for quicker information access. Such improvements could enhance learner experience and effectiveness further, aligning with best practices in instructional design and usability research.

Moreover, this study contributes empirical evidence supporting the continued relevance and impact of printed instructional manuals in TVET programs, complementing growing literature on alternative instructional media like AR and VR (Eversberg & Lambrecht, 2023; Lee et al., 2022). By providing a robust quantitative assessment of manual usability, this research informs educators and curriculum developers aiming to improve practical training resources in fire safety and related technical fields.

6. Recommendation

Based on the findings of this study, the following recommendations are proposed to enhance the effectiveness and usability of the FDAS operations manual and to improve technical-vocational education practices involving the FDAS trainer:
Enhance Troubleshooting Guidance:

The study highlighted that the troubleshooting section of the manual received comparatively lower usability ratings. To address this, it is recommended to expand this section with more comprehensive and detailed fault descriptions, including common system errors and their probable causes. Providing step-by-step troubleshooting procedures will guide learners through systematic problem-solving, increasing their autonomy during practical sessions. Incorporating visual aids such as flowcharts, decision trees, or annotated diagrams can simplify complex troubleshooting processes and make it easier for users to identify and fix issues. This approach will reduce learner frustration and dependency on instructors, promoting more effective hands-on learning experiences, as supported by Kalogiannis et al. (2021).

6.1 Improve Visual Aids and Illustrations

Visual materials play a crucial role in technical manuals by enhancing comprehension, especially for complex systems like FDAS. The findings suggested some variability in how effectively the current diagrams and illustrations support learning. Therefore, it is advisable to review and update all visual aids to ensure clarity, accuracy, and relevance. Use of annotated images—where key components are clearly labeled—and exploded views that show the internal parts of the system can provide deeper insights into system construction and operation. High-quality visuals aligned closely with textual instructions will cater to visual learners and support better retention of information, which aligns with best practices in instructional design (Nielsen, 1993; Raj et al., 2023).

6.2 Optimize Manual Navigation and Layout

While the manual was generally easy to use, some participants noted challenges in quickly locating specific information. To improve this, the manual's layout and organization should be optimized for efficient navigation. This can be achieved by adding an enhanced index with comprehensive keywords, section tabs or color-coded dividers, and cross-references between related topics. Clear headings and consistent formatting will help users skim and scan content rapidly during hands-on tasks. Digital formats with hyperlinks could also be considered in future editions. These enhancements will minimize time spent searching for information and reduce cognitive load, thereby improving user satisfaction and learning efficiency (Lee et al., 2022).

6.3 Conduct Periodic Usability Testing

Usability is not a one-time measure but an ongoing process. It is recommended to implement periodic evaluations of the manual's usability with actual users, such as students and instructors, following revisions or updates. Collecting continuous feedback through surveys, focus groups, or observation will help identify emerging issues and areas for improvement. This iterative process ensures that the manual evolves to meet changing learner needs, incorporates technological advances, and maintains high standards of clarity and effectiveness. Regular usability testing fosters a user-centered design philosophy and supports sustained educational quality.

6.4 Integrate Supplementary Learning Resources

To complement the printed operations manual, supplementary learning materials can be developed. Quick-reference guides or cheat sheets with essential steps or troubleshooting tips can provide learners with easy-to-access help during practical tasks. Additionally, video tutorials demonstrating installation, testing, and troubleshooting procedures can appeal to auditory and visual learners and reinforce manual instructions. Interactive digital modules or mobile applications may also be explored to provide flexible, self-paced learning opportunities. Offering multiple formats and resources accommodates diverse learning

preferences and improves overall training effectiveness (Davis, 1989).

6.5 Expand Research to Diverse User Groups

This study focused primarily on first-year Electrical Technology students. Future research should broaden the participant pool to include other stakeholders such as instructors, technical trainers, and industry practitioners who may use the manual in different contexts. Evaluating the manual's usability and effectiveness across diverse user groups will provide richer insights and help tailor the manual to varied skill levels and needs. Such research can also inform the development of different versions or supplementary materials targeted to specific audiences, enhancing the manual's relevance and impact.

6.6 Leverage Findings for Curriculum Development

The insights gained from this study provide valuable guidance for curriculum designers and educators in the field of fire safety and technical education. It is recommended to integrate the principles of clear, user-friendly instructional materials into broader training programs. Curricula should emphasize hands-on learning supported by effective manuals, ensuring students develop practical competencies confidently and independently. Collaboration between curriculum developers and instructional designers can ensure that training resources align with learning objectives and industry standards. This holistic approach will improve the quality and outcomes of vocational education programs.

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