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Design, Development, and Expert Validation of a CCTV Operation Mock-up Trainer for Industrial Arts Education

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ABSTRACT

Traditional CCTV operation instruction in technical-vocational education relies heavily on theoretical concepts and lacks fully equipped physical hardware, limiting students' practical skill acquisition due to operational restrictions associated with live surveillance systems. To address this gap, this study aimed to design, develop, and validate a physical CCTV Operation Mock-up Trainer with accompanying instructional materials for Industrial Arts students. A descriptive developmental research design following an integrated Waterfall–ADDIE framework was employed. Quantitative data were collected using pilot-tested questionnaires from a needs-assessment cohort (31 students and 6 teachers; Cronbach's α=0.747) and an expert validation panel (6 teachers) selected via purposive sampling. Data were analyzed using descriptive statistics, including mean and standard deviation. Needs-assessment results confirmed a strong demand for a dedicated trainer (M=3.26,SD=0.448) and unanimous endorsement of six core hardware components (M=1.97–2.00). Expert evaluation demonstrated high technical accuracy (M=4.67–4.83), robust instructional usability (M=4.33–4.67), high durability (M=4.67), and excellent safety, highlighted by a perfect score for cable arrangement (M=5.00,SD=0.000). The CCTV Operation Mock-up Trainer received very high expert ratings for technical accuracy, usability, and safety, proving suitable for pilot classroom implementation in technical-vocational education.

Keywords: CCTV operation trainer, technical-vocational education (TVET), Industrial Arts, developmental research, Waterfall–ADDIE framework, instructional materials, expert validation

INTRODUCTION

In recent years, closed-circuit television (CCTV) systems have become central to public safety, commercial security, and critical infrastructure protection worldwide. The rapid expansion of security deployments has created a strong demand for skilled technicians who can install, configure, troubleshoot, and maintain CCTV components. However, training competent operators remains a persistent challenge in technical-vocational education and training (TVET). Live surveillance environments are not conducive to skill-building exercises for novice trainees, and on-the-job exposure carries both ethical and operational risks that prevent beginners from engaging in hands-on wiring, parameter adjustments, and fault resolution.

Previous work has laid meaningful groundwork for CCTV instruction through virtual platforms and specialized laboratory kits. Lin (2015) demonstrated that three-dimensional virtual training platforms can reduce equipment costs. Currás-Francos and Rodríguez-Rodríguez (2023) described a Raspberry Pi-based prototype combining public address and CCTV to train students safely. Similarly, Khoprakhon et al. (2024) developed an AI security system learning kit, while Safin et al. (2021) demonstrated how physical laboratory stands deepen student understanding of camera parameters and digital video recorder (DVR) configurations.

Despite these advances, many TVET institutions lack accessible, dedicated physical mock-up trainers that allow students to practice end-to-end physical configuration—including cable termination, camera placement, power distribution, and DVR navigation—without relying on costly proprietary installations or restricted live networks.

To address this need, we designed, developed, and validated a physical CCTV Operation Mock-up Trainer. The physical trainer provides learners with a safe, accessible, and structured hardware environment to acquire hands-on installation and operational competencies. In doing so, this work potential aligns with SDG 4: Quality Education by promoting practical technical skill development, SDG 9: Industry, Innovation, and Infrastructure by offering a low-cost training solution, and SDG 16: Peace, Justice and Strong Institutions by supporting future security workforce development.

Statement of the Problem

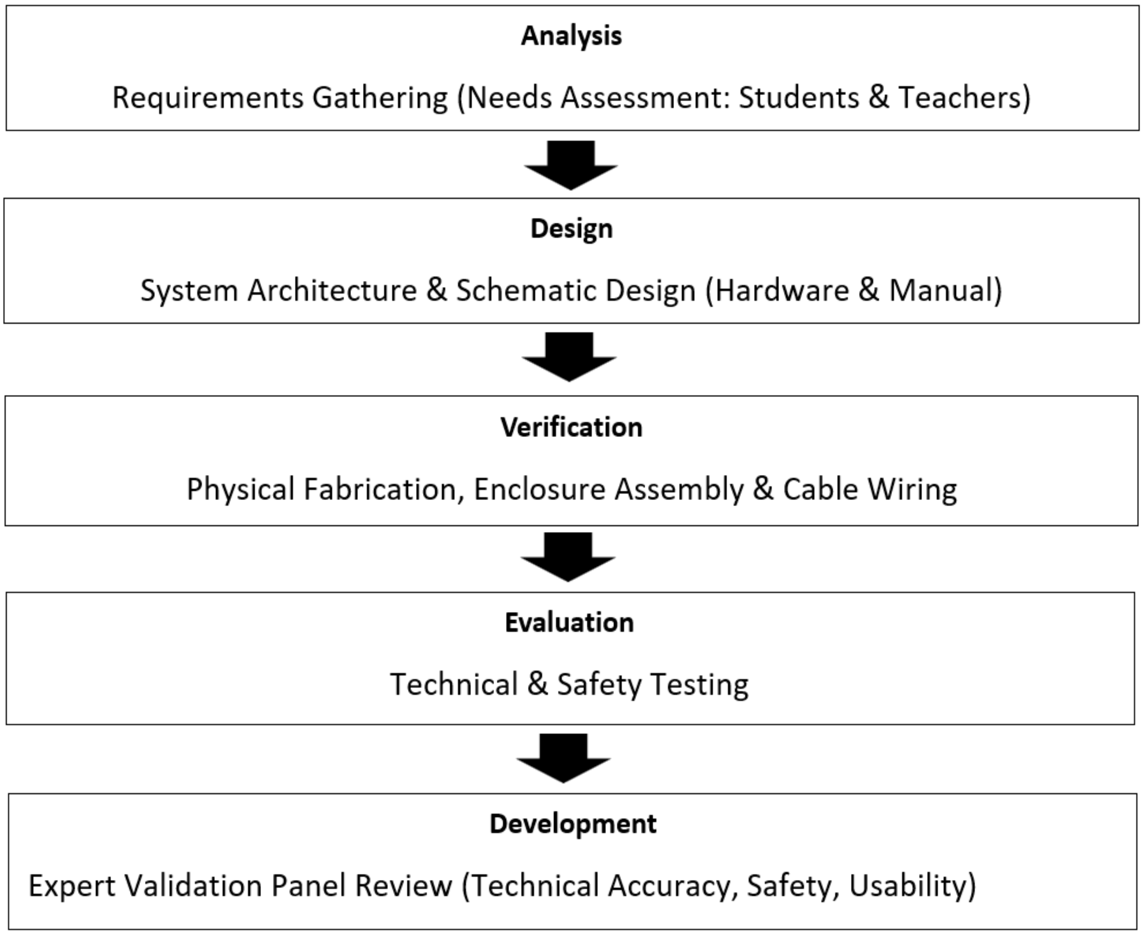
This study aimed to design, develop, and validate a physical CCTV Operation Mock-up Trainer with accompanying instructional materials for Industrial Arts students. Specifically, this study sought to answer the following questions:

1. What are the needs and current challenges encountered in the teaching and learning of CCTV operation in terms of:
    1.1 necessity for a dedicated CCTV operation trainer; and
    1.2 current instructional challenges (disaggregated by students and teachers)?
2. What physical hardware components and core competencies are considered essential for inclusion in the trainer and instructional manual?
3. What is the level of validity of the CCTV Operation Mock-up Trainer as evaluated by experts in terms of:
    3.1 technical accuracy;
    3.2 instructional design; and
    3.3 physical safety and durability?

METHODOLOGY

Research Design

The study employed a descriptive developmental research design. This design is appropriate when creating a physical instructional artifact whose baseline requirements must be established via a needs assessment and whose final design must undergo expert validation before classroom deployment.



To preserve engineering and pedagogical rigor, the developmental process followed an integrated Waterfall–ADDIE framework. The sequential stages of software/hardware engineering (Waterfall) were mapped directly to the instructional design phases (ADDIE): Analysis (needs assessment), Design (schematic layout and manual outline), Development(physical fabrication and cable routing), Verification (bench safety testing), and Evaluation (expert validation).

Research Participants & Evaluators

Participants were selected using a purposive sampling technique across two sequential phases to ensure both targeted user input and rigorous technical evaluation. In the initial phase, a Needs-Assessment Cohort comprising 31 Senior Industrial Arts students and 6 TVET teachers (n=37) was engaged to establish baseline instructional gaps and determine the necessary hardware components for the trainer design. Subsequently, an Expert Validation Panel (n=6) consisting of TVET instructors and subject matter experts (SMEs) was formed to evaluate the developed system. All six expert evaluators possessed formal technical credentials—holding National Certificates (NC II) and Trainers Methodology (TM I) certifications in Electrical Installation and Maintenance or Industrial Electronics—and brought substantial field expertise to the evaluation, averaging 8.5 years of teaching and practical experience in electronic security system installation.

Physical System Architecture & Technical Specifications

The CCTV Operation Mock-up Trainer consists of a mobile, self-contained wooden enclosure housing standard commercial-grade CCTV components. The system operates on an HD-over-Coax (Analog High Definition) architecture.

Component	**Technical Specification**	**Functional Purpose in Training**
CCTV Camera	1080p AHD Fixed Dome Camera (12V DC)	Practicing positioning, focal adjustment, and power wiring.
Digital Video Recorder	4-Channel Hybrid AHD/DVR (1080p Lite, H.264)	Network setup, schedule recording, playback, and OSD menu navigation.
Display Monitor	19-inch LED Monitor (VGA/HDMI Input) 20-	Real-time video monitoring and configuration display.
Cabling & Connectors	RG59 Coaxial Cable with BNC Connectors & DC Plugs	Cable stripping, BNC crimping/termination, and signal integrity testing.
Power & Safety	220V AC Surface Outlet, 12V/5A Power Adapter, 10A Circuit Breaker	Electrical distribution, overcurrent protection, and power safety practice.
System Enclosure	Wooden Cabinet (79.5 cm×81.5 cm×156 cm) on Lockable Casters	Component mounting, cable management, and mobile storage.

To align with Technical and Vocational Education and Training (TVET) industry standards, the trainer unit and its accompanying instructional manual were systematically engineered to cultivate six core practical competencies. The instructional design prioritizes fundamental hardware installation by guiding learners through the physical mounting and precise spatial positioning of CCTV cameras, alongside essential wiring tasks such as cable preparation, BNC connector termination, and DC power wiring. Furthermore, the curriculum addresses system administration and navigation through hands-on exercises in initial DVR setup, storage disk formatting, recording parameter configuration, and display menu navigation via connected monitor interfaces. To ensure operational safety and reliability, the framework integrates basic electrical safety verifications and circuit breaker operations, concluding with critical system troubleshooting protocols designed to resolve signal loss, power failures, and cable continuity issues.

Research Instruments & Validation Procedures

Data were gathered using two researcher-developed and adapted instruments tailored to the evaluation phases. To identify baseline requirements and instructional challenges, a Needs-Assessment Questionnaire featuring a 4-point Likert scale was administered; preliminary pilot testing (n=15) established its internal consistency, yielding an acceptable Cronbach's alpha coefficient of $\alpha=0.747$. Additionally, prototype performance and curriculum integration were evaluated using an Expert Evaluation Rubric structured around three core dimensions: Technical Accuracy, Instructional Usability, and Physical Safety/Durability. Prior to deployment, the content validity of the evaluation rubric was formally established through rigorous review by three independent TVET curriculum experts.

Data Analysis

Quantitative responses were analyzed using descriptive statistics, specifically the Mean (M) and Standard Deviation (SD), to evaluate central tendency and response dispersion across the target criteria. Within this analytical framework, the standard deviation serves as a direct indicator of evaluator consensus and rating consistency, with lower standard deviation values reflecting higher agreement among participants. Importantly, these descriptive measures are intended to characterize evaluator alignment within the study sample and do not establish external validity or broad statistical generalizability.

Ethical Considerations & Safety Protocol

Voluntary informed consent was obtained from all participants. Prior to expert evaluation, the physical trainer underwent an electrical bench audit. Inspection confirmed proper grounding, correct circuit breaker sizing (10A), insulated terminal connections, and complete enclosure of 220V AC lines to ensure zero shock hazards during operation.

RESULTS AND DISCUSSION

A. Needs Assessment Results

A.1 Necessity for a Dedicated CCTV Trainer

As detailed in Table 1, respondents expressed strong demand for a dedicated physical trainer (M=3.26,SD=0.448), agreeing that current instruction is constrained by theoretical delivery and limited hardware access.

Table 1. *Necessity for a New CCTV Operation Trainer (n=37)*

Item	M	SD	Qualitative Description
1. Current methods cover only theoretical aspects.	2.79	0.538	Agree
2. Lack of access to a trainer with real components.	3.03	0.717	Agree
3. Dedicated mock-up trainer would significantly improve outcomes.	3.26	0.448	Strongly Agree
4. Current equipment lacks necessary functional components.	2.91	0.621	Agree

Scale: 3.26–4.00=Strongly Agree; 2.51–3.25=Agree; 1.76–2.50=Disagree; 1.00–1.75=Strongly Disagree

A.2 Instructional Challenges (Disaggregated)

To examine whether instructors and students perceived similar instructional gaps, needs data were disaggregated by cohort.

Table 2. *Current Instructional Challenges Disaggregated by Group*

Instructional Challenge Item	Students (n=31) M (SD)	Teachers (n=6) M (SD)	Overall Combined M (SD)	Qualitative Description
Lack of accessible, complete instructional materials.	3.12 (0.62)	3.28 (0.54)	3.15 (0.610)	Agree
Inability to study real CCTV operation/configuration in detail.	3.06 (0.64)	3.21 (0.50)	3.09 (0.621)	Agree

Scale: 3.26–4.00=Strongly Agree; 2.51–3.25=Agree; 1.76–2.50=Disagree; 1.00–1.75=Strongly Disagree

Both students (M=3.12 and 3.06) and teachers (M=3.28 and 3.21) independently confirmed that limited instructional materials and restricted hardware access hinder practical learning. The small standard deviations across items indicate strong internal consensus on these instructional gaps.

A.3 Endorsed Hardware Content

Stakeholders unanimously endorsed all six physical hardware components as essential for the prototype (M=1.97–2.00). Four components achieved zero dispersion (SD=0.000), demonstrating complete consensus.

Table 3. Desired Hardware Content (n=37)

Component	M	SD	Qualitative Description
CCTV Camera	2.00	0.000	Important
Digital Video Recorder	1.97	0.171	Important
Outlets	2.00	0.000	Important
Cables and Connectors	2.00	0.000	Important
Monitor / Display Screen	2.00	0.000	Important
System Enclosure / Cabinet	1.97	0.171	Important

Scale: 1.50–2.00=Important; 1.00–1.49=Not Important

B. Prototype Evaluation Results

B.1 Technical Accuracy and Instructional Usability

Expert evaluators rated the physical trainer highly across both technical accuracy (M=4.67–4.83) and instructional usability (M=4.33–4.67).

Table 4. *Expert Evaluation: Technical Accuracy & Instructional Usability (n=6)*

Evaluation Criteria	M	SD	Qualitative Rating
Technical Accuracy			
1. Accurate representation of traditional CCTV systems.	4.83	0.408	Very Good
2. Components match actual installation standards.	4.67	0.516	Very Good
Instructional Usability			
3. Easy to set up, use, and understand in a classroom.	4.67	0.516	Very Good
4. Clearly labeled test points, switches, and connections.	4.33	0.516	Very Good

Scale: 4.21–5.00=Very Good / Outstanding; 3.41–4.20=Good; 2.61–3.40=Fair

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Evaluators noted that the prototype accurately mirrors commercial analog HD installations (M=4.83). The low standard deviations (SD≤0.516) confirm close agreement among evaluators regarding technical fidelity and ease of handling.

B.2 Physical Safety, Durability, and Cost

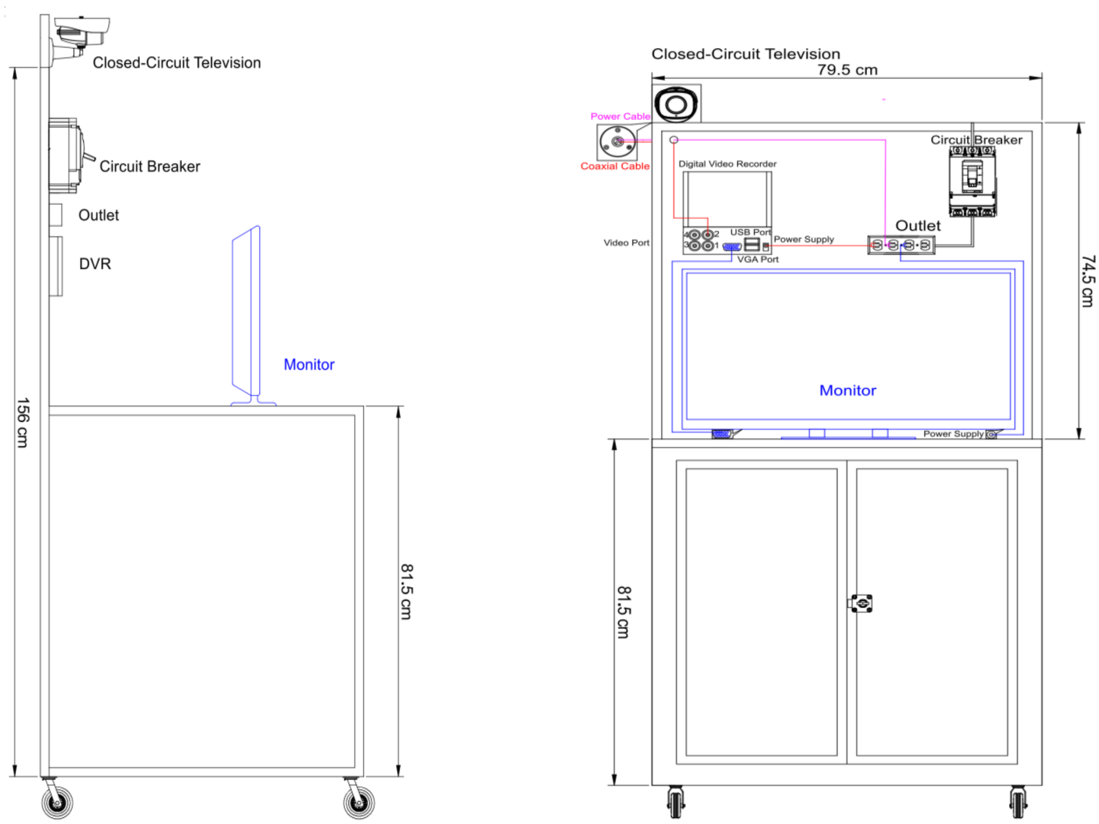
Safety ratings were exceptionally high, led by a perfect mean for cable organization (M=5.00,SD=0.000).

Table 5. *Expert Evaluation: Safety, Durability, and Cost Considerations (n=6)*

Item	M	SD	Qualitative Rating
1. Safe operation (protected 220V AC connections, fused breaker).	4.67	0.516	Very Good
2. Built durable to withstand repeated student practice.	4.67	0.516	Very Good
3. Cables and wiring neatly arranged, bundled, and strain-relieved.	5.00	0.000	Outstanding

Physical Prototype Layout & Wiring Diagram

Side View Front View



Cost Analysis

Fabrication of the trainer cost approximately **₱14,500 PHP (~$250 USD)**. This low fabrication cost underscores its feasibility for budget-constrained TVET institutions seeking hands-on learning alternatives.

LIMITATIONS

Several scope and methodological limitations should be considered when interpreting the findings of this study. First, data collection was restricted to a single higher education institution utilizing a relatively small, purposively selected sample (n=37; comprising 31 students and 6 teachers), which limits the statistical generalizability of the results across broader TVET populations. Second, while the expert validation panel possessed academic credentials and subject matter expertise, prototype evaluation was conducted exclusively by academic TVET instructors without direct representation from active industry-certified security system practitioners. Third, the validation metrics capture expert perceptions regarding the prototype's structural design, safety, and instructional suitability, rather than empirical measures of student learning gains or long-term skill acquisition. Finally, the technical scope of the physical trainer is delimited to traditional HD-over-Coax CCTV architecture, omitting advanced modern technologies such as IP-Power over Ethernet (IP-PoE) networks and artificial intelligence-driven video analytics.

CONCLUSION

This study successfully designed, developed, and validated a physical CCTV Operation Mock-up Trainer tailored for Industrial Arts education. By combining an integrated Waterfall–ADDIE framework with stakeholder needs data, a functional, highly rated training platform was produced. Expert evaluation confirmed high technical accuracy, strong instructional usability, robust physical durability, and excellent electrical safety. While student learning gains remain to be measured in future implementation studies, the developed mock-up trainer provides a safe, low-cost, and validated physical tool to bridge theory and hands-on practice in technical-vocational CCTV instruction.

RECOMMENDATIONS

Based on the study's findings and inherent limitations, several key directions are recommended for future development and research. First, to assess the practical efficacy of the physical trainer, a quasi-experimental pretest–posttest study should be conducted to empirically measure student skill acquisition, task completion speeds, and long-term knowledge retention. Second, future validation phases should engage certified security technicians and commercial industry practitioners to evaluate the system directly against field installation standards. Third, to keep pace with evolving security technologies, subsequent design iterations should expand the trainer's architecture into a modular variant that incorporates modern IP cameras, Power over Ethernet (PoE) switches, and Network Video Recorders (NVRs). Finally, deploying and testing the trainer across multiple TVET institutions is recommended to evaluate its physical durability, adaptability, and instructional impact across diverse classroom environments.

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