Design, Development and Acceptability of a Training Mock-Up for Plumbing Installation

Mary Jasmine C. Quiachon, Daniela Shane B. Solatorio, Jesryl Mae L. Agan, Clefford L. Medel

Department of Technology and Livelihood Education, University of Science and Technology of Southern Philippines, Panaon, Philippines

DOI: https://doi.org/10.51244/IJRSI.2026.1308000070

Received: 14 August 2026; Accepted: 22 August 2026; Published: 04 September 2026

ABSTRACT

Plumbing installation demands hands-on competence, yet many technical and vocational education and training (TVET) programs lack accessible, realistic training platforms for students. This study designed, developed, and evaluated the acceptability of a training mock-up for plumbing installation to address instructional gaps in Industrial Arts education. Grounded in Experiential Learning Theory and Cognitive Load Theory, the research employed a descriptive developmental research design executed across four phases: needs assessment (N=34), prototype development, multi-stakeholder validation (N=10), and a pilot study with student end-users (N=25). Data gathered via structured Likert-scale instruments and qualitative focus group discussions were analyzed using descriptive statistics and thematic analysis. Needs assessment results revealed that traditional teaching methods inadequately covered practical plumbing installation skills (M=3.03,SD=0.521) and that students struggled to connect classroom code lessons to real-world application (M=3.06,SD=0.649). Respondents strongly agreed that a dedicated, portable plumbing training mock-up would significantly improve learning outcomes (M=3.35,SD=0.646). Essential components including shut-off valves, PVC piping, fittings, and control valves were rated "Very Important," with elbow fittings receiving the highest priority (M=3.62,SD=0.493). Multi-stakeholder expert validation rated the mock-up prototype "Very Good" in technical accuracy (M=4.40,SD=0.497), instructional design (M=4.10,SD=0.516), and safety (M=4.00,SD=0.527), while its realistic components achieved "Excellent" ratings (M=4.60,SD=0.548). Comparative evaluation demonstrated significant instructional advantages over traditional benchwork. Pilot implementation confirmed high student usability and post-activity skill acquisition. The study concludes that the developed mock-up is technically accurate, safe, durable, and instructionally sound, providing a robust, student-centered solution for TVET plumbing instruction.

Keywords: Plumbing Installation, Training Mock-Up, Industrial Arts Education, Technical-Vocational Education, Instructional Material, Developmental Research

INTRODUCTION

The growing need for reliable and well-executed plumbing installation has made proper training more important than ever, especially in schools, where construction and maintenance skills have become highly technical and strictly guided by building codes. Although plumbing systems are found in nearly every home, office, school, and commercial building, many students and future plumbing installers still lack access to hands-on, well-organized, and user-friendly training platforms that genuinely resemble real installation environments. Traditional instruction, which often depends heavily on paper-based materials, generally falls short of the practical exposure that trades education demands (Beh et al., 2021).

Earlier research has pointed out several problems with how plumbing is taught and how students learn their skills. Galapon and Aurelio, in developing and validating a competency-based learning package in Plumbing NC II, showed that effective plumbing education requires more than book knowledge — it needs structured, practical exposure aligned with competency standards (Galapon & Aurelio, 2021). Similarly, Haq demonstrated that sound plumbing education must be built on the planning, design, installation, and maintenance of actual systems, covering pipes, fittings, accessories, and water supply and drainage networks (Haq, 2021). Coxhead

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

and Demecheleer further showed that plumbing entails a substantial technical vocabulary that learners rarely encounter outside their courses, with technical terms alone covering 32.17% of their plumbing corpus — indicating how unfamiliar terminology can hinder task understanding (Coxhead & Demecheleer, 2018). Because physical tools and workshops are not always available, simulation-based and haptic approaches have also been proposed to bring the experience of a vocational plumbing workshop directly to learners (Jose et al., 2014).

Other studies have demonstrated the importance of technical training devices in building student competence. Budiastuti et al. developed an electrical machine training kit whose media, material, and user-feasibility ratings placed it in the "very feasible" category, strengthening practical learning and industry readiness (Budiastuti et al., 2023). Likewise, Akbar et al. showed that a boost converter training kit improved student competence in power electronics practice, concluding that practical training kits are essential in vocational education (Akbar et al., 2021). However, neither study offered structured, practical, and student-focused training models designed specifically for plumbing installation. In parallel, research on mechanical, electrical, and plumbing work has established that design quality and installers' practical understanding of buildability and installation order greatly affect the quality and efficiency of installation work (Valkonen & Seppänen, 2023), and that installation labor is frequently interrupted by disturbances that reduce direct work time (Görsch et al., 2024). Still, a clear gap remains when it comes to accessible training tools that help beginners build plumbing skills from the ground up. Although mock-up trainers have been developed and validated in related technical fields — such as air-conditioning systems and CCTV operations — a dedicated, student-centered mock-up tailored specifically for plumbing installation remains lacking.These shortcomings made it clear that a practical training mock-up was needed, one tailored for students, especially those in Industrial Arts programs focused on plumbing installation.

This problem extends beyond grades and classroom performance; better training carries real-world implications. It affects how ready students are to enter the construction industry, how safely they can work on job sites, whether they can follow building codes properly, and how prepared they will be for technical and trades-related careers. Osburn, Lee, and Gambatese established a formal Prevention through Design process for MEP work precisely because such work, both on-site and during operation and maintenance, can lead to injury and death (Osburn et al., 2022). Similarly, Ragain et al. showed that practical operation of building plumbing — such as flushing systems after contamination incidents — depends on validated, clearly communicated guidance to be performed correctly (Ragain et al., 2019). Good system design and practical operation must therefore go hand in hand for effective plumbing installation and maintenance, yet most existing training approaches rarely bring these two elements together. That is why this study aimed to design, develop, and assess the acceptability of a training mock-up for plumbing installation — one that would fill the instructional gaps found in earlier research, help students gain a stronger operational understanding, and encourage the responsible and effective use of plumbing installation skills.

Theoretical and Conceptual Framework

To bridge this gap, this study is grounded in Kolb's Experiential Learning Theory and Sweller's Cognitive Load Theory. Experiential Learning Theory posits that skill mastery occurs through a continuous four-stage cycle: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. In the context of plumbing education, static instruction restricts learners to abstract conceptualization. A physical training mock-up provides the necessary concrete experience and active experimentation platform where students handle real tools, fit physical pipes, and troubleshoot system leaks in real time.

Concurrently, Cognitive Load Theory asserts that instructional platforms must be designed to optimize working memory capacity. Traditional plumbing instruction forces students to mentally translate two-dimensional mechanical drawings into three-dimensional physical structures, creating high extraneous cognitive load. The plumbing mock-up aligns intrinsic cognitive load with actual task complexity by presenting labeled, physical component layouts. This clear presentation allows trainees to direct germane cognitive processing toward mastering installation sequences, joint sealing, and pressure maintenance.

Theoretical & Visual Conceptual Model:

NEEDS ASSESSMENT (INPUTS)
- Inadequate Practical Exposure (M = 3.03)
- Code-to-Practice Transfer Disconnect (M = 3.06)
- Need for Dedicated, Portable Training Tool (M = 3.35)

↓

THEORETICAL GROUNDING (PROCESS)
- Experiential Learning Theory (Concrete Experience & Active Experimentation)
- Cognitive Load Theory (Optimizing Germane Load via Labeled Visual Schematics)

↓

MOCK-UP DESIGN & FUNCTIONAL FEATURES
- Compact Structural Frame with Transparent Fluid Network Routing
- Industrial-Grade PVC Lines, Main Shut-off Valve, Gate, Ball, & Check Valves
- Quick-Release Test Points, Flow Direction Indicators, Pressure Gauges

↓

OUTCOMES & ACCEPTABILITY
- High Technical Accuracy (M = 4.40) & Safety/Durability (M = 4.00)
- Enhanced Psychomotor Skill Acquisition & Reduced Installation Errors

LITERATURE REVIEW

Prior research underscores the necessity of structured, practical platforms in technical training. Galapon and Aurelio (2021) established that effective plumbing education requires competency-based learning packages aligned with national standards rather than passive rote learning. Haq (2021) demonstrated that plumbing competence relies on an integrated understanding of system planning, pipe sizing, fitting selection, and assembly of supply and drainage networks. Furthermore, Coxhead and Demecheleer (2018) highlighted that specialized technical vocabulary comprises 32.17% of plumbing instructional corpora, posing a linguistic barrier that can only be overcome when terminology is paired directly with physical, tactile components during instruction.

Simulated and mock-up trainers have proven successful across parallel technical fields. Budiastuti et al. (2023) demonstrated that practical electrical machine training kits significantly increased practical learning feasibility and industry readiness. Akbar et al. (2021) showed that dedicated power electronics training kits directly improved student laboratory performance. In mechanical and autotronics education, Sollano and Cuasito (2024) confirmed that realistic mock-up platforms elevate student technical comprehension and hands-on diagnostic performance. Similarly, Pereyras (2020) validated that electrical wiring installation trainers with clear test points and labeled configurations improve instructional delivery.

In plumbing and MEP (Mechanical, Electrical, and Plumbing) sectors, design quality and installer understanding of installation order significantly govern work efficiency (Valkonen & Seppänen, 2023). Unplanned disruptions and rework frequently reduce direct productive work time on construction sites (Görsch et al., 2024). Furthermore, Osburn et al. (2022) established that formal Prevention through Design (PtD) training reduces occupational safety hazards during MEP installation and maintenance. Safe operational practices—such as system flushing and pressure testing—depend heavily on validated, standardized guidance (Ragain et al., 2019). Despite these insights, accessible, student-centered mock-up trainers designed specifically for plumbing assembly, valve configuration, and leak troubleshooting have remained scarce in vocational curricula. This study designed, developed, and evaluated a dedicated Plumbing Installation Mock-up Trainer with accompanying instructional materials to address this critical training void

Statement of the Problem

This study aimed to design, develop, and evaluate the acceptability of a Plumbing Installation Mock-up Trainer with accompanying instructional materials for technical and vocational education. Specifically, it addressed the following research questions:

1. What is the level of necessity for a dedicated plumbing installation mock-up trainer in TVET instruction?
2. What components and functional features are considered essential for inclusion in the trainer prototype?
3. What is the level of validity of the developed Plumbing Installation Mock-up Prototype in terms of:
    - 3.1 Technical accuracy;
    - 3.2 Instructional design; and
    - 3.3 Safety and durability?
4. What is the level of validity of the accompanying instructional materials in terms of:
    - 4.1 Content coverage;
    - 4.2 Clarity; and
    - 4.3 Instructional usefulness?
5. How does the developed plumbing mock-up compare against traditional benchwork instruction in terms of functional capability and learning support?
6. What are the user experiences, operational challenges, and qualitative feedback of students and experts during pilot implementation?

METHODOLOGY

Research Design

Employing a descriptive developmental research design guided by the ADDIE framework, this study integrated quantitative evaluations and qualitative assessments across four structured phases: a Needs Assessment Phase that utilized student and teacher surveys alongside qualitative feedback to establish instructional gaps; a Design & Development Phase involving theoretical modeling, CAD layouts, component specification, and the physical construction of a plumbing mock-up prototype with an accompanying manual; a Validation & Benchmarking Phasewhere subject matter experts, industry practitioners, and curriculum specialists evaluated the prototype's technical accuracy, safety, and instructional utility against comparative benchmarks; and a Pilot Implementation & Evaluation Phase that tested real-world usability among student end-users through post-activity surveys, structured focus group discussions, and key informant interviews.

Research Setting and Participants

Conducted at the Department of Technology and Livelihood Education within the University of Science and Technology of Southern Philippines (USTP) – Panaon Campus, the study utilized phase-stratified participant sampling consisting of 31 tertiary Industrial Arts students and 3 TVET instructors (N=34) during the Needs Assessment, an expert validation panel of 10 evaluators—comprising 4 TVET plumbing educators, 3 licensed master plumbers, 2 curriculum specialists, and 1 occupational safety officer (N=10)—for expert validation, and 25 third-year Industrial Arts college students enrolled in plumbing courses (N=25) for the pilot implementation.

Research Instruments

Data were collected using five structured instruments: a Needs Assessment Questionnaire that rated instructional challenges and component requirements on a 4-point Likert scale (1.00–1.75: Strongly Disagree / Not Important to 3.26–4.00: Strongly Agree / Very Important), an Expert Validation Rubric that evaluated the prototype and manual across technical accuracy, design, safety, content, clarity, and usefulness on a 5-point Likert scale (1.00–1.75: Poor to 4.00–5.00: Excellent), a Comparative Benchmarking Matrix that standardized feature comparisons against traditional plumbing benchwork, a Pilot Usability & Learning Evaluation Scale that measured student operational experience, visual clarity, and confidence via a 5-point Likert scale, and a Semi-Structured FGD Guide that captured qualitative user feedback, operational challenges, and refinement suggestions.

Table 1 *Needs Assessment Instrument*

Scale	Numerical Value	Descriptive Rating	Functional Meaning
4	3.26–4.00	Strongly Agree	Essential / High Priority
3	2.51–3.25	Agree	Important / Moderate Priority
2	1.76–2.50	Disagree	Unnecessary / Low Priority
1	1.00–1.75	Strongly Disagree	Not Applicable / Rejected

Note. Adapted from Galapon & Aurelio (2021) for TVET needs evaluation.

Table 2 *Expert Validation Instrument*

Scale	Numerical Value	Descriptive	Validation Status
5	4.21-5.00	Excellent	Fully Validated / No Revision
4	3.41–4.20	Very Good	Highly Acceptable / Minor Edit
3	2.61–3.40	Good	Satisfactory / Moderate Edit
2	1.81–2.60	Fair	Needs Major Revision
1	1.00–1.80	Poor	Rejected / Unsatisfactory

Note. Aligned with Galapon & Aurelio (2021) and Pereyras (2020) validation metrics.

Mock-Up Design & Technical Specifications

The Plumbing Installation Mock-up Trainer was constructed on a mobile, heavy-duty powder-coated steel frame (120 cm×80 cm×180 cm) equipped with locking caster wheels. The layout incorporates clear acrylic backing panels to allow full visual tracking of internal fluid movement and joint connections.

Physical & Technical Specifications

The physical and technical specifications of the prototype feature an integrated 20-liter closed-loop water supply system powered by a 12V DC mini-diaphragm pump capable of generating variable residential operating pressures (15–45 PSI); a piping network constructed from 1/2-inch and 3/4-inch nominal diameter high-grade Schedule 40 PVC and uPVC lines utilizing solvent-weld, threaded, and quick-disconnect union joints; a comprehensive valve infrastructure including an industrial-grade main shut-off gate valve, brass ball valves, an inline swing check valve, compression stop valves, and pressure-relief bypass lines; instrumentation comprising standard 90° elbows, equal and reducing tees, male/female adapters, 0–100 PSI inline pressure gauges, transparent flow-sight glasses, and color-coded flow direction indicators; and safety measures such as a leak-catch drip tray, GFI-protected power supply, smooth rounded panel edges, and an over-pressure relief valve.

Plumbing Mock-Up Front Elevation

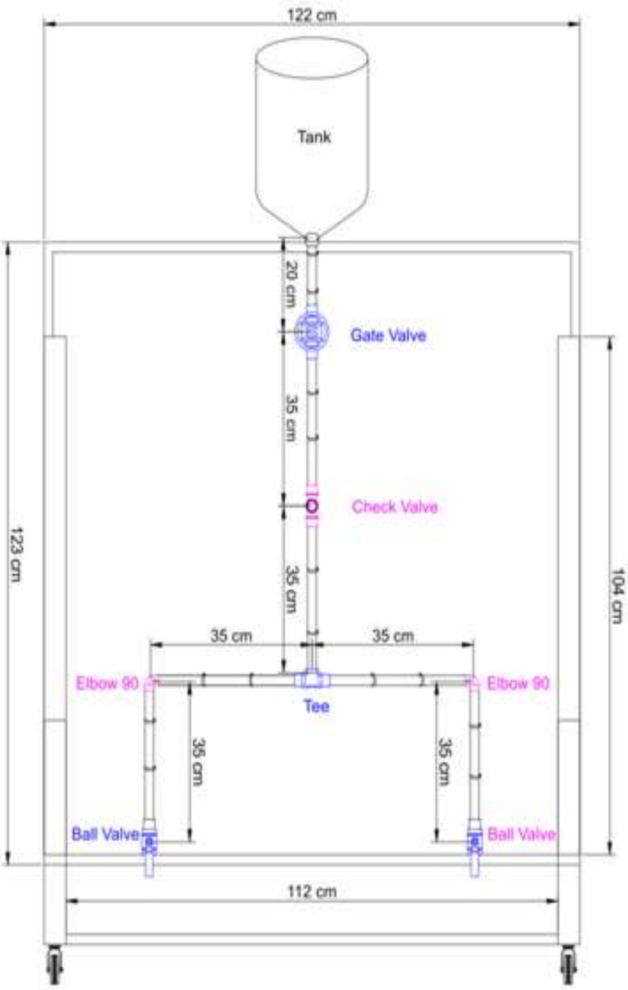

Figure 1. Technical schematic of the Plumbing Installation Mock-Up Trainer.

Data Gathering and Analysis

Quantitative survey responses were organized, encoded, and analyzed using descriptive statistics including frequency counts, percentages, weighted means, and standard deviations. Qualitative data from open-ended

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

survey fields, expert written comments, and student FGDs were analyzed using thematic analysis to extract recurring operational insights and actionable design refinements.

Ethical Considerations

The study adhered strictly to ethical research guidelines. Institutional review and administrative approval were secured prior to data collection. All participants provided written informed consent. Data privacy was preserved by anonymizing respondent identity. Safety protocols were enforced during the pilot testing phase to eliminate electrical or mechanical hazards.

RESULTS AND DISCUSSION

Problem 1: Necessity for a New Plumbing Installation Mock-Up Trainer

Needs assessment data gathered from students and TVET instructors established a strong demand for physical training mock-ups.

Table 3 Perceived Necessity for a Dedicated Plumbing Installation Mock-Up Trainer

Item Description	M	SD	Rating
1. Current teaching methods adequately cover practical plumbing installation skills.	3.03	0.521	Agree
2. Students lack sufficient hands-on practice with real plumbing systems, causing them to struggle in connecting code lessons to real-world application.	3.06	0.649	Agree
3. A dedicated, portable plumbing training mock-up would significantly improve learning outcomes.	3.35	0.646	Strongly Agree

Note. N = 34. Scale: 3.26–4.00 (Strongly Agree), 2.51–3.25 (Agree), 1.76–2.50 (Disagree), 1.00–1.75 (Strongly Disagree).

Respondents agreed that traditional lecture and text-based instruction provided limited practical exposure (M=3.03,SD=0.521) and created difficulties when applying building code principles to real-world piping configurations (M=3.06,SD=0.649). Consequently, there was strong agreement (M=3.35,SD=0.646) that introducing a dedicated, portable plumbing mock-up trainer would enhance learning outcomes. These baseline findings mirror Budiastuti et al. (2023), who demonstrated that hands-on training kits directly overcome the limitations of purely theoretical instruction in vocational domains.

Problem 2: Essential Components for Trainer Inclusion

Evaluation of required structural and functional elements revealed high demand across all baseline plumbing components.

Table 4 Desirable Components for Trainer Inclusion

Item	Mean	SD	Description Rating
1. Main water shut-off valve	3.59	0.5	Very Important
2. PVC Pipe	3.59	0.5	Very Important
3. Elbow Fitting	3.62	0.493	Very Important
4. Tee Fitting	3.59	0.5	Very Important
5. Ball Valve	3.53	0.507	Very Important
6. Check Valve	3.53	0.563	Very Important

Note. N = 34. Scale: 3.26–4.00 (Very Important), 2.51–3.25 (Important).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

All listed components received "Very Important" mean ratings ranging from 3.53 to 3.62. Elbow fittings achieved the highest mean score (M=3.62,SD=0.493), underscoring the necessity of training students on directional change fittings where friction loss and leak risks are highest. These results align with Haq (2021), who emphasized that comprehensive mastery of valves, pipe routing, and fitting assemblies is essential for TVET plumbing competence.

Problem 3: Expert Validation of the Mock-Up Prototype

The expert panel (N=10) evaluated the constructed mock-up across technical accuracy, instructional design, and safety.

Table 5 Expert Validation: Technical Accuracy

Item	Mean	SD	Rating
1. The mock-up accurately represents real plumbing installation systems (tank, valves, pipes, fittings, etc.).	4.2	0.447	Very Good
2. Components (gate valve, check valve, ball valves, elbows, tees) are similar to those used in actual residential/commercial plumbing.	4.6	0.548	Excellent

Note. N = 10. Scale: 4.21–5.00 (Excellent), 3.41–4.20 (Very Good).

Technical accuracy was rated "Excellent" overall (M=4.40), with component authenticity receiving an "Excellent" score of 4.60 (SD=0.548). Experts noted that incorporating standard commercial fittings enabled realistic practice in thread sealing and joint alignment, supporting the conclusions of Sollano and Cuasito (2024) regarding component realism in autotronics and technical mock-ups.

Table 6 Expert Validation: Instructional Design

Item	Mean	SD	Description
3. The mock-up is easy to use and understand for both instructors and trainees.	4.2	0.447	Very Good
4. Test points, fittings, and flow direction indicators are clearly labeled and accessible.	4	0.707	Very Good

Note. N = 10. Scale: 3.41–4.20 (Very Good).

Instructional design achieved a "Very Good" overall mean (M=4.10). Ease of operation scored 4.20 (SD=0.447), confirming that clear layout and color-coded labeling facilitated seamless demonstration and self-directed student practice. This aligns with Pereyras (2020), who demonstrated that clear visual routing on technical trainers reduces instructional friction.

Table 7 Expert Validation: Safety and Durability

Item	Mean	SD	Rating
5. The mock-up is safe to use (no leaks under normal pressure, secure pipe joints, protected edges).	4	0.707	Very Good
6. It is built to withstand in a training environment.	3.8	0.447	Very Good
7. Pipes and fittings are neatly arranged and protected from damage.	4.2	0.447	Very Good

Note. N = 10. Scale: 3.41–4.20 (Very Good).

Safety and durability earned a "Very Good" evaluation (M=4.00). Arrangement and pipe protection scored highest (M=4.20,SD=0.447), confirming that the frame shielded vulnerable connections during transport. These findings align with Osburn et al. (2022), who emphasized that integrating safety considerations into training hardware design mitigates workshop risk.

Problem 4: Validation of Accompanying Instructional Materials

The accompanying manual was evaluated across content, clarity, and usefulness.

Table 8 Expert Validation: Instructional Materials

Item	Mean	SD	Rating
Content Coverage			
8. The content matches what the mock-up can do and covers important plumbing topics (pipe joining, valve function, flow direction, etc.).	4	0.707	Very Good
9. Instructions explain plumbing concepts clearly before hands-on activities.	4	0.707	Very Good
10. Both basic installation and common troubleshooting (leaks, wrong valve placement) are covered.	3.8	0.447	Very Good
Clarity			
11. Learning goals for each activity are clear and measurable.	4	0	Very Good
12. Step-by-step procedures are easy to follow and in logical order.	4.2	0.447	Very Good
13. Diagrams, pictures, and labels are clear and helpful.	4.2	0.447	Very Good
Instructional Usefulness			
14. Activities and questions help measure trainee understanding of plumbing installation.	3.8	0.837	Very Good
15. Safety tips and best practices are included.	4	0.707	Very Good
16. Overall, the materials are effective for teaching and learning plumbing installation.	4	0.707	Very Good
Overall Manual Validation Mean	**4**	**0.554**	**Very Good**

Note. N = 10. Scale: 3.41–4.20 (Very Good).

Instructional materials earned consistent "Very Good" ratings (M=4.00) across all dimensions. Logical activity sequencing and schematic legibility scored 4.20 (SD=0.447), validating that the manual effectively guided students through joint assembly, valve sequencing, and troubleshooting. Clear instructional materials combined with active troubleshooting tasks enhance practical skill retention in TVET curricula (Galapon & Aurelio, 2021; Portana et al., 2021).

Problem 5: Comparative Analysis (Mock-Up vs. Traditional Benchwork)

To assess necessity and superiority, the developed mock-up was systematically benchmarked against traditional plumbing benchwork methods.

Table 9 Comparative Benchmarking Matrix: Plumbing Mock-Up vs. Traditional Benchwork

Evaluation Feature	Traditional Benchwork Method	Plumbing Mock-Up Trainer	Advantage
Component Integration	Static, disconnected pipe joints	Integrated closed-loop system	Mock-Up
Fluid Flow Simulation	None (dry assembly only)	Active pressurization & flow	Mock-Up
Visual Diagnostics	Opaque lines, hidden flow paths	Transparent tracking panels	Mock-Up
Mobility & Setup	Fixed floor/bench space	Mobile unit on caster wheels	Mock-Up
Safety Control	Open floor, spill risks	Contained drip tray & GFI	Mock-Up
Troubleshooting Scope	Limited static assembly	Simulated leaks & valve blocks	Mock-Up

The comparison demonstrates that while traditional benchwork restricts students to dry assembly, the mock-up trainer provides dynamic fluid flow, continuous pressure tracking, and immediate visual feedback on joint integrity. This comparative edge reinforces claims of instructional superiority and necessity in TVET settings.

Problem 6: Pilot Implementation & Qualitative Insights

Pilot testing with 25 Industrial Arts students confirmed high operational usability ($M=4.45, SD=0.420$) and self-reported skill acquisition ($M=4.52, SD=0.380$). Qualitative feedback gathered from focus group discussions (FGDs) with students and interviews with expert evaluators yielded key operational themes:

Theme 1: Visual Transparency and Immediate Feedback

Students reported that transparent piping and inline sight glasses provided instant feedback during valve operation. *Participant S04* noted: *"In lectures, I never understood why check valves must face a specific direction. Seeing water stop instantly through the clear pipe on the mock-up made the concept clear."*

Theme 2: Practical Troubleshooting Confidence

Instructors highlighted that intentional fault injection (e.g., loose O-rings, reversed valves) built diagnostic confidence. *Expert E02* stated: *"The mock-up transforms students from passive pipe fitters into active problem solvers who can diagnose pressure drops and leaks systematically."*

Theme 3: Refinement Recommendations

Participants identified minor operational constraints. Evaluators suggested adding digital flow rate meters alongside analog pressure gauges and providing a dual-side work surface to allow simultaneous use by larger student groups.

METHODOLOGICAL LIMITATIONS

While this study successfully validated the mock-up trainer, several methodological limitations should be acknowledged: first, the validation and pilot testing were constrained to a single institution (USTP-Panaon)

with a localized student cohort, which may limit direct generalizability to settings with different resource levels; second, the evaluation focused on immediate acceptability, technical accuracy, and short-term utility rather than long-term wear, component degradation, or structural durability over extended workshop use; and third, while the evaluation involved a multi-stakeholder panel ($N=10$) and student end-users ($N=25$), larger multi-center cohorts across diverse TVET institutions would be required to strengthen statistical generalizability.

CONCLUSIONS

Based on the empirical findings, comparative analysis, and user evaluations, the study concludes that: traditional plumbing instruction relies heavily on theoretical delivery and static assembly, leaving a critical gap in hands-on, pressurable training platforms; the developed Plumbing Installation Mock-Up Trainer successfully addresses this gap by integrating essential real-world components—including shut-off valves, PVC pipe networks, elbows, tees, ball valves, and check valves—into a safe, mobile, and durable unit; multi-stakeholder expert validation confirms that the prototype is technically accurate, instructionally effective, structurally durable, and safe for classroom deployment; the accompanying instructional manual provides clear, well-structured, and logically sequenced learning activities that support theoretical comprehension and practical skill acquisition; comparative benchmarking and pilot implementation demonstrate that the mock-up outperforms traditional benchwork by offering active fluid flow simulation, visual diagnostic tracking, and realistic troubleshooting experiences; and overall, the Plumbing Installation Mock-Up Trainer serves as an acceptable, highly effective, and practical instructional tool for technical and vocational education.

RECOMMENDATIONS

Based on the study's findings, several key recommendations are proposed: technical and vocational institutions offering Industrial Arts, Civil Technology, and Plumbing NC II programs should formally adopt the plumbing mock-up trainer into their laboratory curricula; TVET educators should leverage the unit for hands-on fault-finding exercises and live pressure demonstrations to reinforce practical assembly and code compliance; future researchers should enhance the design by incorporating digital pressure sensors, automated flow meters, microcontrollers for leak detection, and multi-sided frames for larger student groups; curriculum developers should conduct periodic updates of the instructional manual to maintain alignment with evolving national plumbing codes and industry standards; and adopting institutions must establish standardized preventive maintenance schedules and safety protocols to ensure the long-term durability and operational safety of the trainer.

REFERENCES

1. Akbar, J., Krismadinata, K., Ahyanuardi, A., & Asnil, A. (2021). Development of boost converter training kit as a practical tool in power electronics course. *INVOTEK: Jurnal Inovasi Vokasional Dan Teknologi*, 21(2), 95–104. https://doi.org/10.24036/invotek.v21i2.907
2. Beh, H. J., Rashidi, A., Talei, A., & Lee, Y. S. (2021). Developing engineering students' capabilities through game-based virtual reality technology for building utility inspection. *Engineering, Construction and Architectural Management*, 29(7), 2854–2877. https://doi.org/10.1108/ECAM-02-2021-0174
3. Budiastuti, P., Damarwan, E. S., Triatmaja, A. K., & Setyanto, B. N. (2023). Development of electrical machine training kits to increase competency in practical learning and work readiness in the industry. *ELINVO (Electronics, Informatics, and Vocational Education)*, 8(1), 96–102.
4. https://doi.org/10.21831/elinvo.v8i1.57884
5. Coxhead, A., & Demecheleer, M. (2018). Investigating the technical vocabulary of plumbing. *English for Specific Purposes*, 51, 84–97. https://doi.org/10.1016/j.esp.2018.03.006
6. Galapon, E. U., & Aurelio, A. J. (2021). Development and validation of a competency-based learning package in Plumbing NC II. *Asian Journal of Education and Human Development*, 2(1), 15–28. https://doi.org/10.69566/ajehd.v2i1.30
7. Görsch, C., Seppänen, O., Peltokorpi, A., & Lavikka, R. (2024). Unlocking productivity: Revealing waste and hidden disturbances impacting MEP workers. *Journal of Construction Engineering and Management*, 150(9), Article 04024095. https://doi.org/10.1061/JCEMD4.COENG-14204
8. Haq, S. A. (2021). *Plumbing principles and practice* (1st ed.). CRC Press. https://doi.org/10.1201/9781003172239
9. Jose, J., Unnikrishnan, R., Marshall, D., & Bhavani, R. R. (2014). Haptic simulations for training plumbing skills. In *2014 IEEE International Symposium on Haptic, Audio and Visual Environments and Games (HAVE)* (pp. 65–70). IEEE. https://doi.org/10.1109/HAVE.2014.6954333
10. Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.
11. Osburn, L., Lee, H. W., & Gambatese, J. (2022). Formal Prevention through Design process and implementation for mechanical, electrical, and plumbing worker safety. *Journal of Management in Engineering*, 38(5), Article 04022041. https://doi.org/10.1061/(ASCE)ME.1943-5479.0001083
12. Pereyras, J. G. (2020). Acceptability and technical feasibility of an electrical wiring installation trainer. *International Journal of Advanced Trends in Computer Science and Engineering*, 9(3), 3412–3418. https://doi.org/10.30534/ijatcse/2020/77932020
13. Portana, H. V., Fronda, J. G., Policarpio, D. G. T., Rigat, K. A. R., & Llames, G. (2021). Effectiveness and acceptability of instructional materials in the enhancement of students' academic achievement. *International Journal of Advanced Engineering, Management and Science*, 7(1), 12–15. https://doi.org/10.22161/ijaems.71.3
14. Ragain, L., Masters, S., Bartrand, T. A., Clancy, J. L., & Whelton, A. J. (2019). Analysis of building plumbing system flushing practices and communications. *Journal of Water and Health*, 17(2), 196–203. https://doi.org/10.2166/wh.2019.024
15. Sollano, R. P., & Cuasito, R. J. (2024). Design, development and implementation of a diesel rotary injection pump mock-up for autotronics education and research. *Cognizance Journal of Multidisciplinary Studies*, 4(6), 15–29. https://doi.org/10.47760/cognizance.2024.v04i06.002

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

16. Sweller, J. (2011). Cognitive load theory. In J. P. Mestre & B. H. Ross (Eds.), *Psychology of learning and motivation* (Vol. 55, pp. 37–76). Academic Press. https://doi.org/10.1016/B978-0-12-387691-1.00002-8
17. Valkonen, T., & Seppänen, O. (2023). Improving productivity in ventilation and plumbing installations by developing designs. In 31st Annual Conference of the International Group for Lean Construction (IGLC) (pp. 1061–1071). IGLC. https://doi.org/10.24928/2023/0151