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Portable Sensor and Actuator Trainers in Industrial Technology: A Systematic Review of Development, Pedagogical Integration, and Evaluation

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Abstract: This review synthesizes literature on the design, development, and evaluation of instructional trainers for technical-vocational education, with emphasis on portable sensor and actuator systems. The objective is to examine how open-source microcontroller platforms, pedagogical frameworks, and instructional design models contribute to bridging the gap between theoretical knowledge and industrial practice. Literature was gathered from ERIC, ScienceDirect, Google Scholar, and Philippine E-Journals, covering studies published between 2018 and 2026. Findings highlight that resource scarcity in technical institutions often limits hands-on training, leaving students reliant on simulations that fail to replicate real-world anomalies. Research demonstrates that Arduino-based trainers provide cost-effective, customizable, and pedagogically sound alternatives to proprietary equipment. The integration of sensors and actuators enables students to master fundamental control logic, serving as a precursor to advanced automation systems. The ADDIE model is widely recognized as a rigorous framework for instructional hardware development, ensuring systematic design and evaluation. However, gaps remain in localized studies addressing portable "lab-in-a-box" trainers tailored to multi-major programs in Philippine state colleges. This synthesis underscores the importance of developing affordable, portable instructional trainers to enhance experiential learning and workforce readiness. Recommendations include further R&D on modular trainer designs, expanded evaluation across diverse technical programs, and integration into competency-based curricula.

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I. INTRODUCTION

➢ *Background Context*

Industrial Technology education requires bridging theory with practice through hands-on training. Industry 4.0 demands graduates proficient in automation, sensors, and actuators. Yet, resource scarcity in Philippine state colleges limits access to functional laboratory equipment, creating an "experience gap." Portable trainers offer a viable solution by enabling tactile learning despite facility constraints.

➢ *Scope and Purpose*

This review focuses on literature examining instructional trainers, sensor-actuator integration, and pedagogical frameworks for technical-vocational education. Studies outside hardware development or unrelated to experiential learning are excluded.

➢ *Thesis Statement / Objective*

The review aims to synthesize research on portable instructional trainers, highlight their pedagogical and technical contributions, and identify gaps in localized development for Philippine institutions.

II. METHODOLOGY

➢ *Search Strategy*

Databases: ERIC, ScienceDirect, Google Scholar, Philippine E-Journals. Search terms: *portable instructional trainer*, *Arduino-based education kits*, *sensor-actuator integration*, *technical-vocational pedagogy*, *ADDIE instructional design*.

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➢ *Selection Process*

- *Inclusion Criteria:*

✓ Studies focusing on instructional trainer development and evaluation.
✓ Research examining sensor-actuator integration in education.
✓ Published between 2018–2026.

- *Exclusion Criteria:*

✓ Studies focusing solely on industrial-grade PLC systems.
✓ Non-empirical reports or opinion pieces.

III. MAIN BODY

➢ *Theme 1: Technical-Vocational Education and Resource Scarcity*

Orbeta & Paqueo (2022) and Pacadaljen (2024) noted that Philippine state colleges face budgetary constraints limiting access to industry-standard equipment. Tindan & Anaba (2024) argued that simulations fail to replicate real-world anomalies, underscoring the need for tactile trainers.

➢ *Theme 2: Development of Instructional Trainers*

Sidik et al. (2024) demonstrated that Arduino-based trainers provide cost-effective alternatives to proprietary systems. Candano & Cuasito (2024) emphasized portability and integration into curricula as key factors in trainer effectiveness.

➢ *Theme 3: Sensor and Actuator Integration*

Nahrowi & Hariyanto (2022) highlighted that mastering basic sensor-actuator interfaces is critical for understanding advanced PLC systems. Trainers incorporating ultrasonic, temperature, and proximity sensors with actuators replicate industrial control logic.

➢ *Theme 4: Instructional Design and the ADDIE Model*

Beringuel et al. (2026) confirmed that the ADDIE model ensures systematic design and evaluation of instructional prototypes. Its iterative process enhances acceptability among experts and students.

➢ *Theme 5: Pedagogical Frameworks*

Constructivist and experiential learning theories emphasize active engagement with hardware. TPACK and RBV frameworks highlight the integration of technology, pedagogy, and resource innovation in instructional trainer development.

IV. CONCLUSION AND RECOMMENDATIONS

➢ *Summary of Main Findings*

Portable sensor-actuator trainers address resource scarcity, enhance experiential learning, and prepare students for Industry 4.0. Arduino-based platforms provide affordable, customizable solutions. The ADDIE model ensures pedagogical validity and systematic evaluation.

➢ *Significance*

This synthesis highlights the importance of localized R&D in developing portable trainers for Philippine institutions, ensuring students acquire tactile troubleshooting skills essential for workforce readiness.

➢ *Future Research*

- Expand evaluation of portable trainers across diverse technical programs.
- Investigate modular trainer designs for multi-major adaptability.
- Integrate trainers into competency-based curricula for broader impact.

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