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Cross-Disciplinary Perceptions of Cyber-Physical and Immersive Learning in Vocational Higher Education: Implications for SDG 4

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ABSTRACT

Objective: *To examine whether disciplinary affiliation differentiates vocational students' perceptions of Cyber-Physical Learning (CPL) and Immersive Learning (ILM) support for creative thinking and problem solving. It further considered the findings within a hardware–software convergence framework and their implications for competency-centered vocational education relevant to Sustainable Development Goal 4 (SDG 4).* ***Method:*** *A quantitative, comparative, cross-sectional survey was conducted using purposive sampling at Universitas Negeri Surabaya. The analysis included 222 valid respondents, comprising 109 Electrical Engineering and 113 Informatics Management students. A 31-item questionnaire using a five-point Likert scale assessed four perceived-support constructs: CPL for creative thinking (CPL-CT), CPL for problem solving (CPL-PS), ILM for creative thinking (ILM-CT), and ILM for problem solving (ILM-PS). Four independent-group Mann-Whitney U tests compared the two programs, supplemented by approximate standardized rank-test indicators derived from the reported Z statistics.* ***Results:*** *No statistically significant between-program differences were detected for CPL-CT (p = .663), CPL-PS (p = .585), ILM-CT (p = .636), or ILM_PS (p = .689). The derived standardized indicators were numerically small (r= .027–.037). These findings concern perceived learning support rather than demonstrated learning gains and do not establish practical equivalence or verify the proposed hardware–software convergence mechanism.* ***Novelty:*** *The study provides a cross-disciplinary assessment of four perceived learning affordances rather than comparing the superiority of particular technologies. The findings support consideration of competency-centered access to cyber-physical and immersive learning across vocational programs, with relevance to SDG 4. However, the study does not directly measure SDG attainment, actual skill development, or causal learning effects.*

INTRODUCTION

Digital transformation is changing both industrial work and the educational environments expected to prepare learners for it. Industry 4.0 combines networked devices, automation, computational systems, sensors, data processing, and digital interfaces in increasingly interdependent processes. Education 4.0 discussions consequently emphasize learning designs that integrate technological capability with adaptive problem solving rather than teaching distinct technologies in isolation (Chakraborty et al., 2023; de Souza & Debs, 2024; Mukul & Büyüközkan, 2023). Reviews of skills and higher-education responses to the Fourth Industrial Revolution similarly foreground the need for pedagogical flexibility and capacity to work across technological systems (Aboderin & Havenga, 2024; Teo et al., 2021). For vocational higher education, these developments raise a particular issue: technical specialization remains necessary, but the boundaries through which specializations are conventionally described may not correspond neatly to the socio-technical problems students will encounter.

The conventional distinction between hardware-oriented and software-oriented programs remains intuitively meaningful. Hardware-oriented education frequently stresses physical installation, equipment operation, electrical control, and observable

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