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Cyber-Physical Versus Immersive Learning in Vocational Education: Perceived Support for Creative Thinking and Problem Solving Toward SDG 4

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ABSTRACT

Objective: *To compare vocational higher education students' perceived support from Cyber-Physical Learning (CPL) and Immersive Learning (ILM) for creative thinking and problem solving. It examines whether students' evaluations differ across the two competencies and considers the implications for competency-sensitive learning design relevant to Sustainable Development Goal 4 (SDG 4) on Quality Education.* ***Method:*** *A cross-sectional survey involved 223 applied bachelor students, comprising 109 Electrical Engineering and 114 Informatics Management students. Data were collected using a 31-item questionnaire with a five-point Likert response scale covering four perceived-support constructs: CPL-CT, ILM-CT, CPL-PS, and ILM-PS. Two Wilcoxon comparisons examined differences between the learning environments for each competency.* ***Results:*** *For creative thinking, the reported construct values for CPL (3.9725) and ILM (3.9654) did not differ significantly ($Z=-0.322$, $p=0.747$). For problem solving, CPL received a higher reported value (4.0701) than ILM (3.9753), with a statistically significant difference ($Z=-3.994$, $p<0.001$). These findings indicate competency-specific differences in students' perceived instructional support rather than demonstrated improvements in learning performance.* ***Novelty:*** *To provide a direct competency-specific comparison of cyber-physical and immersive learning environments. The findings strengthen a competency–technology alignment perspective by showing that students' perceptions of instructional support vary according to the targeted competency. This perspective is relevant to SDG 4 because quality vocational education requires learning environments to be selected in relation to instructional objectives and competency requirements rather than technological sophistication alone. The study does not, however, measure progress toward an SDG indicator or establish the causal effectiveness of either learning environment.*

INTRODUCTION

Vocational higher education is expected to prepare graduates for occupational practice while equipping them to respond to changing production and information systems. The integration of automation, connected devices, data infrastructures and computational control has expanded the range of competencies required in contemporary technical work. A systematic review of Industry 4.0 engineering competencies identified recurring demands for technical and transferable abilities without establishing a single agreed competency model (Quintero & Maldonado, 2024). Industry-oriented analysis similarly emphasizes changes in worker knowledge and the organization of skills development as industrial processes become more digitalized (Saniuk et al., 2023). Within this context, the pedagogical question is not simply whether institutions should adopt new technologies, but which learning environments students regard as appropriate for particular competencies.

The educational consequences of technological transformation also vary across sectors and learner populations. In vocational curricula, digital content may be introduced unevenly; Delcker (2023), for example, identified digital features in 200 of 831 curricula examined through text mining. A review of digitalization in accounting

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