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I-CReST 2025: 066-036– Foundations for the Programming Conceptual Understanding Test (PCUT): A Literature Review of Pedagogical Innovations

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ABSTRACT

As programming education evolves, enhancing conceptual understanding among novice learners remains a critical challenge. This literature review synthesizes key pedagogical innovations from 2015 to 2025 that inform the development of a validated assessment instrument for programming conceptual understanding. Five major approaches are explored: conceptual metaphors, robotics and interactive tools, prototype theory, physical programming tools, and ontology-based frameworks. These strategies collectively aim to scaffold abstract reasoning, reduce cognitive load, and foster deeper learner engagement. Conceptual metaphors provide intuitive cognitive bridges between everyday experiences and abstract programming constructs. Robotics and physical tools offer tangible, multimodal learning environments that enhance motivation and comprehension. Prototype theory emphasizes relatable exemplars to support categorization and knowledge transfer, while ontology-based learning structures promote metacognitive reflection and conceptual integration. The review highlights a growing consensus that multimodal, metaphorical, and structured pedagogies significantly improve computational thinking and problem-solving skills. This synthesis supports the design of the Programming Conceptual Understanding Test (PCUT), a novel assessment tool grounded in cognitive science and validated through mixed-methods research. The review concludes by identifying future research directions, including cultural adaptability, scalability, and integration with adaptive technologies to personalize learning. These insights offer a foundation for a more inclusive, effective, and engaging programming education.

Keywords: Programming basics; Learning tools; Student assessment; Teaching methods; Problem solving