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Mapping students' cognitive load profiles in solving geometric integral problems

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Abstract

Designing cognitively accessible mathematics instruction requires ensuring that learners can equitably process, understand, and apply complex mathematical ideas. This study examines students' cognitive load when solving geometric integral problems by analyzing intrinsic, extraneous, and germane load within the framework of Cognitive Load Theory. Using a descriptive qualitative approach, data were collected from 144 university students in mathematics-related programs at a public university in Indonesia through think-aloud protocols, written solutions, and classroom observations. The data were analyzed using NVivo-assisted thematic coding and supported by radar visualizations to strengthen analytical trustworthiness. The findings indicate that intrinsic load constituted the dominant cognitive burden, primarily arising from symbolic-visual confusion and visual-spatial difficulties when students attempted to coordinate algebraic expressions with geometric representations. Extraneous load further increased cognitive demands due to ambiguous verbal instructions, misinterpretation of symbolic cues, and excessive technical language; however, visual scaffolding and self-generated sketches were found to reduce unnecessary processing. Germane load emerged among a smaller group of students who demonstrated conceptual transfer, reflective verification, and schema integration, indicating the development of mathematical reasoning as students connected geometric structures with their corresponding integral representations. Overall, the study highlights the central role of instructional design in regulating cognitive load to support meaningful conceptual understanding and reasoning in solving visually complex mathematical problems.

Keywords

cognitive load theory, integral geometry, mathematical reasoning, visual-symbolic representation, cognitive load profiles