Design of an Adaptive Learning Analytics Framework through Standardization of Learner Behavior Patterns in Metaverse-Based Learning Environments

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Abstract

In metaverse-based learning environments, diverse learner behavior data—such as movement trajectories, interaction activities, and dwell time—are continuously generated in real time. However, significant variability in these behavioral data often arises due to individual differences among learners and heterogeneous environmental conditions, which in turn degrades the reliability and consistency of learning analytics outcomes. To address this challenge, this study proposes a learner behavior pattern standardization framework designed specifically for metaverse-based learning environments and presents a methodological approach for applying the standardized patterns to adaptive educational analysis. The proposed framework aims to enhance cross-learner comparability by normalizing behavioral data based on relative characteristics and structural patterns of learner behavior, rather than relying on absolute coordinates or environment-specific configurations. By focusing on the standardization of behavioral structures prior to analytical modeling, the framework provides a robust foundation for adaptive learning analytics that is less sensitive to individual and contextual variability. This study emphasizes the systematic design and procedural organization of behavioral data standardization, rather than empirical performance comparison, and discusses the potential for future extensions, including large-scale empirical validation and the integration of body-movement-based behavioral analysis.

Keywords

Metaverse-based learning, Learner behavior analysis, Data standardization, Adaptive education.