


# Chapter 7

## Ontology–Based Adaptive Assessment in Digital Education: Inclusive, Transparent, and Fair AI for Assessment

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### ABSTRACT

*This chapter explores the conceptual, pedagogical, and technical foundations of ontology-based adaptive assessment systems in AI-enhanced digital education. Moving beyond the limitations of conventional AI models, ontology-driven approaches support transparent, personalized, and ethically grounded alternatives by embedding semantic reasoning, explainable feedback, and fairness-aware logic into the assessment process. Drawing on theories such as the Zone of Proximal Development, Cognitive Load Theory, and Universal Design for Learning, this chapter presents a framework for modeling learner behaviors, structuring task progression, and generating context-sensitive feedback. Empirical use cases illustrate improvements in learning efficiency, perceived fairness, and engagement.*

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*Benchmarking analysis reveals advantages over traditional models. The chapter also examines institutional readiness, policy development, ethical data governance, and faculty involvement and concludes with future directions for scaling, cultural responsiveness, and interoperability.*

## **1. INTRODUCTION**

The integration of Artificial Intelligence (AI) into digital learning environments has enabled scalable, adaptive, and increasingly personalized forms of assessment. Techniques such as machine learning (ML), intelligent tutoring systems (ITS), learning analytics, and Computerized Adaptive Testing (CAT) support real-time monitoring, automate complex evaluation tasks, and facilitate differentiated instruction aligned with learner progress and pedagogical goals (Mulder et al., 2023; Renumol, 2022). Despite these advancements, concerns persist regarding algorithmic fairness, lack of interpretability, and opacity in decision-making, particularly in high-stakes educational contexts (Khalil et al., 2023).

One widely studied strategy to address these limitations is stealth assessment, which unobtrusively captures behavioral and cognitive indicators during learning without disrupting instructional flow (Shute et al., 2022). Embedded in contexts such as serious games and MOOCs, stealth assessment supports real-time adaptation. However, the underlying models often rely on behavioral proxies and statistical inference, limiting transparency and personal relevance in feedback delivery. These challenges raise valid concerns about validity, cultural sensitivity, and pedagogical alignment (Klinger et al., 2016; Thomas & Alkhafaji, 2023).

To enhance interpretability and instructional alignment, researchers have proposed ontology-based adaptive assessment frameworks. These approaches employ semantic web technologies to represent domain knowledge, learner states, instructional goals, and feedback logic in structured, auditable forms (Hadyaoui & Cheniti-Belcadhi, 2022, 2023a). Ontologies enable semantic alignment with curricular objectives and provide a foundation for context-aware personalization. Drawing on theories such as Cognitive Load Theory (Sweller, 1988), the Zone of Proximal Development (ZPD) (Vygotsky & Cole, 1978), and Self-Regulated Learning (Zimmerman, 2002), ontology-driven systems offer dynamic scaffolding, adaptive sequencing, and support for learner autonomy. For example, ontological reasoning can adjust task complexity based on cognitive load indicators, maintaining optimal challenge levels while minimizing frustration or disengagement.

Importantly, ontology-based assessment is not positioned as a replacement for established psychometric models such as Item Response Theory (IRT) or CAT. Rather, it complements them by prioritizing transparency, semantic adaptability, and ethical

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