

# Chapter 3

## Design of Emotionally– Aware Digital Twin Models for Socio– Affective Learning Analysis

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### **ABSTRACT**

*This research designs an emotion-based digital twin model for analyzing social-emotional learning in the context of smart education. The proposed model, using multimodal data including facial expressions, voice, physiological signals, and behavioral interactions, identifies the emotional and social state of the learner in real time and provides adaptive educational interventions based on that. The three-layer structure of the system architecture includes data collection, social-emotional analysis, and real-time decision-making. The results show that this model can help improve the learning experience, increase participation, and maintain the psychological well-being of learners.*

### **1- INTRODUCTION**

In recent decades, technological advances in education have fundamentally transformed the traditional structure of learning. The development of smart learning environments, along with the rapid growth of artificial intelligence, the Internet of Things, and educational data mining, has provided a new platform for personaliza-

DOI: 10.4018/979-8-3373-5117-9.ch003

tion, adaptability, and interactivity; but at the heart of these advances, one of the fundamental and sometimes overlooked components, namely the emotional and social dimension of the learner, still requires deep and systematic attention. Understanding emotions, motivations, and social relationships in the learning process not only plays a supporting role, but also affects the depth of understanding, the persistence of information, and the active participation of the learner (Longhi & Behar, 2024).

In such a context, the concept of the digital twin has entered the field of education as one of the newest technological approaches. Essentially a real-time digital representation of a physical entity, the digital twin has grown significantly in industry and engineering and is now entering more human-oriented fields such as health and education (Nozari, Abdi, & Jahangard, 2025). In the context of education, this concept means creating a dynamic model of the cognitive, behavioral, and emotional state of a learner that is continuously fed with real-time data and guides instructional decisions in real time (Longhi, Behar, & Machado, 2024). What distinguishes this model from other learning analytics systems is its ability to simultaneously adapt to the individual's behavioral and emotional changes and reflect them in the learning environment.

However, the main challenge in designing such twins is to accurately model emotions and social interactions in dynamic learning environments. Emotions play a crucial role in regulating learner behavior, selecting cognitive strategies, and persevering in the learning process. When learners are faced with difficult content, emotional states such as anxiety, anger, or confusion may lead to disengagement or reduced learning quality. In contrast, emotions such as curiosity, trust, and satisfaction can increase cognitive engagement and deepen interaction (Movahed, Movahed, & Nozari, 2024). This means that advanced learning systems must be able to identify, interpret, and respond to these emotions in order to optimize the learning experience at the individual level.

On the other hand, social interaction analysis is also an integral part of modern education, especially in virtual or collaborative environments. Learners' relationships with each other, group participation styles, and social dynamics can be important indicators of the level of emotional engagement, social support, and group cohesion, all of which should be reflected in the digital twin model (Nozari, Abdi, & Szmelter-Jarosz, 2025). Therefore, designing a comprehensive model that accurately models both the emotional dimension and social interactions is a serious necessity for the next generation of personalized learning systems.

In order to address this need, the present study focuses on designing an emotion-based digital twin for analyzing social-emotional learning. In this model, a combination of multimodal data including facial expressions, speech patterns, physiological signals, and behavioral interactions is used to identify the emotional and social state of the learner in real time. This information is then stored in the digital model in

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