Convergence of Artificial Intelligence, Ontologies, and Qualia in e-learning re-design

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Abstract. Nowadays, e-learning systems rely heavily on artificial intelligence (AI) as the core operational mechanism to deliver adaptive, personalized, and scalable learning experiences. However, the effectiveness of e-learning depends not only on computational capabilities but also on the conceptual basis of the knowledge under representation. Ontologies provide the formalized frameworks through which AI-based educational systems organize, correlate, and retrieve the educational content. Beyond the technical and structural aspects of e-learning lies the deeper philosophical foundation, that of Qualia, which refer to the phenomenological and subjective learners' sense, such as their perception of continued support, their engagement with the content in a meaningful way, and the quality of sensation on learning. This paper introduces the need for an e-learning entity which is based on the interplay between AI, Ontologies, and Qualia, arguing for an integrated framework that involves computational intelligence, semantic structure, and philosophical foundation.

Keywords: E-learning, Artificial Intelligence, Ontologies, Qualia.

1 Introduction

The ultimate goal of education is the development of individual autonomy, otherwise self-governance in the deepest and broader sense, i.e. intellectual, emotional, ethical, and social self-realization [1], [2]. This core purpose must remain the same also in the context of e-learning [3]. Autonomy does not simply mean the ability to study independently, but the cultivation of critical thinking, self-determination, emotional awareness, and the capacity to make informed decisions [4]. Autonomous learners are guided toward becoming active participants in their own learning path, not passive recipients of information [5]. Designing e-learning systems that recognize this complexity ensures that the digital transformation of education remains faithful to its most human-centered goal.

E-learning has been flourishing in recent years, largely as a result of rapid advancements in artificial intelligence (AI) and the implementation of educational ontologies

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that can be used to organize content in any field and thus make it machine interpreted [6]. Both technologies have revolutionized how learners interact with knowledge, offering adaptive learning paths [7]. Indeed, the extensive body of literature clearly indicates that the design and implementation of e-learning systems are primarily grounded in the achievements of artificial intelligence, often in conjunction with educational ontologies [8 – 13]. These two pillars form the operational and structural backbone of most modern digital learning platforms. Through them, systems model learner behavior, and personalize content. However, there is a scarcity of research that identifies philosophical dimensions [14], [15] as a third foundational element in the development of e-learning environments. The novelty of this paper is the inclusion of Qualia, that is the science of subjective experience, into e-learning design. Even though philosophy of mind has debated qualia for decades, computer science lacks a shared conceptual and formal schema to represent personalized states (e.g., frustrated, overwhelmed, pleased, surprised, etc.) in ways that are computable and interoperable [16]. While AI and Ontologies have provided the operational and structural foundation for e-learning, the integration of Qualia introduces the essential human dimension of how do learners feel. Incorporating such philosophical perspective could radically enhance the way educational technologies relate to learners, not only as cognitive agents but as sentient individuals. Bridging this gap may be essential for the next generation of e-learning.

In this vein, alongside AI (i.e. the operational mechanism) and Ontologies (i.e. the semantic structure), Qualia are introduced as the qualitative basis of e-learning design. The concept of Qualia is not claimed access to consciousness, but standardization of attributions of learners' experience (e.g., confusion, anxiety, curiosity, etc.). Based on the AI-Ontologies-Qualia triad, AI can estimate such attributions from data, Ontologies can guarantee consistency, and Qualia can direct pedagogical interventions toward the quality of learning.

The motivation for writing this paper is to obtain information about the basic terms and the use of AI, ontologies, and qualia in education in order to get better guidance when creating next generation e-learning. In this sense, the aim of this paper is to present these three distinctive but enmeshed domains and give an overview of recent research in the field, in the context of education. The research question of this paper is focused on finding how to combine AI, ontologies, and qualia in e-learning design in order to overcome its current limitations and meet the educational needs of the next generation.

The paper is structured as follows. Section 2 explores the theoretical background of AI, ontologies, and qualia in e-learning. Next, the interplay among the three domains is discussed in Section 3. Future research directions are discussed in Section 4. Finally, Section 6 concludes the paper.

2 Theoretical Background

This section broadly conceptualizes AI, Ontologies, and Qualia as the main theoretical building blocks of next generation e-learning systems design. The aim is not a systematic literature review [17] nor a systematic mapping study [18]; rather is conceptual

clarity of the corresponding domains in order to motivate their interrelation in the remainder of the paper.

2.1 Artificial Intelligence as Operational Mechanism

Artificial Intelligence (AI) is the subfield of computer science which offers a spectrum of technologies, including machine learning, deep learning, knowledge representation and reasoning, computer vision, natural language processing, in order to enhance efficiency, productivity, and decision-making in all sectors of everyday life [19].

In the education sector, AI has recently been adopted and used, particularly in the design of digital educational environments [20], [21]. Innovations such as intelligent tutoring systems, personalized and adaptive learning, conversational agents, predictive analytics, gamification, and AI-based assessment confirm the growing impact of AI on learner engagement, instructional design, and performance monitoring [22]. However, the integration of AI in e-learning also presents significant challenges [23]. These include data privacy, algorithmic bias, transparency, and educator resistance [24].

Indeed, bibliography on AI in education is both vast and rapidly expanding, reflecting the increasing stakeholders' interest in leveraging AI to transform learning and teaching. The growing body of literature can broadly be divided into two major categories. The first one focuses on specific applications of AI in e-learning, like natural language processing in detecting misconceptions of learners about a specific concept [25]; intelligent tutoring systems development for providing learners with personalized, adaptive, and interactive instructions [26], [27]; adaptive and personalized learning platforms design that customize content to individual learner progress [28]; and conversational agents which answer questions, explain concepts, provide feedback, guide learners through problem-solving steps, and simulate role-play scenarios for skills development [29]. Studies in this category emphasize mainly technical design, implementation, and performance evaluation, demonstrating how AI technologies can enhance instructional delivery, personalize learning experiences, and improve educational outcomes. The second one addresses the specific challenges associated with AI integration in education, especially ethical concerns [30], such as algorithmic bias [31], data privacy [32], academic integrity [33], [34], teachers' role [35], as well as issues like pedagogical alignment [36], and the potential of over-reliance on automation [37].

This path of research tends to adopt a critical, interdisciplinary perspective, incorporating insights from education, computer science, philosophy and social science. Both categories form a comprehensive framework for understanding the integration of AI in education, where technological innovation and critical evaluation progress in parallel. The application-focused research drives the development of advanced learning systems and tools that can enhance teaching and learning, while the challenge-oriented scholarship ensures these innovations are implemented in ethical and pedagogically sound way.

In a nutshell, AI in education is an interdisciplinary field that studies how AI innovations are integrated into educational settings. However, most research focuses on technological and ethical aspects, which cannot achieve a deep understanding of the

complex nature of instant sense-making of learners. Indeed, current AI-based educational platforms, as operational mechanisms, can produce detailed analytics, personalized recommendations, and adaptive feedback, but without addressing the subjective, emotional experiences of learners, these outputs may remain underutilized.

2.2 Ontologies as Knowledge Structure

Ontologies aim at capturing the semantics of domain expertise by deploying knowledge representation schemes, enabling a machine to understand the relationships between concepts in a domain [38].
In short, ontologies are semantic web technologies that are thought as the structure of web-based applications [39]. They explicitly define the relationships between concepts within a specific domain, enabling shared understanding and interoperability among systems and humans [40]. They are rooted in philosophy, especially by using the term in singular, that is "ontology", to refer to a unified and fundamental branch of metaphysics, but then they widely adopted, in plural, in computer science as "domain ontologies", by providing a formal representation for knowledge structure, thus enabling data integration, and reasoning [41]. Nowadays, they are no longer only theoretical approaches; they are semantic tools to facilitate the goals of sharing, and reusing knowledge [42].

Traditionally, studies on ontologies in the context of education are viewed from two perspectives, "ontologies in education" and "educational ontologies". Although these terms are often used interchangeably, they signify distinct research directions. The first term refers broadly to the application of ontology engineering within educational settings. For instance, ontologies were used for curriculum modelling and management, for describing learning domains, learning data, and e-learning services [43], [44]. Recent studies in the field of e-learning refer that ontologies allow systems to adapt content based on learner profiles, preferences, and performance [45]; allow institutions to track performance and enhance decision-making [46]; aligns gamification elements with cognitive models to improve learner engagement [47]; and facilitate curriculum modeling and knowledge alignment across different platforms, fostering standardization [8]. On the other hand, educational ontologies are specific domain ontologies that focus on the standardization of specific learning domains and educational concepts, such as learning objectives through Bloom's taxonomy, instructional strategies, or assessment types [48 – 50].

In summary, ontologies have gained the attention of scientists in e-learning field since they are used as tools for organizing and managing information due to their inherent features, including resource sharing and reuse, knowledge modeling, and inference.

2.3 Qualia as the Philosophical Foundation

Qualia are the felt, subjective "what it is like" aspects of experience [51]. The term became central in late 20th century debates about mind and consciousness [52]. As a

theoretical foundation of computer science, Qualia mark the difference between processing information and experiencing it [53 – 55].

Indeed, scholars and engineers have already explored the conceptual, ethical, and architectural implications of qualia within AI. One of the dominant themes in the latest literature is that while AI systems have made significant progress in simulating emotional expressions [56], the problem of simulating subjective feelings remain unresolved [57]. Another notable area of recent expansion lies in affective computing, particularly with respect to ethical implications, such as data privacy and user satisfaction [58 – 60]. In a broad sense, the research on qualia in computer science, and, in particular in AI, reflects a rich multidisciplinary dialogue. The field is advancing rapidly, from abstract philosophical studies to concrete architectural experiments [61].

Especially, in the context of education, qualia are rarely discussed explicitly in e-learning literature; they are indirectly related with AI-based learning systems. For instance, the design of emotion-sensitive intelligent tutoring systems relies on tracking facial expressions, or voice tone to infer user emotions and adapt content accordingly [62]. These systems approximate qualia by interpreting behavioral patterns [63]. Despite substantial progress in e-learning domain, by relating education, cognitive science and neuroscience [64], qualia remain unutilized in explaining the e-learning processes that are accompanied by felt experience [65]. Unfortunately, for e-learning designers, many of the desirable traits are not inherently measurable via traditional, quantitative means, but they are emergent properties dependent on qualitative aspects of mechanistic, unconscious reactions.

3 The Interplay of AI, Ontologies, and Qualia in E-learning

Re-designing and modernizing e-learning is now imperative to satisfy the diverse disclosure requirements of learners, educators, institutions, regulators, and industry partners. This goal requires a coherent convergence of AI for operational intelligence and personalization, Ontologies for structured and interoperable knowledge, and Qualia to capture the phenomenological and affective dimensions of learning.

Although there is no existing body of literature that explicitly focuses on the intersection of AI, Ontologies, and Qualia in e-learning, a number of studies across these domains provide conceptual and technical insights for their interrelation. These works, while often studying the concepts in isolation, collectively contribute to a broader understanding of how subjective experience (Qualia), structured knowledge representation (Ontologies), and intelligent adaptation (AI) may converge in the design of next-generation e-learning. More precisely, AI is increasingly used to personalize learning experiences through adaptive algorithms and intelligent tutoring systems [66], [67] while ontologies serve as structured frameworks that formalize domain knowledge and learners' models [68], [69]. Simultaneously, the concept of qualia has gained traction in affective computing and user experience design, particularly in emotionally responsive learning environments [70]. Taken together, these fields open new possibilities for modeling and enhancing not only the cognitive but also the emotional and reactive dimensions of digital learning.

This paper proposes a novel, interdisciplinary theoretical framework for understanding the relational interaction between learners and advanced e-learning models through the lens of the triad AI-Ontologies-Qualia.

The following Table 1 gives an overview of the three pillars work together in designing next generation e-learning.

Table 1. AI-Ontologies-Qualia triad for e-learning.

	Definition in e-learning	Scope in e-learning	Interdependencies
Artificial Intelligence	The application of data-driven algorithms that personalize instruction, automate feedback, and optimize learning pathways at scale	Operational mechanism (augment teaching and personalize learning by using technological advancements)	AI depends on Ontologies for clear meaning of context and on Qualia to prioritize which experiences matter
Ontologies	Formal, shared models of concepts and their relationships that structure educational knowledge for interoperability, personalization, and reasoning	Knowledge structure (formal, shared semantic models that define domains, learner profiles, and instructional processes, enabling interoperability, precise metadata, adaptive personalization, and explainable analytics across platforms)	Ontologies depend on AI to populate instances and on Qualia to formalize experiences
Qualia	The subjective qualities of learners' experience that shape motivation and decision-making	Theoretical foundation (recognition and modelling of the learners' lived experience)	Qualia depend on AI for operationalization and on Ontologies for standardization

The integration of AI, Ontologies, and Qualia-like modeling, although still in the early stages of development, is reshaping e-learning. Ontologies provide the semantic structure of the model, given that they provide the formal knowledge representation of learner preferences and content and AI operates as the main mechanism that enables adaptive and context-sensitive interaction, through the use of machine learning technologies [71], [72]. Qualia, while not directly programmable, as theoretical foundation

of the model, serve as motivational goals for creating emotionally and ethically aware learning environments. Though still largely theoretical, such proposal indicates a direction where Qualia, AI, and Ontologies convergence could support e-learning re-design.

4 Future Directions

As future work, the Qualia Ontology for e-learning will be constructed, aligned with existing educational ontologies and in accordance with AI advancements. Its core will include classes and relations standardizing attributions of learner experience with explicit dimensions, modalities, context, and evidence. For instance, the class of LearningEpisode refers to a time-bounded instructional activity for a specific learner, such as watching a video, solving a problem, or taking a quiz. Each LearningEpisode is characterized by a Modality (e.g., visual, auditory, or textual) within which experience arises, and by PhenomenalQuality terms that capture what the LearningEpisode felt like (e.g., clarity, perceived complexity, or novelty). The qualia core is represented by the class AffectiveState, which encodes states such as confusion, curiosity, boredom, anxiety.

This ontology is under construction and its purpose is to encode what learners are likely experiencing a learning path in a consistent and interoperable way. By completing and using this ontology in an e-learning environment, mechanism (i.e. what the system does), meaning (i.e. how things are named and related), and experience (i.e. why it matters for learning) are clearly interwined, thus preventing pedagogical errors and enabling transparent and controllable content adaptation to learners' aspirations.

5 Conclusion

Next generation e-learning seems to stand at the confluence of technological innovation, semantic structure, and philosophical research. AI provides the technological mechanisms for adaptability and efficiency; ontologies offer the conceptual schemes for knowledge representation; and qualia explain the grounds of private feelings. Their interplay can lead to intelligent, coherent, and private thinking enriched e-learning environments. This triadic form may mark a shift toward e-learning systems that respect the spirit of democracy in learning such as, the objectivity of knowledge, the subjectivity of experience, and the equal access to learning.

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