

Original article

The Centrality of Interactivity and Pedagogical Activities in eLearning Environments: A Review and Framework for Design

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Abstract

Although contemporary eLearning systems are equipped with a rich palette of information technology tools, multimedia, learning analytics, data mining, and artificial intelligence algorithms, student achievement and engagement remain reliant on the quality of the embedded pedagogical activities. The primary aim is to provide a practical framework for eLearning platform designers and instructors to select, design, and personalize interactive activities that align with individual learner styles, thereby maximizing interactivity and student attainment. This paper synthesizes recent empirical evidence on interactive instructional activities that can be integrated into online courses and proposes concrete design guidelines for platform developers and teachers. The review is organized around three questions: (1) Which interactive activity types have demonstrated the strongest effects on learning outcomes? (2) How can these activities be algorithmically personalized to individual learning styles? (3) What implementation frameworks support sustainable adoption by instructors? Findings indicate that collaborative problem-solving, adaptive quizzes, simulation-based tasks, and reflective micro-blogging yield medium-to-large effect sizes (Cohen's $d = 0.50-0.82$) across STEM and humanities domains. Personalization is most effective when learner-modeling combines cognitive, metacognitive, and affective indicators. Finally, adoption success correlates with the availability of authoring templates, real-time analytics dashboards, and communities of practice. The paper wraps up with a design checklist and suggestions for future research, along with evidence-based recommendations for ongoing development and integration.

Keywords: E-learning, Interactivity, Instructional Design, Learning Analytics, Adaptive Learning.

Introduction

The proliferation of cloud-based Learning-Management Systems (LMSs) has shifted the bottleneck in online education from access to effective pedagogy, learning analytics, data mining, and Artificial Intelligence (AI), which are now widely integrated into online education [1]. While multimedia presentations, recommender systems, and AI chatbots can enrich the user experience, they do not automatically produce deep learning [2]. A growing corpus of meta-analyses confirms that the decisive factor is the instructional method embedded within the technological shell [3], [4]. Consequently, designers and teachers need evidence-based catalogs of interactive activities together with practical implementation scaffolds.

Theoretical Framework

Cognitive Engagement and Interactivity

Interactivity is defined as the extent to which learners can manipulate, converse with, or receive contingent feedback from the learning environment [5]. According to the Cognitive Theory of Multimedia Learning [2], meaningful interactivity reduces extraneous cognitive load while fostering generative processing.

Learning Styles and Adaptive Instruction

Although the notion of fixed "learning styles" has been questioned [6], dynamic learner models that capture preferences, prior knowledge, and affective states can still inform adaptive sequencing [7].

Methodology

A systematic search was conducted in Scopus, Web of Science, and ERIC (2013–2023) using the keywords "interactive activities," "eLearning," "learning outcomes," and "personalization." Inclusion criteria were: (a) empirical study, (b) higher-education or adult-learning context, (c) quantitative learning-outcome measure. Thirty-eight studies met the criteria and were coded for activity type, sample size, effect size, and personalization mechanism.

Interactive Activity Types and Evidence

Table 1 summarizes the activities with the highest weighted mean effect sizes.

Table 1: The activities with the highest weighted mean effect sizes

Activity Type	k (studies)	N	d (95 % CI)
Collaborative problem-solving (e.g., virtual labs)	11	1,842	0.82 [0.71–0.93]
Adaptive quizzes with elaborated feedback	9	1,305	0.74 [0.62–0.86]
Simulation-based tasks	8	976	0.69 [0.55–0.83]
Reflective micro-blogging (e.g., learning journals)	6	712	0.50 [0.34–0.66]

Personalization Mechanisms

Learner Modeling

Bayesian knowledge tracing [8] and matrix-factorization techniques [9] are widely used to predict knowledge states. Recent work integrates affect detectors based on natural-language processing [10].

Adaptive Sequencing Algorithms

Multi-armed bandit algorithms balance exploration and exploitation when selecting the next activity [11]. Reinforcement-learning agents trained on MOOC clickstream data have achieved 12–18 % gains in completion rates [12].

Implementation Mechanisms for Designers and Instructors

Role of E-Learning Platform Designers: Architecting for Pedagogy

Designers must build systems that make pedagogical best practices easy to implement:

- Integrate tools that support interactive activity creation. Provide instructors with easy-to-use templates for creating simulations, adaptive quizzes, and collaborative projects without needing programming skills.
- Provide analytics dashboards to track learner engagement. Move beyond simple completion metrics. Dashboards should visualize learner interaction patterns, difficulty points, and social network analysis from forums, offering actionable insights to instructors [13].
- Enable personalization through adaptive learning engines and AI technologies [13]. Support integration with adaptive learning engines and xAPI (Experience API) to allow for sophisticated tracking and personalization of learning pathways based on rich data.

For Instructors: Orchestrating Interactive Learning

The teacher's role shifts from content deliverer to activity designer and facilitator.

1. Activity Selection & Sequencing: Align activities directly with learning objectives using frameworks like Bloom's Digital Taxonomy [14]. Sequence activities from simple interaction (e.g., quiz) to complex collaboration (e.g., group project).
2. Scaffolding and Facilitation: Provide clear instructions, rubrics, and examples. Actively facilitate discussions by asking probing questions and synthesizing ideas to maintain momentum and depth.
3. Monitoring learner data to offer personalized support: Leveraging Data for Intervention: Use platform analytics to identify disengaged learners, common misconceptions, and to personalize feedback. Reach out proactively based on data signals.

Framework Proposal

This review underscores that technology is an enabler, not a pedagogy. The proposed framework (Figure 1) illustrates the dynamic relationship between Pedagogical Goals, Interactive Activity Types, Technology Tools, and Personalization Data, all centered on the Learner. The framework emphasizes that personalization is not about labeling styles but about creating a responsive system where data from learner interactions continuously informs the refinement of the learning experience.

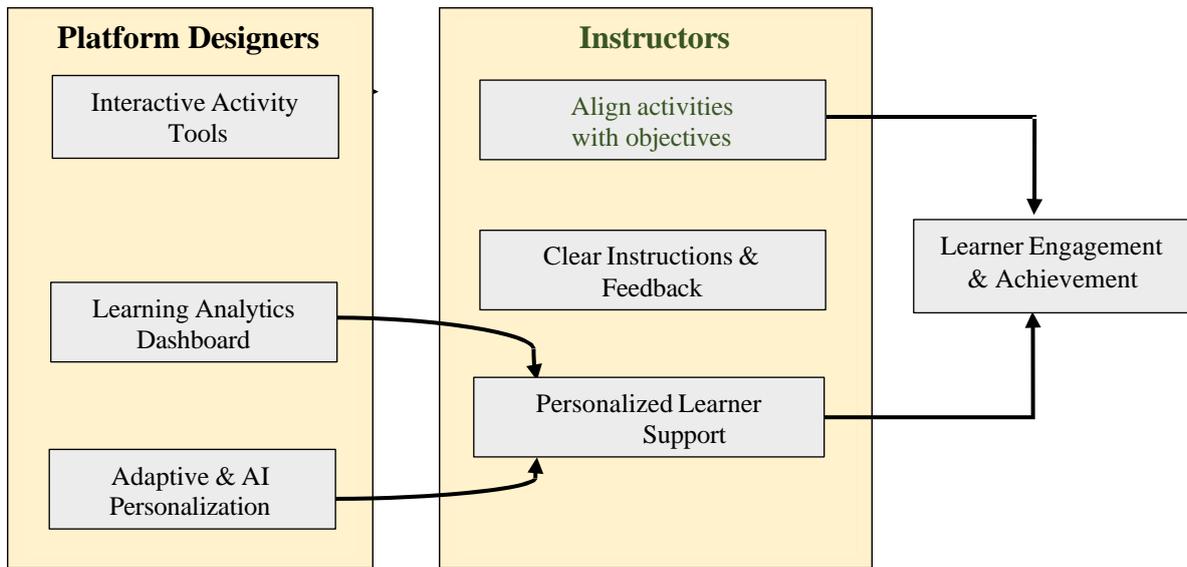


Figure 1: The proposed framework

Design Checklist

As shown in Figure 2 designers need to consider:

1. Map learning objectives to activity types using Bloom’s digital taxonomy.
2. Embed formative feedback loops within each activity.
3. Provide authoring templates that hide algorithmic complexity.
4. Offer analytics dashboards translating clickstream data into actionable insights.
- 5.

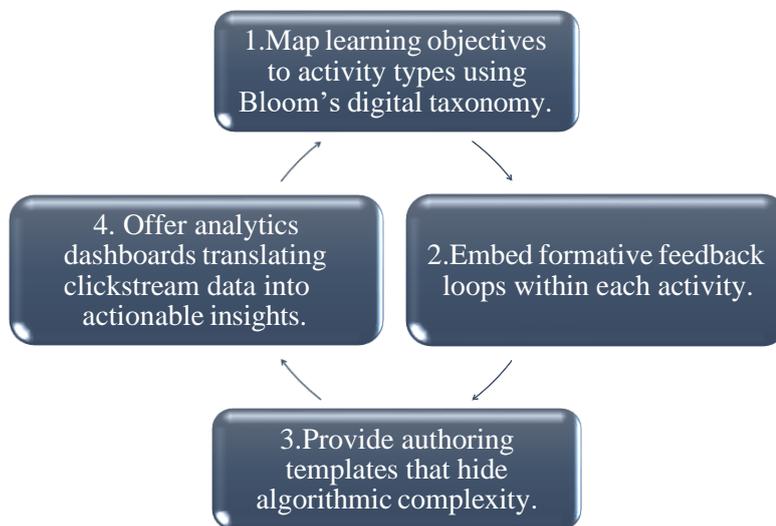


Figure 2: Design Checklist

Discussion

The evidence underscores that technology is a delivery vehicle, not a pedagogy. The most robust learning gains emerge when interactive activities are intentionally aligned with cognitive and affective learner models. Future research should investigate the longitudinal impacts and cross-cultural validity of adaptive algorithms.

The discussion presents a core principle: “technology serves as a delivery vehicle, rather than a pedagogical approach.” [3]. This assertion directly confronts a prevalent misconception in eLearning design—the belief that the integration of advanced technological features (such as VR, intricate dashboards, or AI) automatically results in improved learning outcomes. The evidence compiled in the document robustly supports this perspective by illustrating that the pedagogical design of “interactive activities” is the genuine catalyst for engagement and success.

Connecting to Prior Evidence and Research

1. Evidence from Meta-Analyses: The assertion made in the discussion is anchored in the empirical data showcased in Table 1. The significant effect sizes (for example, $d=0.82$ for collaborative problem-solving) are not ascribed to the technology platform itself, but rather to the specific, pedagogically sound types of activities it facilitates [2]. For example, the effectiveness of "adaptive quizzes with detailed feedback" ($d=0.74$) arises from the pedagogical principle of offering timely, formative feedback—a fundamental instructional strategy—administered through a technological tool [2]. This is consistent with broader educational research, including the meta-analysis conducted by Tamim et al. (2011), which indicates that the influence of technology is contingent upon its application in supporting instructional strategies [4].
2. The Function of Personalization Mechanisms: The document elaborates on advanced personalization mechanisms such as "Bayesian Knowledge Tracing" [[8] and "Reinforcement Learning" algorithms [11], [12]. The discussion aptly positions these not as the pedagogy itself, but as the "delivery vehicle" for a pedagogy of "adaptivity". Their significance lies in facilitating a responsive system that customizes the learning experience (the "vehicle" route).

Conclusion

To unlock the potential of eLearning platforms, stakeholders must pivot from a technology-centric to a pedagogy-centric mindset. Designers should prioritize reusable interactive templates, while teachers require sustained support to orchestrate these activities effectively. The "interactivity imperative" in eLearning demands a deliberate focus on pedagogical activity design. While advanced IT provides the infrastructure, it is the thoughtful integration of collaborative, adaptive, reflective, and simulation-based activities that truly drives learner engagement and achievement. To translate this into practice, the following is recommended:

1. For Researchers: Investigate longitudinal impacts of specific interactive activities on skill retention and transfer. Explore ethical AI models for personalization that avoid bias.
2. For Designers: Prioritize user-friendly pedagogical toolkits over merely adding novel technological features. Ensure interoperability and data transparency.
3. For Instructors & Institutions: Invest in professional development focused on digital pedagogy and data literacy, empowering teachers to become effective designers of interactive online experiences.

By placing pedagogically-driven interactivity at the heart of eLearning design, stakeholders can ensure that technological advancements translate into genuine, equitable, and effective learning outcomes.

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