

The role of activity theory in understanding emerging e-learning practices in higher education: A systematic review of contexts, contradictions, and technological mediation

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ABSTRACT

This study investigates the role of Activity Theory (AT) in e-learning context, prompting an understanding of e-learning initiatives in higher education. Despite a growing body of AT-informed research on e-learning practices in higher education, existing studies remain fragmented, with limited attention to contradictions as generative forces, under-exploration of technology's mediating role, and a lack of systematic synthesis. The review was composed systematically: the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) was applied; four robust databases, Scopus, ScienceDirect, Google Scholar, & JSTOR, were used to screen the most relevant studies. Authors reached a consensus on coding 31 studies into three categories, which encompass an *Analytical Lens*, *Conceptual Framing*, and *Intervention-based Design*. The most common type is the *Analytical Lens*, followed by *Conceptual Framing* and *Intervention-based Design*. Contradictions at all four levels of *Activity Theory* drive adaptation and change in e-learning. Primary tensions (e.g., learner motivation, faculty digital competence) are typically managed with short-term fixes, while secondary contradictions between tools, rules, and objectives are most frequent, prompting pragmatic task and role negotiations and, at times, curriculum redesign. Tertiary contradictions between reform-oriented innovations (e.g., flipped or AI-enhanced learning) and entrenched traditions most reliably catalyse expansive learning and institutional transformation when backed by professional development and governance. Quaternary contradictions across academic, social, and policy systems produce uneven outcomes, with success depending on cross-unit coordination and policy alignment.

Keywords: activity theory, PRISMA, higher education, technology's mediating role

INTRODUCTION

The evolving nature of e-learning technologies has reformed teaching and learning practice in higher education, leading to diverse e-learning initiatives, such as flipped classrooms, mobile learning, AI-assisted learning, and VR/AR. These technological upgrades have introduced new forms of digital pedagogy, ranging from open educational practice, collaborative design, technology-supported peer assessment, to student-to-student connectedness. These developments drive sociotechnical transformations that interplay with pedagogical shifts, institutional norms, and learner identities. Therefore, there is a pressing demand for a robust analytical framework that can address sociocultural, institutional, and technological complexities.

E-learning systems in post-secondary education function within multilayered contexts where tools, individuals,

communities, rules, and objectives interact in dynamic and often contradictory ways. The shift from teacher-centered to learner-centered paradigms, the integration of intelligent systems into instructional processes, and the redefinition of learning spaces through digital mediation all underscore the need for an analytical lens that transcends linear cause-effect models. Traditional frameworks that focus exclusively on behavioral or cognitive dimensions are often insufficient to account for the broader sociocultural and institutional dynamics at play (Hu & Raman, 2024). Therefore, a comprehensive understanding of how these systems are implemented, negotiated, and transformed requires a systemic, context-sensitive approach that can capture both the structural and emergent properties of e-learning activity.

In response to the complex demands of analyzing the evolving landscape of digital learning environments, Activity Theory (AT) has emerged as an increasingly prominent

theoretical and methodological framework in educational technology research. Originally grounded in Vygotsky's (1978) cultural-historical theory of mediated action, AT was expanded by Leont'ev (1981) to incorporate collective activity systems and later systematized by Engeström (1987) into a holistic, third-generation model capable of capturing the dynamic, mediated, and socio-historically situated nature of human practices.

At its core, AT conceptualizes learning not as an isolated cognitive event but as a socially embedded, tool-mediated activity oriented toward an object (or goal). An activity system, as described by Engeström (1987), comprises six interrelated components: the subject (individual or group engaged in the activity), the object (the goal or motive driving the activity), tools/artifacts (material or symbolic mediators), rules (norms and regulations shaping interactions), the community (the broader social group involved), and the division of labor (distribution of tasks and authority within the system). These elements jointly constitute the minimal meaningful unit of analysis for exploring the design, implementation, and transformation of technology-supported learning environments (Jonassen & Rohrer-Murphy, 1999; Koszalka & Wu, 2004; Zheng et al., 2020).

Engeström's (2001) third-generation AT further expands this model to allow for the examination of multiple, interacting activity systems—a critical development for understanding cross-institutional collaboration, technological mediation, and distributed agency in contemporary e-learning contexts. In this formulation, the object of activity remains central, serving not only as the motivator of human action but also as the site of potential transformation. As Kuutti (1997), and Hung and Wong (2000) note, it is through the transformation of the object into an outcome that the execution and evolution of an activity is rendered meaningful.

A distinctive feature of AT is its emphasis on contradictions—historically accumulated tensions within or between components of the system—as drivers of systemic change. These contradictions, whether they manifest between tools and rules, subjects and division of labor, or within the object itself, are not viewed as mere disruptions but as generative forces that can lead to expansive learning and innovation. Engeström (1987) argues that surfacing, negotiating, and resolving such contradictions enables researchers to trace how systems evolve over time and to identify leverage points for pedagogical redesign and institutional transformation.

This analytical capacity has made AT especially useful in the study of educational technologies where human agency, digital tools, and institutional norms intersect in complex and often non-linear ways. For instance, in game-based learning environments, AT has been used to map how digital artifacts mediate the learner's interaction with content and community (Carvalho et al., 2015). In the context of social media use for learning, Rambe (2012) applied AT to reveal tensions between informal peer interaction and formal institutional expectations. More broadly, scholars have employed AT to examine the integration of learning management systems, mobile learning applications, AI-powered tools, and hybrid or blended learning practices (Hite & Thompson, 2019; Kaptelinin & Nardi, 2006; Zheng et al., 2020).

Karanasios et al. (2018) highlight that AT is particularly adept at addressing the challenge of studying the interaction between technology and actors, given its capacity to model both individual and collective dimensions of activity. As a cross-disciplinary framework, AT accommodates analysis across multiple layers of sociocultural, institutional, and technological complexity, making it a powerful lens through which to investigate not only what is happening in e-learning systems but why and how those systems are evolving.

Although AT has been increasingly adopted to study the implementation and use of e-learning technologies in higher education, there remains a lack of systematic, data-driven synthesis that organizes existing research around how AT is specifically applied. Current literature spans a wide array of e-learning contexts—such as mobile learning, flipped classrooms, AI-supported learning, blended learning, and immersive technologies like VR and AR—as well as digital pedagogical approaches including open educational practice, collaborative design, technology-supported peer assessment, and student-to-student connectedness. These studies often, however, remain contextually fragmented and conceptually diffuse, limiting our understanding of how AT is employed to frame, interrogate, and interpret the systemic and cultural dimensions of such diverse initiatives.

Furthermore, while contradictions—historically accumulated tensions within or between activity system components—are a foundational concept in AT, they are rarely the central analytic focus. Few studies explicitly trace how contradictions are identified, negotiated, and transformed to enable systemic learning and innovation. This represents a missed opportunity to recognize AT's theoretical strength and its constraints in learning and teaching practice. Similarly, though e-learning tools and platforms are routinely discussed as part of the learning environment, their role as mediating artifacts—shaping not only interaction but also subject-object relations, community structures, and rule systems—is often under-theorized. As a result, the profound ways in which technology reorganizes learning practices, redistributes agency, or restructures institutional norms remain insufficiently explored.

While AT provides a robust framework for analyzing mediated human activity, the reviewed literature also reveals important limitations in fully explaining the complex, dynamic, and technologically entangled nature of contemporary e-learning environments. As evidenced across the corpus, technology does not merely function as a neutral mediating artifact but actively reshapes subject-object relations, redistributes agency, and reconfigures institutional practices across diverse contexts. However, AT remains descriptively rich yet analytically constrained in accounting for why similar technologies produce divergent outcomes, how contradictions scale from local adaptations to systemic transformation, and how agency is distributed across human and non-human actors (Bullen & Morgan, 2015; Kessler, 2020; Lai, 2021; MacLeod et al., 2019).

To address these limitations, complementary theoretical perspectives provide important extensions to AT's analytical scope. In particular, Affordance Theory offers a micro-level lens to explain how learners and teachers perceive and enact technological possibilities, thereby clarifying variations in

how primary contradictions are resolved (Gibson, 1979; Leonardi, 2011; Norman, 1999). Sociotechnical Systems (STS) theory further situates technological mediation within interdependent social and technical subsystems, helping to explain the persistence or transformation of secondary contradictions through alignment—or misalignment—between organizational structures and technological infrastructures (Sawyer & Jarrahi, 2023; Trist & Bamforth, 1951). In addition, Actor–Network Theory (ANT) provides a critical perspective on distributed agency by recognizing both human and non-human actors, such as platforms, algorithms, and data infrastructures, as active participants in shaping learning practices and institutional outcomes (Latour, 2005).

Although AT remains the primary analytical framework guiding this review, these complementary perspectives are introduced here to foreground its analytical boundaries and are to provide deeper interpretation of the findings and address theoretical blind spots identified during the synthesis.

This study aims to address these gaps by conducting a PRISMA-based, thematically structured synthesis of AT-informed studies in higher education e-learning contexts. The research questions guiding our studies are:

RQ1. How has AT been applied to study the implementation and use of e-learning initiatives in higher education?

RQ2. What are the most commonly examined context-specific forms of emerging e-learning initiatives (e.g., mobile learning/flipped classrooms/AI-supported learning/synchronous learning/blended learning/VR/AR or digital pedagogy/open educational practice/collaborative design/technology-supported peer assessment, and student-to-student connectedness), and how are they analyzed through AT?

RQ3. What kinds of contradictions are identified in these studies, and how are they resolved or transformed?

RQ4. Based on existing AT-informed studies, what catalytic and constraining roles does technology play as a mediating tool in learning and teaching practices, and what theoretical limitations of AT are revealed in explaining these roles?

RESEARCH METHODOLOGY

To ensure a methodologically rigorous and transparent Systematic Literature Review (SLR), this section outlines the adopted strategies and tools across five key domains: (1) PRISMA framework; (2) databases used; (3) time frame for included articles; (4) SLR screening process; and (5) data extraction and analysis procedures.

PRISMA Framework

PRISMA facilitates the formulation of focused research questions, the establishment of inclusion and exclusion criteria, and ensures comprehensiveness and accountability throughout the review (Knobloch et al., 2011; Moher et al., 2009; Page et al., 2020). In this study, PRISMA guided the collection, screening, and synthesis of 568 articles. The EndNote reference manager was employed for initial article

management and citation integration. For collaborative screening and removal of duplicates, Rayyan was utilized, allowing real-time reviewer tagging and conflict resolution. The subsequent quality assessment and data extraction were conducted using EPPI-Reviewer, a specialized platform that supports multi-layered review synthesis.

Given that the included studies comprised a heterogeneous mix of qualitative, quantitative, and mixed-methods designs, a single, design-specific appraisal tool would have been insufficient to ensure consistent evaluation. Therefore, the Mixed Methods Appraisal Tool (MMAT) was selected and implemented within EPPI-Reviewer, as it enables the concurrent and standardized assessment of diverse methodological approaches under a unified framework (Hong et al., 2018). This integration ensured methodological consistency, reduced appraisal bias across study types, and enhanced the transparency and comparability of quality evaluation. Finally, thematic coding and pattern recognition were performed using NVivo, which enabled in-depth qualitative analysis and visualization.

Databases Used

Given the interdisciplinary nature of AT and e-learning, four comprehensive databases were systematically searched to capture a wide breadth of scholarly discourse. Primary databases: ScienceDirect and Google Scholar formed the core of the English-language search. Scopus is known for its expansive coverage of high-impact educational journals across disciplines, while Google Scholar aggregates diverse scholarly content, including education. Supplementary databases: To increase robustness, two additional repositories—JSTOR and Scopus—were included. These databases are highly respected in the field of education, providing access to a range of peer-reviewed journals, empirical studies, and policy-related research.

Time Frame for Research Articles

The review targets literature published between 2015 and 2025, a period that marks significant advancements in both educational technology and theoretical applications of AT. The mid-2010s witnessed a global transformation in how educational institutions approached e-learning, shifting from infrastructure expansion to the integration of pedagogical innovation, digital tools, and systemic reform. This timeline allows the review to capture developments from foundational e-learning initiatives to the recent emergence of AI-supported and mobile learning environments.

The Process of Screening Articles

The SLR screening process was executed in a three-phase structure consistent with PRISMA guidelines:

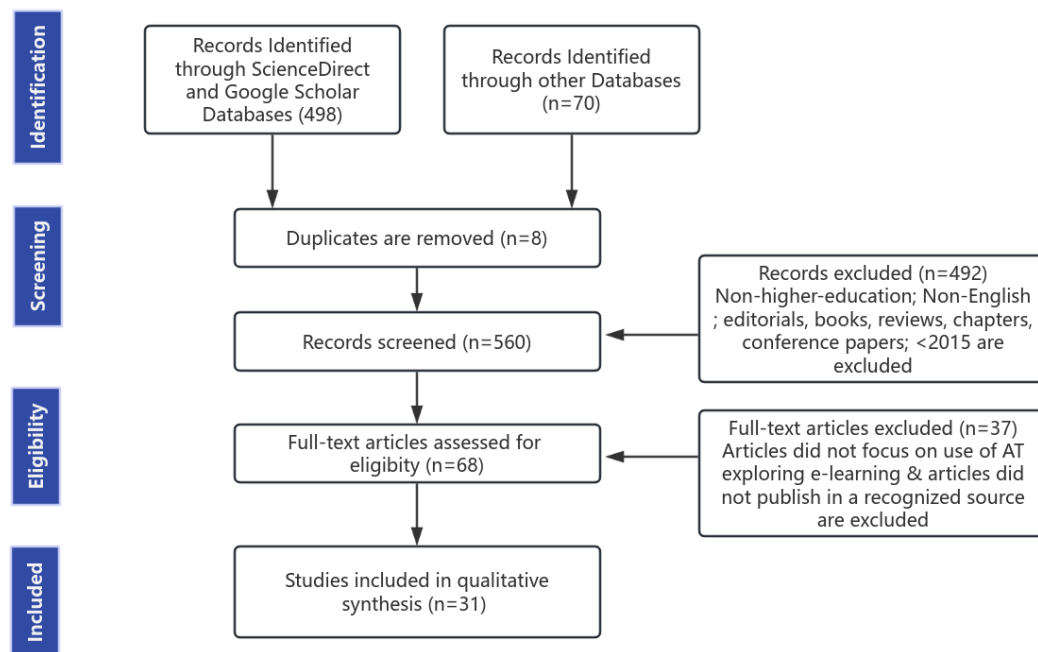
Identification: Initially, a structured keyword development process was undertaken, informed by prior literature, thesauri, and domain-specific terminology. For article searches, Boolean operators and advanced search strings (see [Table 1](#)) were used across ScienceDirect and Google Scholar in May 2025. This process yielded 498 articles, with an additional 70 articles retrieved through manual searches in Scopus, and JSTOR using comparable terms.

Table 1. Search strings

Scopus
TITLE-ABS-KEY (("activity theory" OR "cultural historical activity theory" OR CHAT OR Engeström) AND ("e-learning" OR "digital learning" OR "online learning" OR "technology-enhanced learning") AND ("higher education" OR university OR "post-secondary") AND ("e-learning initiatives" OR "e-learning technologies" OR "digital pedagogy"))
Google scholar
("activity theory" OR "cultural-historical activity theory" OR CHAT OR Engeström) AND ("e-learning" OR "digital learning" OR "online learning" OR "technology-enhanced learning") AND ("higher education" OR university OR "post-secondary education") AND ("e-learning initiatives" OR "e-learning technologies" OR "digital pedagogy")
ScienceDirect
("activity theory" OR "cultural historical activity theory" OR CHAT OR Engeström) AND ("e-learning" OR "digital learning" OR "online learning" OR "technology-enhanced learning") AND ("higher education" OR university OR "post-secondary") AND ("e-learning initiatives" OR "e-learning technologies" OR "digital pedagogy")
JSTOR
("activity theory" OR "cultural historical activity theory" OR CHAT OR Engeström) AND ("e-learning" OR "digital learning" OR "online learning" OR "technology-enhanced learning") AND ("higher education" OR university OR "post-secondary") AND ("e-learning initiatives" OR "e-learning technologies" OR "digital pedagogy")

Table 2. Criteria of inclusion & exclusion

Criterion	Inclusion	Exclusion
Language	English	English
Publication type	Articles	Chapters, Books, Conference paper
Educational Level	Higher education	None-higher-education
Publication date	2015-2025	Before 2015
Subject area	Education, Social science	Other than Education & Social science

**Figure 1.** Screening model for the study (Adapted from Moher et al., 2009)

Screening: The Rayyan platform facilitated initial screening, during which duplicate articles were excluded. Titles and abstracts of the remaining articles were reviewed independently by multiple authors to determine relevance based on predefined inclusion/exclusion criteria.

Eligibility and Inclusion

Following full-text reviews, only peer-reviewed journal articles published in English and falling within the domains of education and social sciences were retained. Articles such as editorials, conference abstracts, and non-empirical studies were excluded (see [Table 2](#)). The inclusion process culminated

in a final selection of 560 articles, representing a balanced corpus for thematic coding and synthesis. Following the thorough examination, a total of 68 articles did not meet the inclusion criteria and were excluded. As a result, only 31 articles were available for further analysis ([Figure 1](#)).

Data Extraction and Analysis

Data from the selected studies were extracted into a pre-designed coding sheet based on the AT framework. Key components recorded included study context, theoretical framing, components of activity systems (subjects, tools, rules, community, division of labor, outcomes), contradictions

Table 3. Detailed quality appraisal of included studies (MMAT criteria)

Reference	Method	Score	RQ Clarity	Data Collection	Data Analysis	Bias & Limitations	Coherence
(Voogt et al., 2015)	Case Study	4	✓	✓	✓	△	✓
(Bullen & Morgan, 2015)	Case Study	3	✓	△	✓	△	✓
(Kaatrakoski, et al, 2016)	Mixed Methods	5	✓	✓	✓	✓	✓
(Su, 2017)	Quasi-experimental design	4	✓	✓	✓	△	✓
(Kwon, et al, 2018)	Quasi-experimental design	4	✓	✓	✓	△	✓
(Nambi, 2019)	Systematic Review	4	✓	✓	✓	△	✓
(Zheng, et al., 2019a)	Systematic Review	3	△	✓	✓	△	✓
(Zheng, et al, 2019b)	Systematic Review	2	△	✓	✓	△	△
(Chung, et al, 2019)	Systematic Review	4	✓	✓	✓	△	✓
(MacLeod, et al., 2019)	Systematic Review	4	✓	✓	✓	△	✓
(Yildiz, et al., 2020)	Systematic Review	4	✓	✓	✓	△	✓
(Kessler, 2020)	Case Study	3	✓	✓	△	✓	△
(Astudillo & Martín-García, 2020)	Systematic Review	2	△	✓	△	✓	△
(Burke, 2020)	Qualitative Approach	3	✓	✓	△	△	✓
(Scavarelli, et al., 2021)	Systematic Review	4	✓	✓	✓	△	✓
(van der Westhuizen, et al., 2021)	Case Study	2	△	✓	✓	△	△
(Lai, 2021)	Qualitative Approach	3	△	✓	✓	△	✓
(Vu & Le, 2022)	Qualitative Approach	3	△	✓	✓	✓	△
(Ramani, 2022)	Case Study	2	△	△	✓	△	✓
(Yang & Kyun, 2022)	Systematic Review	4	✓	✓	✓	△	✓
(Li, 2022)	Meta-analysis	5	✓	✓	✓	✓	✓
(Kobusingye, 2022)	Systematic Review	4	✓	✓	✓	△	✓
(Han et al., 2023)	Qualitative Approach	4	✓	✓	✓	△	✓
(Zaim, et al., 2024)	Qualitative Approach	5	✓	✓	✓	✓	✓
(Adam, et al., 2024)	Meta-analysis	3	△	✓	✓	✓	△
(Cui, et al., 2024)	Mixed Methods	4	✓	✓	✓	△	✓
(Ma, et al., 2025)	Systematic Review	4	✓	✓	✓	△	✓
(Rong & Yao, 2025)	Qualitative Approach	4	✓	✓	✓	△	✓
(Lejia, 2025)	Systematic Review	4	✓	✓	✓	△	✓
(Alhusaiyan, 2025)	Systematic Review	4	✓	✓	✓	△	✓
(Yu & Wang, 2025)	Mixed Methods	5	✓	✓	✓	✓	✓

✓ = Criterion met; △ = Partially met; X = Not clearly met

4–5 = High quality; 2–3 = Moderate quality; 0–1 = Low quality

(Adapted from Hong et al., 2018)

identified, and mediating technologies. To ensure the methodological rigor of the synthesis, each included study was first subjected to a structured quality appraisal using the Mixed Methods Appraisal Tool (MMAT) within EPPI-Reviewer.

The MMAT served a critical role in this study by enabling the systematic and standardized evaluation of heterogeneous research designs (Hong et al., 2018), including qualitative, quantitative, and mixed-methods studies. Specifically, each study was assessed against five core criteria:

- (1) clarity of research questions,
- (2) appropriateness of data collection methods,
- (3) adequacy of data analysis,
- (4) consideration of bias and limitations, and
- (5) coherence between data and interpretations.

The results of this appraisal are presented in **Table 3**, which provides a transparent overview of the methodological quality of all included studies. Each study was independently assessed by two reviewers, and discrepancies were resolved through discussion. Studies were assigned quality scores based on the number of criteria met (ranging from 0–5).

The outcomes of the MMAT assessment informed the subsequent data extraction and analysis process in two important ways. First, studies identified as high quality were prioritized during thematic interpretation, serving as primary evidence in identifying patterns and conceptual relationships. Second, findings from moderate-quality studies were retained but interpreted with caution to minimize the potential influence of methodological limitations. This approach

ensured that the synthesis remained comprehensive while maintaining analytical rigor and credibility.

Following quality appraisal, thematic analysis was conducted using NVivo to identify recurring patterns, contradictions, and conceptual trends. The extracted data were grouped into thematic categories reflecting the research questions, with particular attention paid to how AT was employed methodologically.

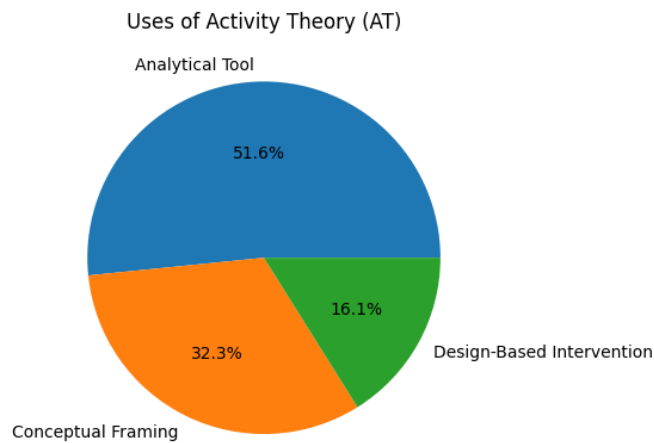
This detailed appraisal demonstrates that the overall methodological quality of the included studies is moderate to high, with the majority of studies scoring between 3 and 5. Greater analytical weight was assigned to higher-quality studies during thematic synthesis, thereby enhancing the overall reliability and validity of the review findings.

Segmentation of Articles

In parallel with the thematic segmentation of article types, the research team also classified studies based on the application of AT. This categorization followed a systematic review process wherein coders examined how AT was operationalized within each study. Building upon preliminary readings of articles from the most recent publication years (2023–2025), coders independently proposed initial analytical groupings, which were then subject to collective scrutiny and iterative refinement. Multiple rounds of intercoder comparison and interpretive discussion led to a consensus on three analytical categories, detailed in **Table 4**. These categories include: Conceptual Framing, where AT is employed to map and contextualize elements of learning

Table 4. Description of segments of articles

Segment	Description
Conceptual framing	Articles that use Activity Theory as a theoretical lens to conceptualize the structure and dynamics of e-learning environments. This includes mapping activity systems (e.g., subjects, tools, rules, community) to frame the context in which teaching and learning occur. These studies focus on how Activity Theory can be used to understand the elements and interactions in e-learning systems without necessarily conducting empirical intervention.
Analytical tool	Articles that apply Activity Theory to identify, explain, or interpret systemic tensions, contradictions, and sociocultural dynamics within e-learning practices. This category includes studies that use Activity Theory to analyze real-world practices, focusing on how different elements of the activity system interact and where disruptions or misalignments emerge. These tensions are often used to reflect on and improve policy, pedagogy, or design.
Design-based intervention	Articles that use Activity Theory in participatory or developmental research designs, such as change laboratories, tool co-design, or expansive learning interventions. These studies go beyond analysis to actively engage stakeholders in transforming the activity system, with the aim of generating practical and theoretical innovations for e-learning practices.

**Figure 2.** Distribution of AT in technology-enhanced learning (2015–2025) (Source: Authors' own elaboration)

environments; Analytical Tool, where AT facilitates the identification and interpretation of systemic contradictions and sociocultural dynamics; and Design-Based Intervention, wherein AT is integrated into participatory methodologies such as tool co-design or expansive learning laboratories. This analytical segmentation provides deeper insight into the functional diversity of AT in e-learning research and complements the broader thematic classification schema.

Coder Consensus

The principal author conducted an in-depth analysis of each included article to determine the mode of AT application, categorizing them into one of three analytical types: Conceptual Framing, Analytical Tool, or Design-Based Intervention. Simultaneously, to assess intercoder reliability, the second author undertook the same process for identical articles, applying the identical analytical categories. In instances of disagreement, the coders convened to reconcile the final coding. The initial agreement percentages were 98% for all articles. This percentage does not account for agreement occurring by chance. Therefore, Cohen's Kappa coefficient was calculated to provide a more rigorous evaluation of intercoder reliability. The resulting Kappa value indicated almost perfect agreement ($\kappa = 0.93$), according to established interpretation benchmarks, thereby confirming the consistency and dependability of the coding process.

RESULTS

Segments of Articles

Figures 2 and 3 delineate the segmentation of articles within the 31 selected literature. In the context, studies centered on analytical tool predominated consistently over time. The subsequent sections elucidate the segmentation of articles in greater detail. Across the corpus (2015–2025), AT is consistently employed as the guiding framework, but the mode of application shows notable variation. As illustrated in Figure 2, three distinct uses of AT emerge: Analytical Tool ($n = 16$, 51.6%), Conceptual Framing ($n = 10$, 32.3%), and Design-Based Intervention ($n = 5$, 16.1%).

Dominance of Analytical Tool ($n = 16$, 51.6%)

The majority of studies (e.g., Kaatrakoski et al., 2016; Kwon et al., 2018; Li, 2022; Rong & Yao, 2025; Su, 2017) employ AT as a diagnostic and interpretive lens. These works primarily focus on analysing real-world contradictions in technology-enhanced learning environments, surfacing tensions between institutional rules, learner needs, tools, and community practices. This dominance reflects a pragmatic trend: AT is valued for its capacity to unpack complexity in blended, online, and AI-mediated learning contexts.

Growth of Conceptual Framing ($n = 10$, 32.3%)

A substantial portion of studies (e.g., Lejia, 2025; Nambi, 2018; Yıldız et al., 2020; Zheng et al., 2019a) utilize AT as a theoretical structuring device. Instead of analysing empirical practice, these works synthesize prior studies to map learning ecosystems or predict emerging challenges. This shift signals AT's growing role as a road map for theorizing digital education, particularly in relation to AI, mobile learning, and future-oriented pedagogical transformations.

Less Frequent but Impactful Design-Based Intervention ($n = 5$, 16.1%)

A small set of studies (Astudillo & Martín-García, 2020; Cui et al., 2024; Han et al., 2023; Voogt et al., 2015) actively employ AT to redesign or transform practice. These interventions emphasize expansive learning cycles, participatory co-design, and iterative testing. While less common, their significance lies in demonstrating AT's transformative potential, moving from mere diagnosis toward sustainable systemic change.

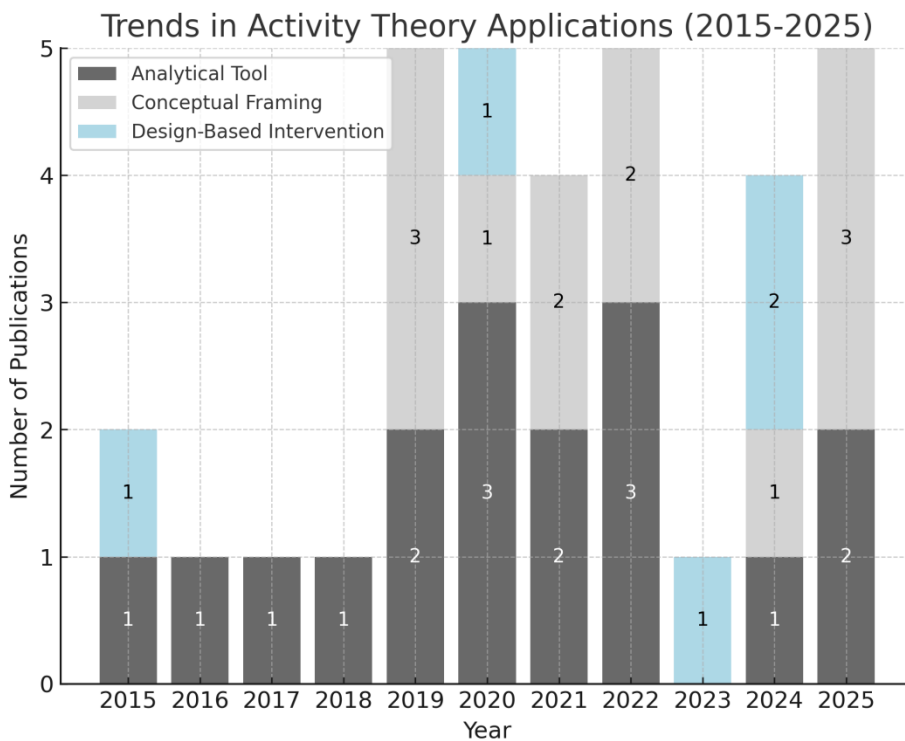


Figure 3. Trends of AT application (2015–2025) (Source: Authors' own elaboration)

The most commonly examined context-specific forms of emerging e-learning initiatives include blended learning, online learning, and AI-mediated or mobile learning environments. Across the reviewed studies, these patterns suggest that AT's diagnostic utility dominates current scholarship, while its role as a theoretical road map and as a tool for systemic transformation remains secondary yet crucial for future research.

As shown in **Figure 3**, the bar chart displays the pattern of development between 2015 and 2025. Early period (2015–2017): AT was primarily applied analytically to examine learner practices and contradictions. Mid-period (2018–2020): Studies increasingly adopted AT for conceptual mapping of technology-enhanced learning trends, while some began experimenting with design-based approaches. Recent period (2021–2025): A dual trajectory is evident: (a) continued reliance on AT as an analytical tool in AI-assisted and blended learning contexts, and (b) expansion of AT's conceptual role in framing future directions of AI, VR, and personalized learning.

The application of AT in e-learning research demonstrates three complementary but distinct approaches. As an analytical tool, it provides empirical depth by surfacing contradictions within specific practices (e.g., Bullen & Morgan, 2015; Su, 2017; Zaim et al., 2024), though its utility often remains diagnostic, offering design implications without driving systemic change. When used as a conceptual framing, AT captures broader structures and long-term trends, mapping learning ecosystems across contexts (e.g., Ma et al., 2025; Zheng et al., 2019a). However, this perspective can be overly abstract and risks overlooking the lived contradictions faced by teachers and learners. In contrast, design-based interventions employ AT in participatory and iterative ways, directly supporting systemic transformation (e.g., Cui et al., 2024; Voogt et al., 2015). Yet, their implementation demands

significant resources and contextual adaptation, which may explain the relative scarcity of such studies.

The three primary themes are LDM (consisting of 3 sub-foci), DP (consisting of 4 sub-foci), and TEL (consisting of 3 sub-foci); Each sub-focus has been explained in **Table 5**.

This analytical approach ensures the findings are not only comprehensive but also applicable across diverse e-learning settings, thus enhancing their relevance and applicability. To enhance the validity and transparency of the coding process, particularly in cases where category boundaries overlapped (Design-Based Intervention, Analytical Tool, Conceptual Framing), the following tables provide explicit criteria and decision rules used to classify each study. They are Coding Matrix for Classifying AT Application, Stepwise Classification Protocol, Operational Scoring Matrix, and Full Coding Matrix of Included Studies (n = 31).

The coding matrix presented in **Table 6** was developed to systematically classify the application of AT across the included studies into three distinct categories: Analytical Tool, Conceptual Framing, and Design-Based Intervention. This matrix operationalizes key dimensions of AT usage—namely primary purpose, use of AT components, role of contradictions, research design, and outcome type—to ensure consistent and transparent categorization. Studies classified under Analytical Tool employ AT as a structured framework to diagnose and interpret contradictions within empirical contexts, typically through observational or explanatory designs. In contrast, Conceptual Framing refers to studies that use AT in a more abstract or illustrative manner to theorize activity systems without systematic empirical analysis. Design-Based Intervention captures studies in which AT actively informs the redesign or transformation of activity

Table 5. Categories of primary research focus and its sub-focuses

Research Focus	Sub-focus	The description of sub-focuses
Learning Delivery Modes	OL=Online Learning	OL refers to the use of internet-based platforms and digital tools to deliver teaching and learning experiences beyond the confines of traditional classrooms. It emphasizes flexibility, accessibility, and scalability, enabling students to engage with educational content synchronously or asynchronously across diverse contexts.
	ML=Mobile Learning	ML involves the use of portable digital devices such as smartphones and tablets to access and participate in learning activities. It highlights mobility, just-in-time learning, and contextual engagement, enabling learners to study seamlessly across different environments.
	BL=Blending Learning	BL integrates online and face-to-face instruction into a cohesive pedagogical approach. It leverages the strengths of both modalities, fostering flexibility, active participation, and sustained engagement, while ensuring that digital resources complement in-person learning experiences.
Digital Pedagogy	CL=Collaborative Learning	CL emphasizes knowledge construction through group interaction, shared problem-solving, and collective reflection. Supported by digital platforms, it fosters peer-to-peer learning, critical thinking, and community building in both synchronous and asynchronous formats.
	FC=Flipped Classrooms	FC is a pedagogical model that inverts the traditional learning sequence by shifting direct instruction outside of class, typically via digital resources. Classroom time is then repurposed for interactive activities, problem-solving, and higher-order learning tasks, maximizing the value of face-to-face engagement.
	ID=Instructional Design	ID refers to the systematic process of designing, developing, and evaluating learning experiences that integrate digital tools and methods. It draws on pedagogical theories, learner needs, and technological affordances to create effective, engaging, and goal-oriented e-learning environments.
	OEP=Open Educational Practices	OEP involves the use, adaptation, and creation of open resources combined with innovative pedagogical strategies to foster inclusivity and learner empowerment. It emphasizes collaboration, co-creation of knowledge, and the democratization of access to educational opportunities.
Technology-enhanced Learning	AL=AI-assisted Learning	AL leverages artificial intelligence technologies to enhance the teaching and learning process. It includes intelligent tutoring, automated feedback, and data-driven insights that support personalized instruction, streamline administrative tasks, and optimize learner outcomes.
	APL=Adaptive Personalized Learning	APL involves tailoring learning experiences to the unique needs, preferences, and progress of individual learners. Often powered by AI and analytics, it dynamically adjusts content, pacing, and assessment pathways to maximize engagement and achievement.
	IL=Immersive Learning(VR/AR)	IL uses virtual and augmented reality environments to create experiential, interactive learning experiences. By simulating real-world contexts or constructing imaginative scenarios, it fosters deep engagement, skill application, and situated learning that transcends the limitations of traditional modalities.

Table 6. Coding matrix for classifying AT application

Dimension	Analytical Tool	Conceptual Framing	Design-Based Intervention
Primary Purpose	Diagnose, explain, or interpret contradictions in real practice	Theorize or map activity systems conceptually	Transform or redesign activity systems
Use of AT Components	Explicit use of ≥ 3 components (subject, tools, rules, etc.) to analyze empirical data	Components used descriptively or illustratively	Components actively manipulated in intervention design
Role of Contradictions	Central analytic focus (identified, categorized, interpreted)	Mentioned or implied, not systematically analyzed	Used as drivers for change/redesign
Research Design	Observational / explanatory	Theoretical / synthesis	Design-based / participatory / change lab
Outcome Type	Insights, explanations, implications	Conceptual models, frameworks	Measurable change, redesigned practice, innovation

systems, often through participatory or interventionist methodologies aimed at producing measurable change.

Building upon the coding matrix presented in **Table 7**, a stepwise classification protocol was further established to operationalize the decision-making process and ensure consistency in categorizing studies, particularly in cases where boundaries between categories were ambiguous. This protocol applies a hierarchical set of rules that prioritize the primary analytical intent of each study. The Intervention Priority Rule assigns studies to the Design-Based Intervention category when they actively modify or redesign activity systems,

reflecting the highest level of theoretical application. Where no intervention is present, the Contradiction Centrality Rule classifies studies as Analytical Tool if contradictions are systematically identified and analysed as the core focus. In the absence of both intervention and contradiction-driven analysis, the Abstraction Rule assigns studies to Conceptual Framing, indicating a primarily theoretical or interpretive use of AT. To resolve residual overlaps, a Tie-breaker Rule enforces a hierarchical priority (Intervention > Analytical > Conceptual), ensuring mutually exclusive and logically consistent classification outcomes. Together with the coding

Table 7. Stepwise classification protocol

Rule Name	Rule Description	Classification Outcome	Priority Logic
Rule 1: Intervention Priority Rule	If the study actively modifies or redesigns the activity system	Design-Based Intervention	Takes highest priority, even if analytical elements are present
Rule 2: Contradiction Centrality Rule	If contradictions are systematically identified and analyzed as the main outcome	Analytical Tool	Focus is on tensions, conflicts, or contradictions within the system
Rule 3: Abstraction Rule	If AT is used mainly to structure understanding without deep empirical analysis	Conceptual Framing	Typically theoretical or interpretive, not data-intensive
Rule 4: Tie-breaker Rule	If a study fits multiple categories	Apply Hierarchical Priority	Intervention > Analytical > Conceptual

Table 8. Operational scoring matrix

Criterion	Score=0	Score=1	Score=2
Contradiction Analysis	None	Mentioned	Systematic
AT Component Usage	Minimal (≤ 2)	Moderate (3–4)	Extensive (≥ 5)
Intervention Presence	None	Proposed	Implemented
Empirical Depth	None	Moderate	Strong

Design-Based Intervention → Intervention = 2; Analytical Tool → Contradiction = 2 AND Intervention ≤ 1 ; Conceptual Framing → Contradiction ≤ 1 AND Intervention = 0

Table 9. Full coding matrix of included studies (n = 31)

Reference (n=31)	Contradiction	AT Components Usage	Intervention	Empirical Depth	Category	Justifications
(Voogt et al., 2015)	2	2	2	2	DB-Intervention	Collaborative redesign, co-design process
(Bullen & Morgan, 2015)	2	1	0	2	Analytical Tool	Learner tensions in digital practices
(Kaatrakoski, et al, 2016)	2	2	0	2	Analytical Tool	Contradictions in OEP systems
(Su, 2017)	2	1	0	2	Analytical Tool	Learning anxiety vs performance tensions
(Kwon, et al, 2018)	2	1	0	2	Analytical Tool	Structured vs exploratory learning tensions
(Nambi, 2019)	1	1	0	1	Conceptual Framing	AT used as ICT integration framework
(Zheng, et al., 2019a)	1	1	0	1	Conceptual Framing	Ecosystem mapping
(Zheng, et al, 2019b)	2	1	0	2	Analytical Tool	Empirical synthesis of TEL practices
(Chung, et al, 2019)	1	1	0	1	Conceptual Framing	Theoretical synthesis
(MacLeod, et al., 2019)	2	1	0	2	Analytical Tool	Connectedness tensions
(Yildiz, et al., 2020)	1	1	0	1	Conceptual Framing	Trends mapping
(Kessler, 2020)	2	2	0	2	Analytical Tool	Tool-mediated writing strategies
(Astudillo & Martín-García, 2020)	2	2	2	2	DB-Intervention	BL design framework
(Burke, 2020)	2	1	0	2	Analytical Tool	Online teaching contradictions
(Scavarelli, et al., 2021)	2	1	0	2	Analytical Tool	VR/AR tensions
(van der Westhuizen, et al., 2021)	1	1	0	1	Conceptual Framing	Social work tech integration
(Lai, 2021)	2	1	0	2	Analytical Tool	AI learning preferences
(Vu & Le, 2022)	2	1	0	2	Analytical Tool	Student tool mediation
(Ramani, 2022)	2	1	0	2	Analytical Tool	CV writing activity system
(Yang & Kyun, 2022)	1	1	0	1	Conceptual Framing	AI learning SLR
(Li, 2022)	2	1	0	2	Analytical Tool	Meta-analysis using AT
(Kobusingye, 2022)	1	1	0	1	Conceptual Framing	AT as theoretical lens
(Han & et al., 2023)	2	2	2	2	DB-Intervention	DBR for synchronous learning
(Zaim, et al., 2024)	2	1	0	2	Analytical Tool	Qualitative TEL tensions
(Adam, et al., 2024)	1	1	0	1	Conceptual Framing	APL meta-analysis
(Cui, et al., 2024)	2	2	2	2	DB-Intervention	AT-based cross-cultural design
(Ma, et al., 2025)	1	1	0	1	Conceptual Framing	AI chatbot SLR
(Rong & Yao, 2025)	2	1	0	2	Analytical Tool	TEL contradictions
(Lejia, 2025)	1	1	0	1	Conceptual Framing	Flipped classroom design principles
(Alhusaiyan, 2025)	1	1	0	1	Conceptual Framing	AI language learning trends
(Yu & Wang, 2025)	2	1	0	2	Analytical Tool	Mixed-method TEL analysis

matrix, this protocol enhances methodological rigor by making the classification process explicit, reproducible, and theoretically grounded.

Extending the coding matrix and the stepwise classification protocol, the operational scoring matrix presented in **Table 8** provides a quantitative layer to support and validate the categorization process. This matrix translates key analytical dimensions—contradiction analysis, AT component usage, intervention presence, and empirical depth—into standardized scores (0–2), thereby enabling a more systematic and replicable assessment of how AT is applied across studies. By assigning differential weights to the

depth and centrality of AT usage, the scoring framework reinforces the hierarchical logic established in the classification protocol. Specifically, studies classified as Design-Based Intervention are required to demonstrate implemented intervention elements (score = 2), while Analytical Tool studies must exhibit systematic contradiction analysis (score = 2) in the absence of strong intervention. Conversely, Conceptual Framing is characterized by limited contradiction engagement and no intervention presence.

Building upon the coding matrix, stepwise classification protocol, and operational scoring framework, **Table 9** presents the full coding matrix of the 31 included studies, offering a

Table 10. Summary of key data in selected studies

Reference	Segment	Research Method	LDM			DP		TEL				
			OL	ML	BL	CL	FC	ID	OEP	AL	APL	
(Voogt et al., 2015)	Design-Based Intervention	Case Study								√		
(Bullen & Morgan, 2015)	Analytical Tool	Case Study	√									
(Katrakoski, et al, 2016)	Analytical Tool	Mixed Methods									√	
(Su, 2017)	Analytical Tool	Quasi-experimental design										
(Kwon, et al, 2018)	Analytical Tool	Quasi-experimental design					√					
(Nambi, 2019)	Conceptual Framing	Systematic Review							√			
(Zheng, et al., 2019a)	Conceptual Framing	Systematic Review					√					
(Zheng, et al, 2019b)	Analytical Tool	Systematic Review					√					
(Chung, et al, 2019)	Conceptual Framing	Systematic Review		√								
(MacLeod, et al., 2019)	Analytical Tool	Systematic Review					√					
(Yildiz, et al., 2020)	Conceptual Framing	Systematic Review			√							
(Kessler, 2020)	Analytical Tool	Case Study										√
(Astudillo & Martín-García, 2020)	Design-Based Intervention	Systematic Review			√							
(Burke, 2020)	Analytical Tool	Qualitative Approach					√					
(Scavarelli, et al., 2021)	Analytical Tool	Systematic Review										
(van der Westhuizen, et al., 2021)	Conceptual Framing	Case Study	√									
(Lai, 2021)	Analytical Tool	Qualitative Approach										√
(Vu & Le, 2022)	Analytical Tool	Qualitative Approach										√
(Ramani, 2022)	Analytical Tool	Case Study							√			
(Yang & Kyun, 2022)	Conceptual Framing	Systematic Review										√
(Li, 2022)	Analytical Tool	Meta-analysis				√						
(Kobusingye, 2022)	Conceptual Framing	Systematic Review				√						
(Han et al., 2023)	Design-Based Intervention	Qualitative Approach	√									
(Zaim, et al., 2024)	Analytical Tool	Qualitative Approach										√
(Adam, et al., 2024)	Conceptual Framing	Meta-analysis										√
(Cui, et al., 2024)	Design-Based Intervention	Mixed Methods		√								
(Ma, et al., 2025)	Conceptual Framing	Systematic Review										√
(Rong & Yao, 2025)	Analytical Tool	Qualitative Approach			√							
(Lejia, 2025)	Conceptual Framing	Systematic Review						√				
(Alhusaiyan, 2025)	Conceptual Framing	Systematic Review										√
(Yu & Wang, 2025)	Analytical Tool	Mixed Methods					√					

Note: LDM=Learning Delivery Modes; DP=Digital Pedagogy; TEL=Technology-enhanced Learning; OL=Online Learning; ML=Mobile Learning; BL=Blending Learning; FC=Flipped Classrooms; CL=Collaborative Learning; AL=AI-assisted Learning; IL=Immersive Learning(VR/AR); ID=Instructional Design; OEP=Open Educational Practices; APL=Adaptive Personalized Learning; A checkmark (√) indicates that the corresponding study explicitly addresses or applies the specified category, concept, or approach.

comprehensive and transparent account of how each study was systematically evaluated and classified. This table integrates both qualitative judgments and quantitative scores by aligning key dimensions—contradiction analysis, AT component usage, intervention presence, and empirical depth—with the final categorical assignment (Design-Based Intervention, Analytical Tool, or Conceptual Framing).

Table 10 synthesizes the selected studies by integrating research segments, methodological approaches, and thematic focuses across Learning Delivery Modes (LDM), Digital Pedagogy (DP), and Technology-Enhanced Learning (TEL), revealing several key patterns. Subsequently, identified sub-foci associated with primary research focus, resulting in a total of 10 sub-foci. Subsequently, identified sub-foci associated with primary research focus, resulting in a total of 10 sub-foci.

As an analytical tool, AT provides strong empirical depth by diagnosing contradictions in real-world practices. Studies such as Bullen and Morgan (2015), Su (2017), and Zaim et al. (2024) exemplify how AT can illuminate tensions between rules, tools, and community roles in digital learning environments. This diagnostic strength allows researchers to make visible the often-hidden complexities of institutional and pedagogical practices. However, its weakness lies in the fact that such studies usually stop short of implementing systemic change, producing recommendations rather than actual interventions.

In contrast, the conceptual framing mode emphasizes AT's role as a structuring device for mapping broad educational ecosystems and predicting long-term trends. Studies such as Zheng et al. (2019a), and Ma et al. (2025) highlight how AT can serve as a road map to theorize the shifting dynamics of e-learning, including AI and mobile learning. While valuable for offering a big-picture synthesis, this mode risks abstraction: it often fails to account for the lived contradictions faculty and learners encounter in daily practice, resulting in elegant but less actionable frameworks.

The third category, design-based intervention, pushes AT into applied transformation by employing participatory and iterative processes. For instance, Voogt et al. (2015), and Cui et al. (2024) show how contradictions are not merely diagnosed but actively resolved through redesign, leading to new learning models and professional practices. This approach demonstrates AT's transformative power but comes with a significant drawback: it is resource- and context-intensive, limiting its widespread adoption and leaving it underrepresented in the corpus.

A closer comparison of studies highlights the distinctive contributions and limitations of each mode. For example, Katrakoski et al. (2016) apply AT analytically to Open Educational Practices, uncovering contradictions between institutional efficiency and pedagogical quality. By contrast, Zheng et al. (2019a) take a conceptual route, using AT to map ICT-supported collaborative learning in informal contexts without diagnosing specific tensions. Similarly, while Li (2022) empirically analyses contradictions in blended language

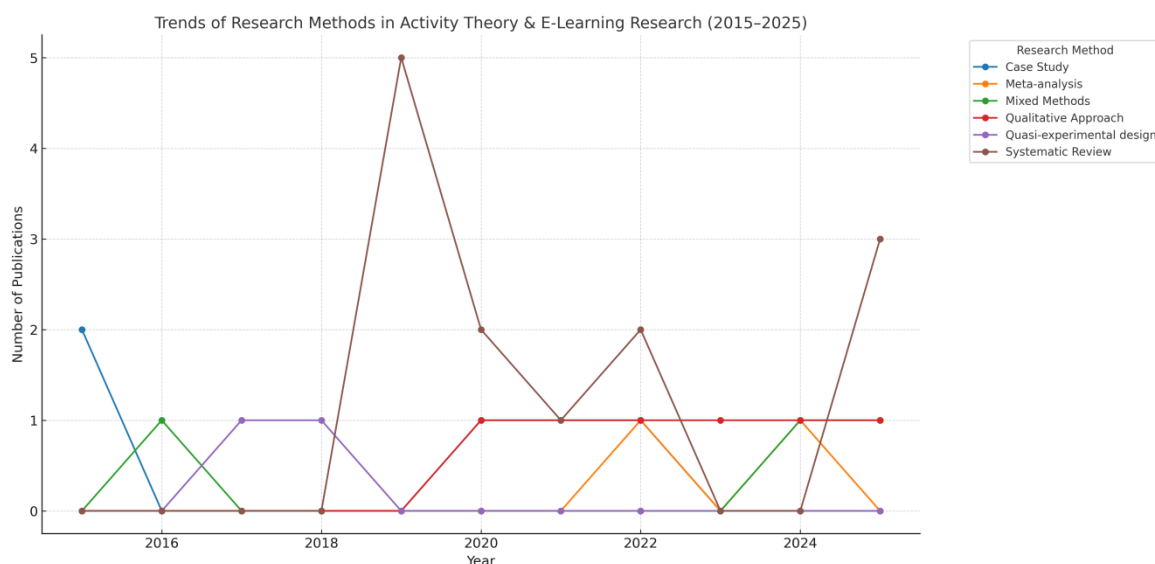


Figure 4. Trends of Research Methods in AT Theory (2015–2025) (Source: Authors' own elaboration)

learning, Lejia (2025) employs AT conceptually to frame flipped classroom design principles without empirical validation.

The contrast between analytical and design-based approaches is also instructive. Bullen & Morgan (2015) identify contradictions in digital literacy through an analytical lens but do not attempt to transform practice. Conversely, Voogt et al. (2015) employ AT design-based principles to co-design collaborative professional practices, directly resolving tensions such as scheduling conflicts through participatory redesign. Likewise, while Zaim et al. (2024) surface contradictions around generative AI adoption in education, Cui et al. (2024) advance into intervention by designing and validating a cross-cultural WeChat learning model, showing AT's capacity to bridge diagnosis and transformation.

Finally, the contrast between conceptual framing and design-based intervention illustrates a theoretical-practical divide. Nambi (2018) conceptually positions AT as a "diagnostic checklist" for ICT integration in teacher education, staying at the level of theorization. In contrast, Astudillo and Martín-García (2020) demonstrate AT's applied potential by using expansive learning cycles to redesign blended learning environments, showing how AT can be mobilized to guide transformation rather than simply describe it.

These analyses underscore that AT's analytical use dominates because of its diagnostic efficiency and empirical accessibility, while conceptual framing gains traction for its theoretical breadth in mapping future directions. However, design-based interventions, though fewer, showcase AT's transformative capacity—a potential that remains under-explored due to high resource demands. The interplay between these modes suggests that the field would benefit from more integrated approaches that move beyond diagnosis and conceptualization toward sustainable transformation.

In **Figure 4**, research methods in studies from 2015 to 2025 applying AT reveal a clear progression from initial exploratory work to a more diverse and consolidated methodological landscape. Early investigations largely relied on case studies

and quasi-experimental designs to probe practical interventions and test emerging models. From 2019 onward, however, systematic reviews became increasingly prominent, signalling both the consolidation of accumulated knowledge and the field's growing maturity. Beginning in 2020, qualitative approaches gained traction as researchers sought to capture the nuanced experiences of educators and learners navigating expanding online and hybrid systems. After 2022, the adoption of meta-analyses alongside a renewed emphasis on mixed methods further widened the methodological toolkit, allowing for both synthesis across studies and in-depth exploration of complex pedagogical and technological dynamics. In brief, this evolution illustrates a shift from isolated, practice-focused inquiries to integrated, multi-layered approaches that illuminate contradictions, transformations, and long-term developments in e-learning environments.

This review adopts Engeström's (2001) contradiction typology, which categorizes systemic tensions into four levels. Primary contradictions (1st-order) occur within a single element of the activity system, such as poorly designed digital tools or ambiguous instructional goals that create internal inconsistencies. Secondary contradictions (2nd-order) emerge between elements, for instance when innovative technologies clash with rigid institutional rules or assessment policies. Tertiary contradictions (3rd-order) arise during transitions from established to new activity systems, such as the shift from teacher-centered pedagogies to learner-driven models in blended learning. Finally, quaternary contradictions (4th-order) manifest between interacting activity systems, for example, tensions between a university's internal policies and the operational requirements of external technology vendors. Applying this framework to the 31 selected studies enables a systematic classification of contradictions (**Table 11**) and illuminates the strategies (**Table 12**) employed—whether adaptive workarounds, expansive learning interventions, or systemic redesigns—to mitigate or transform these tensions within evolving e-learning environments.

Table 11. Findings of contradiction types and resolution strategies

Reference	Segment	Contradiction Type 1				Contradiction Type 2				Contradiction Type 3				Contradiction Type 4				Total
		P	S	T	Q	P	S	T	Q	P	S	T	Q	P	S	T	Q	
(Voogt et al., 2015)	Design-Based Intervention		1				2											S1-T1
(Bullen & Morgan, 2015)	Analytical Tool				3	1				1								Q1-S1-P1
(Kaatrakoski, et al, 2016)	Analytical Tool			2			2			3						1		T2-S1-Q1
(Su, 2017)	Analytical Tool	2					1				2					1		P1-S1-T1-Q1
(Kwon, et al, 2018)	Analytical Tool	1					3											P1-S1
(Nambi, 2019)	Conceptual Framing				2	1					2		1					Q1-S1-T1-P1
(Zheng, et al., 2019a)	Conceptual Framing			3			1			1				3				T1-S1-P1-S1
(Zheng, et al, 2019b)	Analytical Tool	1					3				3							P1-S2
(Chung, et al, 2019)	Conceptual Framing			1		1					3							T1-P1-S1
(MacLeod, et al., 2019)	Analytical Tool				3				1			2						Q3
(Yildiz, et al., 2020)	Conceptual Framing		3				3			2						2		S2-P1-T1
(Kessler, 2020)	Analytical Tool	3					1				2					1		P1-S1-T1-Q1
(Astudillo & Martín-García, 2020)	Design-Based Intervention	2						2				1						P1-S1-T1
(Burke, 2020)	Analytical Tool		2					1										S1-T1
(Scavarelli, et al., 2021)	Analytical Tool	1					3				1					2		P1-S2-T1
(van der Westhuizen, et al., 2021)	Conceptual Framing			2														T1
(Lai, 2021)	Analytical Tool			2		3					1							T1-S1-P1
(Vu & Le, 2022)	Analytical Tool				1		2					3						Q1-S1-T1
(Ramani, 2022)	Analytical Tool		2					1					3					S1-T1-Q1
(Yang & Kyun, 2022)	Conceptual Framing			2			1						3					T1-S1-Q1
(Li, 2022)	Analytical Tool			2			1											T1-S1
(Kobusingye, 2022)	Conceptual Framing			2			1											T1-S1
(Han et al., 2023)	Design-Based Intervention	1				2						3						S1-P1-Q1
(Zaim, et al., 2024)	Analytical Tool	1				3						2				2		S1-P1-T1-Q1
(Adam, et al., 2024)	Conceptual Framing			2				1				3						T3
(Cui, et al., 2024)	Design-Based Intervention	1					1				2							S3
(Ma, et al., 2025)	Conceptual Framing			2				1				3						T3
(Rong & Yao, 2025)	Analytical Tool	3					1				2					2		P1-S1-T1-Q1
(Lejia, 2025)	Conceptual Framing			1				2				2				2		T4
(Alhusaiyan, 2025)	Conceptual Framing			2				3				2						T3
(Yu & Wang, 2025)	Analytical Tool		1					2				2				2		S4

Note: P=Primary contradictions (1st-order); S=Secondary contradictions (2nd-order); T=Tertiary contradictions (3rd-order); Q=Quaternary contradictions (4th-order); 1=Adaptive Workarounds; 2=Transformation; 3=Ignored/Unresolved; Total indicates that the total number of specific contradiction types emerged in each study.

Table 12. Resolution strategies

Resolution Strategy	Core Logic	Indicators	Typical Outcome
Adapted=1	Incremental compromise	Adjustments made within existing system, partial alignment	Short-term fixes, coexistence of old & new
Transformed=2	Systemic reconfiguration	Rules, roles, and tools redefined, innovation emerges	Expansive learning, new practices established
Ignored=3	Tension left unresolved	Old practices persist, contradiction mentioned but not acted upon	Stagnation, status quo maintained

The findings of reviewed studies provide a framework evaluating the tensions, adaptations, and transformations when integrating e-learning practices in higher education. According to **Table 11**, contradictions at the primary level—those tensions internal to subjects or tools—appear repeatedly as affective, skill-based, or role-related frictions that are most often managed at the micro level. Studies of immersive and AI-assisted learning show how anxiety, motivation, and limited metacognitive ability can either be transformed into learning affordances when pedagogical support is present (Scavarelli et al., 2021; Su, 2017) or ignored when institutional guidance is absent (Kessler, 2020; Lai, 2021). Mobile learning research likewise documents learners negotiating freedom versus structure, with instructors and designers implementing adaptive scaffolds to maintain engagement (Chung et al., 2019; Kwon et al., 2018). Other primary tensions—such as ambiguous learning goals or teachers’ limited expertise with particular digital tools in blended contexts—may go unaddressed, persisting as background constraints that later surface as larger problems (Rong & Yao, 2025). In sum, primary contradictions tend to be the locus of immediate, practice-level responses: they are adapted through scaffolds,

workarounds, or localized professional development, or they are left unattended when institutions lack capacity or incentives to intervene (Zaim et al., 2024; Zheng et al., 2019b).

Secondary contradictions—misalignments between tools, rules, division of labor, and objects—constitute the most frequent site of pragmatic negotiation across the corpus. Many projects encountered tooling that did not support intended pedagogical aims or assessment logics, and teachers and students routinely adapted tasks, roles, or assessment rubrics to salvage coherence (Chung et al., 2019; Cui et al., 2024; Voogt et al., 2015). Yet secondary contradictions are sometimes ignored, especially where platform design limits higher-order learning or where device-centric approaches clash with authentic community practices (Kwon et al., 2018; Yıldız et al., 2020). There are also examples where secondary contradictions provoked deeper change: localization efforts that adapted global ICT frameworks to local contexts, or re-specification of learning objects so that assessment and tools aligned with creative digital storytelling aims, show how secondary frictions can catalyze systemic redesign when actors intentionally treat them as design problems (Nambi, 2018; Yu & Wang, 2025). The variability at this level underscores that

secondary contradictions are tractable through policy, PD, and tooling—but only when actors deliberately invest in negotiating rules and tool affordances rather than simply implementing workarounds (Kaatrakoski et al., 2016; Kessler, 2020).

Tertiary contradictions—where reform-oriented systems confront incumbent activity systems—most consistently generate expansive learning and institutional transformation in the studies examined. Flipped classrooms, blended learning reforms, and AI-driven pedagogies frequently create dissonance around roles, evaluation logics, and curricular sequencing that cannot be resolved by local tweaks alone and instead require rearticulation of the object of activity. Flipped classroom initiatives, for instance, redefined teacher and learner roles and foregrounded self-regulated learning practices (Lejia, 2025), while transitions to Open Educational Practices and participatory design methods provoked reflection and reinterpretation that led to durable change (Kaatrakoski et al., 2016; Voogt et al., 2015). AI and immersive experiments similarly pushed institutions to renegotiate assessment and governance arrangements, with several studies documenting transformative reconfiguration of rules and division of labor when leadership, resources, and participatory processes supported such work (Astudillo & Martín-García, 2020; Scavarelli et al., 2021; van der Westhuizen et al., 2021). That tertiary contradictions regularly precipitate transformation indicates that systemic clashes—when surfaced and supported—are the most powerful engines of pedagogical innovation, though they do not always succeed when institutional readiness is low (Adam et al., 2024; Ma et al., 2025).

Quaternary contradictions—tensions between distinct activity systems, such as academic versus social systems or global standards versus local realities—are structurally the most complex and therefore the most uneven in outcome. In online and collaborative contexts, learners circumvented mismatches between institutional platforms and social tools by maintaining parallel practices, a strategy that allowed individuals to function but left formal systems unchanged (Bullen & Morgan, 2015; MacLeod et al., 2019). Conversely, some institutions successfully localized external ICT frameworks, transforming quaternary tensions into design opportunities that strengthened local practice (Nambi, 2018; Zaim et al., 2024). Notably, Rong and Yao (2025) show that quaternary contradictions can be addressed at scale: their blended learning reform reconciled university curriculum requirements and institutional culture with pedagogical innovations, leading to transformation rather than circumvention. Overall, quaternary contradictions require cross-unit coordination, vendor negotiation, or policy alignment to resolve; without such collective capacity, these contradictions are more likely to be tolerated or ignored (Han et al., 2023; Ramani, 2022).

Across levels, boundary-crossing and mediational practices recurrently link micro-level adaptations to macro-level transformation. Integrators and boundary actors—students and faculty who treated tools as boundary objects and orchestrated learning across formal and informal ecology—helped stabilize emergent practices long enough for institutions to codify them (Bullen & Morgan, 2015; Voogt et

al., 2015; Vu & Le, 2022). Mobile apps, WeChat Mini Programs, and AI tools were effective mediators when they were integrated into shared workflows and supported by cross-functional governance; where interoperable tools and boundary infrastructure existed, adaptation matured into systemic change (Cui et al., 2024; Ma et al., 2025). Conversely, the absence of such mediation-tool-oriented resources meant that adaptations frequently remained local and fragile, with innovations reverting to ad hoc workarounds rather than institutionalized practice (Kwon et al., 2018; Yıldız et al., 2020).

The distribution of resolution strategies suggests a rough yet instructive hierarchy: primary contradictions are most often adapted or ignored, secondary contradictions are commonly adapted and only sometimes transformed, tertiary contradictions most reliably drive transformation when institutional conditions permit expansive learning, and quaternary contradictions display the most variable outcomes because they depend on multi-actor coordination beyond single units. AI-assisted learning exemplifies this pattern: tertiary tensions about integrating generative AI into pedagogy have driven reconfigured standards in some institutions (Lai, 2021; Zaim et al., 2024), whereas primary tensions around autonomy and metacognition were often under addressed (Kessler, 2020; Lai, 2021). Mobile and blended learning follow a similar logic: initial device or platform misfits provoke adaptations (Yıldız et al., 2020; Kwon et al., 2018), but when actors deliberately use such tensions as design inputs systemic curricular and assessment redesigns can follow (Kobusingye, 2022; Lejia, 2025; Li, 2022; Rong & Yao, 2025).

For policy and design practice, the evidence points to clear levers: first, make contradictions explicit and treat them as diagnostic inputs for design rather than nuisances to be worked around; second, invest in boundary infrastructure and cross-unit governance to enable mediational practices to scale; third, align evaluation logics with emergent objects so that novel practices are not forced back into legacy rule systems. Practically, this means transforming individual adaptations into supported pilots, linking pedagogy to procurement and professional development, and establishing participatory redesign teams that can convert secondary and tertiary tensions into sustainable institutional change (Burke, 2020; Ramani, 2022; Voogt et al., 2015; Zaim et al., 2024). Finally, the corpus reveals a temporal maturation in how contradictions are harnessed diagnostically: early studies often emphasized tool-centric, localized responses, while later work demonstrates greater institutional readiness to reconfigure rules, roles, and objects—particularly in flipped, blended, and AI-enhanced initiatives where tertiary contradictions were leveraged for expansive learning (Lejia, 2025; Ma et al., 2025; van der Westhuizen et al., 2021). Nevertheless, persistent ignored contradictions—especially at system interfaces that require cross-institutional coordination or market negotiation—remind us that the pathway from contradiction to transformation is contingent on governance, resources, and the political economy of institutional change. In other words, these studies affirm AT's central claim: contradictions are not merely problems to be mitigated but potentials to be designed for; when surfaced with analytic

clarity and supported with boundary resources and governance, they become the prime movers of developmental change in e-learning ecosystems.

DISCUSSION

AT and the Mediating Role of Technology

Based on existing AT-based studies, technology consistently emerges as a catalytic mediator in learning and teaching practices, while also revealing conceptual and analytical constraints within AT itself. Rather than functioning as a neutral instrument, technology reshapes subject-object relations, redistributes agency, and reconfigures institutional practices across diverse e-learning contexts. At the same time, the uneven resolution of contradictions across cases exposes the conditions under which AT's explanatory reach is strongest—and where it becomes insufficient.

Catalytic Roles of Technology Revealed through AT

A primary strength of AT lies in its capacity to conceptualize technology as a mediating artifact embedded within activity systems. Across AI-assisted learning, AR/VR environments, mobile learning, digital storytelling, and blended or flipped classrooms, AT foregrounds the subject-tool-object relationship, enabling researchers to examine how technologies simultaneously extend learner capabilities and transform the object of learning.

At the primary contradiction level, reviewed studies repeatedly identify affective, skill-based, and role-related tensions internal to learners or tools. Anxiety, fluctuating motivation, and limited metacognitive capacity are shown to be transformed into learning affordances when pedagogical scaffolding, adaptive interfaces, and tutorials are present (Scavarelli et al., 2021; Su, 2017). This pattern is further supported by recent evidence on AR-mediated learning, where Kazu et al. (2026) demonstrate that AR significantly enhances student engagement, motivation, knowledge retention, and practical skill acquisition when aligned with constructivist and situated learning approaches. Mobile learning research illustrates this dynamic particularly clearly, documenting how learners negotiate tensions between autonomy and structure through adaptive supports provided by instructors and designers (Chung et al., 2019; Kwon et al., 2018). This is further reinforced by recent global evidence, as Samala et al. (2025) highlight the transformative potential of mobile learning in higher education and emphasize the need for continuous pedagogical and technological innovation. In blended and flipped classrooms, technological mediation similarly reframes teacher-directed objectives into self-regulated, reflective, and collaborative learning practices (Lejia, 2025; Rong & Yao, 2025).

However, primary contradictions are also the most fragile: where institutional guidance is absent or teachers lack expertise with digital tools, tensions such as ambiguous learning goals or low confidence persist as background constraints, later resurfacing as more systemic problems (Kessler, 2020; Lai, 2021; Rong & Yao, 2025). Across the corpus, primary contradictions are therefore most often

adapted locally or ignored, rather than transformed, through scaffolds, workarounds, or limited professional development (Zaim et al., 2024; Zheng et al., 2019b).

At secondary and tertiary levels, AT proves particularly effective in illuminating how technology catalyzes social and organizational change. Secondary contradictions—misalignments between tools, rules, division of labor, and learning objects—constitute the most frequent site of pragmatic negotiation. Teachers and students often adapt tasks, roles, or assessment criteria to reconcile technological constraints with pedagogical intentions (Chung et al., 2019; Cui et al., 2024; Voogt et al., 2015). In some cases, such contradictions remain unresolved, especially when platform designs constrain higher-order learning or clash with authentic community practices (Kwon et al., 2018; Yıldız et al., 2020).

Yet secondary contradictions can also act as design levers. Studies of digital storytelling and localized ICT initiatives show how intentional re-specification of learning objects and assessment logics can align tools with creative or contextual goals, leading to instructional redesign rather than superficial adaptation (Nambi, 2018; Yu & Wang, 2025). These cases demonstrate that secondary contradictions are tractable through policy, professional development, and tooling—but only when actors deliberately negotiate rules and affordances rather than rely on temporary fixes (Kaatrakoski et al., 2016; Kessler, 2020).

Tertiary contradictions, where reform-oriented practices confront incumbent activity systems, most consistently generate expansive learning and institutional transformation. Flipped classrooms, blended learning reforms, Open Educational Practices, and AI-assisted pedagogies provoke dissonance around roles, evaluation logics, and curricular sequencing that cannot be resolved through local adjustments alone. Instead, they require rearticulation of the object of activity. Empirical studies show how such tensions redistribute labor—teachers becoming facilitators, learners assuming self-regulatory responsibility—and lead to durable changes when leadership, resources, and participatory processes support redesign (Astudillo & Martín-García, 2020; Kaatrakoski et al., 2016; van der Westhuizen et al., 2021; Voogt et al., 2015). Where institutional readiness is low, however, even tertiary contradictions fail to mature into transformation (Adam et al., 2024; Ma et al., 2025).

Across these levels, AT-informed studies reveal a hierarchy of developmental outcomes: primary contradictions are most often adapted or ignored, secondary contradictions are frequently adapted and occasionally transformed, and tertiary contradictions most reliably catalyze systemic change when conditions permit expansive learning (Voogt et al., 2015; Zheng et al., 2019b).

Constraining Roles and Theoretical Limitations of AT

Despite its strengths, the reviewed corpus also exposes important constraints in AT's explanatory capacity when analyzing technological mediation. First, AT is often descriptively rich but causally under-specified in explaining why identical technologies yield divergent outcomes across institutions. While contradictions are systematically mapped, AT-informed analyses frequently do not explain how specific

design features, user perceptions, or institutional power relations condition whether mediation succeeds or fails. This limitation is visible in cases where insufficient institutional support or misaligned tool design leaves even primary contradictions unresolved, constraining learner development despite technological adoption (Kessler, 2020; Lai, 2021).

Second, AT exhibits a human-centred bias, privileging human intentionality while offering limited analytical leverage for examining the active role of non-human actors. As AI-assisted systems increasingly shape feedback, assessment, monitoring, and decision-making, AT struggles to fully capture how algorithms, platforms, and data infrastructures mediate practice and redistribute control.

Third, although AT conceptualizes quaternary contradictions across interacting activity systems, it lacks fine-grained tools for analyzing cross-system power relations, policy dynamics, and infrastructural dependencies. As a result, quaternary tensions—such as mismatches between institutional platforms and external social or policy systems—are frequently circumvented through parallel practices rather than transformed (Bullen & Morgan, 2015; MacLeod et al., 2019). Only where cross-unit coordination, policy alignment, or localization of external frameworks is achieved do such contradictions become opportunities for institutional redesign (Nambi, 2018; Rong & Yao, 2025; Zaim et al., 2024).

Across levels, boundary-crossing and mediational practices emerge as critical but under-theorized mechanisms linking micro-level adaptation to macro-level transformation. Studies show that boundary actors—students and faculty who treat tools as boundary objects and orchestrate learning across formal and informal ecologies—play a decisive role in stabilizing innovations long enough for institutions to codify them (Bullen & Morgan, 2015; Voogt et al., 2015; Vu & Le, 2022). Where interoperable tools, shared workflows, and cross-functional governance exist, adaptation matures into systemic change (Cui et al., 2024; Ma et al., 2025); where such infrastructure is absent, innovation remains localized and fragile (Kwon et al., 2018; Yıldız et al., 2020).

These findings affirm AT's central claim that contradictions are not merely obstacles but generative tensions. Technology acts as a catalytic mediator when contradictions are surfaced, interpreted diagnostically, and supported through governance, boundary infrastructure, and participatory design. At the same time, persistent ignored contradictions—especially at system interfaces requiring cross-institutional coordination or market negotiation—highlight the limits of AT in explaining power, scalability, and governance effects. In sum, AT-informed studies demonstrate that the pathway from contradiction to transformation is contingent rather than automatic. When contradictions are treated as design inputs rather than nuisances, they become prime movers of developmental change in e-learning ecosystems; when they are ignored or worked around, technological mediation remains local, fragile, and reversible.

Complementary Perspectives to Address AT's Analytical Limitations

The reviewed corpus confirms that AT provides a robust analytical framework for identifying developmental tensions and tracing trajectories of change in technology-mediated

learning. Across diverse e-learning initiatives, AT effectively surfaces contradictions and links technological mediation to shifts in pedagogical practice, role configurations, and institutional arrangements. However, as the preceding analysis demonstrates, AT alone is insufficient to fully explain three recurrent phenomena: why similar technologies generate divergent outcomes across institutions, why some contradictions scale into institutional transformation while others remain localized or stagnate, and how agency and power are redistributed through digital infrastructures. To address these limitations, many studies—explicitly or implicitly—draw on complementary theoretical perspectives. In particular, Affordance Theory, Sociotechnical Systems (STS) theory, and Actor–Network Theory (ANT) extend AT's explanatory reach by clarifying micro-level mediation, organizational constraints, and infrastructural power respectively.

Affordance Theory complements AT by strengthening analysis of how technological mediation is perceived, interpreted, and enacted by learners and teachers. Drawing on Gibson's (1979) relational conception of affordances, further developed by Norman (1999), and Leonardi (2011), this perspective emphasizes that technologies do not determine action; rather, action emerges from the relationship between users' capabilities, intentions, and perceived possibilities for use.

When integrated with AT, affordance theory helps explain variation in how primary contradictions unfold across ostensibly similar technological settings. The reviewed studies consistently identify learner anxiety, fluctuating motivation, limited metacognitive capacity, and role ambiguity as primary-level tensions (Kwon et al., 2018; Scavarelli et al., 2021; Su, 2017). While AT diagnoses these tensions, affordance theory clarifies why technological scaffolds resolve them in some contexts but not others. Mediation occurs only when learners and teachers perceive tools as usable, legitimate, and pedagogically meaningful. This distinction helps explain why adaptive interfaces and AI-generated feedback transformed affective tensions into learning affordances in some cases (Scavarelli et al., 2021; Su, 2017), whereas in others the same technologies remained largely inert due to weak pedagogical framing or misaligned expectations (Lai, 2021; Kessler, 2020). At the same time, affordance theory has limited capacity to account for how affordances themselves are shaped or constrained by institutional rules, governance arrangements, and power asymmetries. As such, it enhances but does not replace AT's systemic orientation, pointing instead to the need for complementary organizational and infrastructural perspectives.

Sociotechnical Systems (STS) theory extends AT by situating technological mediation within interdependent social and technical subsystems (Sawyer & Jarrahi, 2023; Trist & Bamforth, 1951). From an STS perspective, uneven outcomes in e-learning initiatives are not anomalies but predictable consequences of misalignment between pedagogy, leadership, professional development, assessment regimes, and technological infrastructure.

This perspective is particularly valuable for explaining the persistence and uneven resolution of secondary contradictions identified across the corpus. Misalignments between tools,

rules, division of labor, and learning objects are widespread (Chung et al., 2019; Cui et al., 2024; Voogt et al., 2015). While AT identifies these contradictions, STS explains why they so often lead to workarounds rather than transformation: without joint optimization of social and technical elements, technological mediation remains localized and fragile (Kwon et al., 2018; Yıldız et al., 2020). STS also clarifies why some secondary contradictions catalyze redesign while others stagnate. Studies documenting the localization of global ICT frameworks or the redesign of digital storytelling systems illustrate cases where institutions invested in coordinated change across policy, tooling, and professional development (Nambi, 2018; Yu & Wang, 2025). In contrast, where technology adoption was treated primarily as a technical upgrade, secondary contradictions were accommodated rather than resolved (Astudillo & Martín-García, 2020; Kessler, 2020). In this way, STS addresses an organizational blind spot in AT by explaining how governance capacity conditions the developmental potential of contradictions.

Actor–Network Theory (ANT) further challenges AT's predominantly human-centred assumptions by conceptualizing technology as an active mediator within heterogeneous networks of human and non-human actors (Latour, 2005). Whereas AT treats tools as mediating artefacts embedded in activity systems, ANT foregrounds how platforms, algorithms, analytics dashboards, standards, and data infrastructures actively shape practice by structuring visibility, accountability, and decision-making.

ANT is particularly valuable for analyzing AI-assisted learning, platform-based governance, and data-driven pedagogies, where agency is increasingly distributed across sociomaterial networks. Several reviewed studies show that AI systems do not merely support learning but actively reconfigure assessment logics, feedback cycles, and surveillance practices, intensifying tertiary contradictions around autonomy, evaluation, and control (Scavarelli et al., 2021; van der Westhuizen et al., 2021; Zaim et al., 2024). ANT helps explain how such contradictions become stabilized—or exacerbated—once pedagogical reforms are translated into code, algorithms, and standards that are difficult to contest or reinterpret locally.

Moreover, ANT sheds light on quaternary contradictions that AT often identifies but struggles to resolve analytically. Platform ecosystems, vendor contracts, interoperability standards, and global policy frameworks function as powerful non-human actors, helping explain why cross-system tensions are frequently bypassed rather than transformed (Bullen & Morgan, 2015; Han et al., 2023; MacLeod et al., 2019). Where institutions successfully localized external systems, ANT reveals the extensive negotiation required to realign networks of actors, technologies, and policies (Nambi, 2018; Rong & Yao, 2025).

These perspectives, collectively, do not displace AT but extend it into a more robust analytical ecology. AT provides the developmental grammar for identifying contradictions and tracing trajectories of change; affordance theory clarifies how mediation is perceived and enacted at the micro level; STS explains organizational capacity and systemic alignment; and ANT exposes infrastructural power and distributed agency in digitally mediated learning environments.

Across the reviewed studies, consistent insight emerges: contradictions are not inherently transformative. Their potential depends on perceptual alignment (affordances), organizational coordination (sociotechnical alignment), and infrastructural negotiability (network dynamics). When these conditions are absent, contradictions tend to be adapted around, ignored, or stabilized as constraints; when they are present, contradictions become engines of expansive learning and institutional transformation. In this sense, the corpus affirms and qualifies AT's central claim. Contradictions do indeed drive development—but only when supported by corresponding governance, design, and boundary-crossing capacities that allow technological mediation to move beyond local adaptation toward sustained systemic change.

CONCLUSIONS

This review of 31 AT-based studies of e-learning in higher education demonstrates that contradictions are not peripheral challenges but central mechanisms driving the evolution of digitally mediated learning ecosystems. The findings highlight a field in methodological and conceptual transition: while AT has predominantly been mobilized as an analytical tool (51.6%) to surface contradictions in practice, a significant body of work employs it as a conceptual framework (32.3%) to map educational ecosystems and theorize long-term trajectories, and a smaller but impactful subset uses it as a design-based intervention (16.1%) to enact expansive learning and systemic transformation. This distribution underscores both the diagnostic utility and the transformative potential of AT, suggesting that its value lies not only in identifying misalignment but also in leveraging them as design inputs for innovation.

Across the four levels of contradictions, distinct logic structure emerges. Primary contradictions, such as learner motivation or teachers' digital competence, are commonly managed through micro-level adaptations—essential but often transient in their effects. Secondary contradictions, arising from misalignments between tools, rules, and objects, demonstrate how technological mediation can serve as both source of tension and resolution mechanism, prompting either temporary workarounds or more enduring redesigns of assessment and pedagogy. Tertiary contradictions, generated by the clash between reform-oriented practices and entrenched traditions, show the greatest transformative capacity. Here, technologies such as AI and VR/AR become catalysts for expansive learning, shifting subject–object relations, redistributing roles, and reconfiguring institutional logics. Quaternary contradictions, spanning boundaries between institutional, cultural, and policy systems, are the most unpredictable: while some are circumvented, others spur structural redesigns when supported by governance infrastructures and cross-boundary collaboration.

In conclusion, e-learning technologies mediate and amplify four contradiction types by redistributing labor, reshaping rules, and redefining objects of activity, but the developmental trajectory depends on how contradictions are addressed: ignored contradictions perpetuate inertia, adapted ones yield incremental adjustment, while transformed

contradictions catalyse durable systemic change. AT, in this review, positions not merely as a retrospective analytical framework but as a forward-looking resource for educational design. Its contribution lies not in eliminating contradictions but in rendering them visible, interpretable, and actionable. When supported by appropriate governance structures, boundary infrastructures, and complementary theoretical perspectives, contradictions become engines of expansive learning rather than sources of stagnation. The following section outlines directions for future research that build on these insights and address the theoretical and practical gaps identified in the corpus.

RECOMMENDATIONS

The findings, for researchers, point to the necessity of advancing beyond descriptive and retrospective case analyses toward interventionist, longitudinal, and hybrid methodologies that can capture the dynamic evolution of contradictions within activity systems. While existing studies have richly documented the presence of tensions across tools, subjects, and institutional structures, the mechanisms through which these contradictions are surfaced, negotiated, and resolved remain under-explored. Future AT-informed research should therefore adopt design-based research, developmental work research, and participatory action approaches, enabling scholars not only to analyze contradictions but also to actively co-create contexts in which expansive learning can emerge. Moreover, comparative and cross-system studies are needed to examine how contradictions manifest differently across cultural, disciplinary, and institutional environments, thereby deepening understanding of the transferability and context-specificity of AT-guided interventions.

Also the findings, for practitioners and policymakers, underscore that the sustainability of digital transformation in higher education hinges less on the acquisition of technologies than on the institutional capacity to orchestrate meaningful organizational learning. This involves creating conditions under which contradictions are not suppressed or bypassed but deliberately surfaced and collectively addressed. Critical infrastructures include ongoing faculty professional development, cross-unit coordination mechanisms, and supportive governance frameworks that enable iterative experimentation rather than enforcing rigid compliance. Boundary infrastructures—such as interdepartmental working groups, policy sandboxes, and collaborative innovation hubs—can play a pivotal role in aligning technological affordances with pedagogical and organizational goals. Without such supports, digital initiatives risk stagnating as isolated pilot projects, unable to scale or sustain transformative impact.

The future trend for conducting AT-based research should be centered on resolution strategies, enabling conditions, and governance structure that dictate whether contradictions catalyse expansive learning or entrench existing inequities. This inclination indicates that although documented stories of using e-learning technologies gives points why analyzing emerging e-learning practices using AT theoretical framework is a necessity, building cumulative, evidence-based insights on

how contradictions function as both signposts of systemic tension and levers for innovation in the digital transformation of higher education provides a possibility for optimizing the effectiveness of e-learning technologies for researchers and practitioners.

LIMITATIONS

While this review synthesizes 31 AT-based studies to illuminate the role of technology as a mediating tool, the evidence base is constrained by both methodological and data-related limitations. First, the predominance of case studies and retrospective analyses means much of the literature is descriptive rather than interventionist, limiting the ability to establish causal or longitudinal insights into how contradictions evolve over time. Second, the uneven distribution of methodological approaches—51.6% employing AT primarily as an analytical tool, and only 32.3% as a design-based intervention—skews findings toward diagnosis rather than transformation, leaving gaps in understanding the mechanisms through which contradictions are actively negotiated and resolved. Third, data across the studies are fragmented and context-specific, often drawn from small-scale institutional settings or discipline-specific environments, which constrains the generalizability and transferability of findings across cultural and systemic contexts. Finally, reliance on self-reported data, interviews, and document analysis in many studies raises the risk of interpretive bias, while the lack of triangulated, mixed-method, or cross-system comparative designs restricts the robustness of claims about the systemic and expansive learning potential of AT-informed interventions. This review was not pre-registered (e.g., in PROSPERO or OSF), which may increase the risk of reporting bias. Although systematic procedures (e.g., PRISMA and structured quality appraisal) were followed, this is acknowledged as a limitation, and future research should incorporate more regionally diverse and recent studies—particularly from European and North American contexts—and adopt pre-registration practices to enhance transparency and reproducibility.

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