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Navigating Global Complexity in Digital Learning Spaces through FOSMA: A Multidimensional Framework for Higher Education Institutions

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Abstract

The rapid integration of digital, audiovisual, and network technologies into higher education globally has led to the emergence of increasingly complex learning environments and spaces, often described using general terms such as online, hybrid, or digitally enhanced. Although widely used, these terms capture only selected aspects of educational practice and are insufficient for understanding the multidimensional nature of contemporary digital learning spaces. This complexity is especially evident in large higher education institutions with many types, labels, and categories of learning spaces. This paper seeks to facilitate navigation through this complexity by proposing a multidimensional conceptual framework for categorizing and interpreting digital learning spaces. The framework enables the comparable description of different pedagogical and technological configurations without introducing evaluative or hierarchical ranking. The proposed framework aims to support shared understanding and communication among pedagogical, technical, and administrative stakeholders, as well as to inform strategic planning and the sustainable development of digital learning spaces within the broader digital learning environment – the ecosystem of higher education institutions.

1 Introduction

Due to digital transformation (DT), technologies such as information technology (IT), networking infrastructures (NET), audiovisual (AV) systems, and emerging learning tools have become integral to

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higher education, leading to learning spaces commonly described as online, blended, hybrid, digitally or AI-enhanced (Christou et al., 2023; Ellis & Goodyear, 2016; Hwang, 2014). These terms are widely used in research, institutional planning, and educational policy. However, studies consistently show that they lack shared definitions and are often used to describe different educational practices under the same label (Moore et al., 2011; Singh & Thurman, 2019).

At the same time, in a synchronous ed-tech higher education ecosystem, learning environments are no longer defined only by physical classrooms or by distance delivery (Roussos et al., 2023; Tang et al., 2025). Teaching and learning increasingly combine physical and digital spaces, synchronous and asynchronous interaction, and varying levels of technological support. Research on digital learning spaces shows that learning is shaped by the interaction of pedagogy, space, and participation, rather than by technology alone (Dron & Anderson, 2022; Johnson et al., 2022; Laurillard, 2013).

Despite this global complexity, learning environments are still commonly described using simple labels such as online or hybrid (Guri-Rosenblit & Gros, 2011; O'Neill, 2024; Singh & Thurman, 2019). These labels tend to emphasize where learning takes place or when interaction occurs, while leaving other important aspects—such as pedagogical organization, orchestration, and the role of technology—implicit (Ellis & Goodyear, 2016; Graham, 2006; Johnson et al., 2022). As a result, similar learning environments may be described using different terms, while the same term may refer to practices that differ substantially (Singh & Thurman, 2019; Smith & Hill, 2019; Tang et al., 2025).

This issue is well documented in the literature and became more pronounced after COVID-19, with the introduction of additional terms such as emergency remote teaching and HyFlex learning (Johnson et al., 2022; Papaioannou et al., 2023). The absence of a common analytical language limits the comparability of research and complicates the planning and coordination of learning spaces (Anderson & Dron, 2011; Boyarinov, 2021; Pardo-Baldov et al., 2023; Singh & Thurman, 2019).

These challenges are particularly evident in large[‡] Higher Education Institutions (HEIs)[§], where learning environments and spaces are deployed at scale. In such contexts, hundreds of teaching spaces must support diverse instructional practices, while institutional classifications of spaces focus primarily on infrastructure and operational needs (Boyarinov, 2021; Johnson et al., 2022; Roussos et al., 2023). Although necessary, these classifications offer limited insight into how learning is pedagogically organized within these spaces, especially in hybrid and digitally mediated settings (Anderson & Dron, 2011; Laurillard, 2013). Without a shared way to describe learning spaces, communication between academic, technical, and administrative stakeholders becomes fragmented, limiting coherent development of digital learning ecosystems (Roussos et al., 2025; Tang et al., 2025; Tondeur et al., 2024).

1.1 Scope of the Study

This study uses a scoping approach to examine how digital learning spaces are described in the research literature. Its aim is not to evaluate educational methods or learning outcomes, nor to analyze each existing learning space label, but to examine how digitally supported learning spaces are currently described. Moreover, the study aims to identify and conceptually synthesize the key dimensions used to differentiate these spaces. Lastly, the study seeks to provide a structured conceptual lens to support shared understanding, comparison, and future institutional planning for digital learning spaces within the broader digital learning environment of higher education institutions.

‡ Aristotle University of Thessaloniki includes 11 schools, 41 departments, 1,599 faculty members, 78,840 undergraduate students, 11,105 postgraduate students, and 4,681 doctoral candidates – in total ~95.000 students. With over 600 learning spaces, institutional coordination across pedagogy, space, and technology is inherently complex.

§ Universities, colleges, and further education institutions that offer and deliver higher education

1.2 Methodology of the Study

Studies were found using Google Scholar, Scopus, and Web of Science, focusing on work published after 2000 when digital learning became common in higher education. The search used keywords like:

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online learning, distance education, blended learning, hybrid learning, digital classrooms, synchronous, asynchronous, learning spaces, digital learning spaces, learning formats, learning technologies, digital transformation classroom, AI in education
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Important theoretical works were included for their lasting impact. Sources were selected if they provided definitions, types, or discussions of digital learning environments or addressed terminology. Technical studies without teaching insights were excluded. Sources were analyzed for descriptions of learning environments, comparing ideas about teaching organization, space, time, and technology use.

Focusing primarily on higher education, especially large HEIs where scale and diversity intensify the limits of single-label classifications, the framework supports shared understanding, institutional coherence, and scalable planning.

2 The Need for a Common Language in Digital Learning Environments

The challenge in describing digital learning environments and spaces is not only terminological, but structural (Carlos et al., 2024; Johnson et al., 2022; O'Neill, 2024). Learning environments are inherently multidimensional, combining pedagogical design, organization of learning processes, spatial configuration, temporal interaction, and technological support (Christou et al., 2023; Papaioannou et al., 2023; Tondeur et al., 2024). A common language is therefore needed to make these underlying dimensions explicit and comparable. Hence, this is an ongoing process to achieve a common language. Key dimensions frequently conflated in the literature include:

- **Learning Format – How learning is organized:** Learning format refers to the pedagogical structure of teaching and learning activities, such as lectures, flipped classrooms designs. Although these formats differ substantially in instructional intent and learner engagement, they are often grouped under broad hybrid labels, masking important distinctions (Ellis & Goodyear, 2016; Papaioannou et al., 2023; Tondeur et al., 2024).
- **Learning Orchestration – Who guides the learning process:** Orchestration concerns how learning activities are guided and coordinated, ranging from teacher-led models to learner-centred and data-driven approaches. Recent developments introduce algorithmic orchestration, where analytics and AI systems increasingly influence instructional decisions (Anderson & Dron, 2011; Christou et al., 2023; Hwang, 2014; Tang et al., 2025).
- **Learning Space – Where learning takes place:** It includes physical, virtual, and hybrid locations where learning occurs. Research highlights the growing diversity of learning spaces, yet spatial characteristics often remain underspecified, contributing to conceptual ambiguity (Carlos et al., 2024; Ellis & Goodyear, 2016; Garrison & Vaughan, 2008; Hümmer et al., 2026; Khamitova, 2023; de Borba et al., 2020).
- **Learning Mode – When and how learners interact:** Learning mode describes temporal interaction patterns, primarily synchronous and asynchronous engagement. While both modes can support meaningful learning, many studies fail to clarify temporal structure

when using general terms such as online or hybrid (Boyarinov, 2021; Hrastinski, 2008; Hümmer et al., 2026; Laurillard, 2013; Singh & Thurman, 2019)

- **Learning Augmentation – Which technologies are used:** Learning augmentation captures how digital technologies support and enhance learning processes. Although tools such as LMSs, learning analytics, and AI systems are widely adopted, related terms (e.g., adaptive or intelligent learning) are often used inconsistently, limiting analytical clarity (Hwang, 2014; Hümmer et al., 2026; Khamitova, 2023; Roussos et al., 2025; Tang et al., 2025; Tondeur et al., 2024; de Borba et al., 2020).

3 Institutional Framing of Digital Learning in HEIs

Digital learning in Higher Education Institutions involves multiple, interrelated levels, including organizational, technical, administrative, and pedagogical domains (Carlos et al., 2024; Tang et al., 2025; Roussos et al., 2025). To support coherent institutional planning and educational practice, it is necessary to clarify key concepts, the levels at which they operate, and the relationships between them. This study adopts a layered perspective in which strategic and institutional structures shape learning environments, learning spaces, and pedagogical practice, while teaching and learning processes simultaneously inform and reshape these structures through continuous feedback (Figure 1).

Concept	Level of Operation	Primary Role	Why It Matters
DTS - Digital Transformation Strategy	Strategic / Governance	Sets the long-term vision, priorities, and governance for digital transformation	Ensures coherence between policy, funding, innovation, and institutional goals
DLE - Digital Learning Environment	Institutional / Systemic	Defines the institutional ecosystem that supports digital learning	Aligns governance, policy, platforms, and support structures
DLS - Digital Learning Spaces	Operational / Spatial	Organizes and categorizes teaching and learning spaces	Supports space planning, infrastructure management, and scalability
FOSMA Framework	Pedagogical / Analytical	Describes learning activities through multiple pedagogical dimensions	Enables meaningful comparison and understanding of learning configurations

Table 1 - Distinction between the DTS, DLE, DLS, and the FOSMA framework

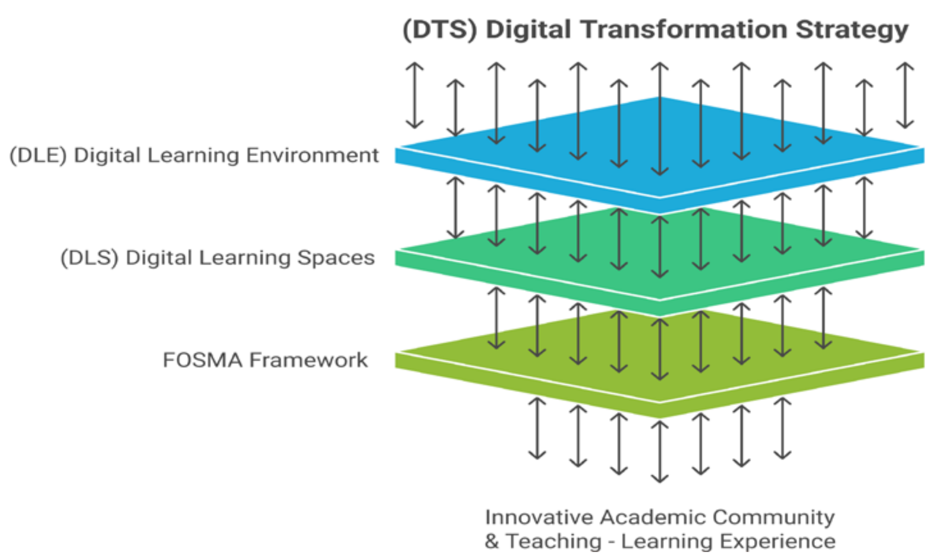

Figure 1 - From Digital Transformation Strategy to Pedagogical Practice: A Layered Institutional Model

Instead, it concentrates on articulating the pedagogical dimensions of learning activities through the FOSMA framework, which represents the most granular level of this interconnected structure.

The paper deliberately focuses on the pedagogical–analytical level and does not analyze the institutional digital transformation strategy (DTS), the digital learning environment or ecosystem (DLE), or the operational organization of learning spaces (DLS) (Table 1).

4 The FOSMA Framework: From Labels to Pedagogical Dimensions

The FOSMA framework is presented as a conceptual model to clarify the terminology of digital learning spaces in higher education ecosystems, not as fixed types but as combinations of five dimensions, thereby delivering a common language for higher education. This section introduces a theory-building framework to address persistent conceptual confusion among terms such as online, hybrid, in-person, and digital learning. The central issue is that these terms are widely used in academic practice but have not been integrated into a unified conceptual framework that clearly distinguishes between pedagogical organization, control of learning processes, learning location, temporal interaction patterns, and technological mediation (Boyarinov, 2021). The sequence underlying FOSMA is:

Format → **O**rchestration → **S**pace → **M**ode → **A**ugmentation

The FOSMA framework works like a chain: all five parts must be present for a digital learning space to make sense (Figure 1). If one part is missing or unclear, the whole description becomes weak and confusing. When learning is described solely in terms of where it happens or which tools are used, important pedagogical and organizational elements are overlooked. This sequence reflects the principle that educational design should begin with the intended learning and conclude with the selection of technological tools (Figure 2).

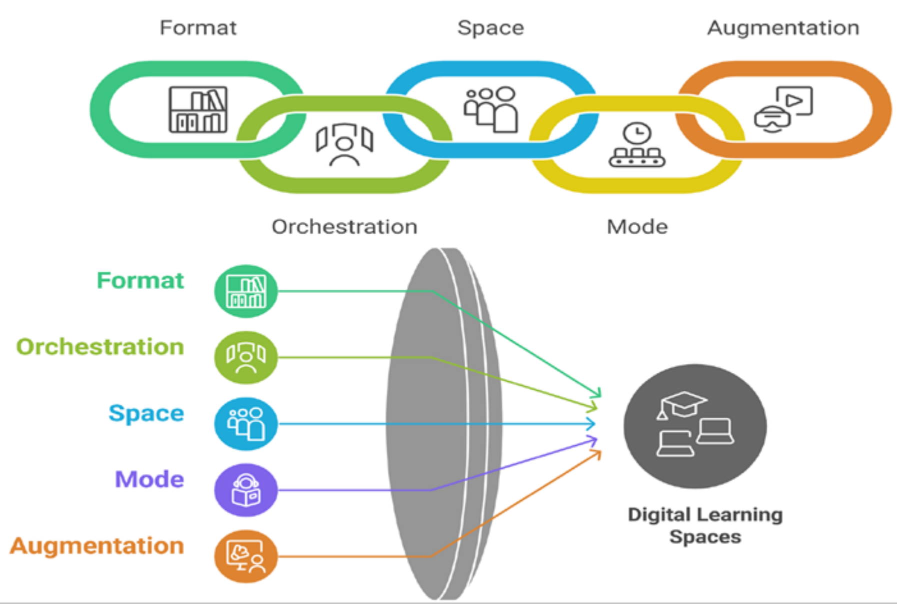

Figure 2 - The FOSMA Conceptual Chain for Digital Learning Spaces

In other words, learning is designed first, and technology is selected last; nevertheless, all five FOSMA dimensions are required in order to fully and unambiguously describe a learning environment (Table 2).

Type	Description
Format (F)	How learning is pedagogically organised (e.g., lecture-based, flipped classroom, project-based, HyFlex).
Orchestration (O)	Who guides and structures the learning process (e.g., teacher-led, learner-centred, system-supported).
Space (S)	Where learning takes place (e.g., on-campus, off-campus, mixed-location, immersive spaces).
Mode (M)	When and how interaction occurs (e.g., synchronous, asynchronous, blended-temporal).
Augmentation (A)	What technologies and tools use in learning process (e.g., LMS, video conferencing, learning analytics, AI, AR/VR).

Table 2 - The five FOSMA dimensions describing pedagogical and technological aspects of learning spaces

FOSMA shows that a clear understanding of a digital learning space is possible only when Format, Orchestration, Space, Mode and Augmentation are examined together.

4.1 The Five Key Dimensions

The FOSMA framework conceptualizes digital learning spaces as multidimensional configurations rather than fixed learning types. Each learning space is represented as an ordered vector:

$$L=(Fi,Oj,Sk,Ml,Am)$$

where each configuration represents a specific combination of pedagogical format, orchestration, space, mode, and technological augmentation. The following configurations are indicative and do not constitute a taxonomy.

$i \in \{1,\ldots,5\}$ indicates the selected value of **Format**
$j \in \{1,\ldots,5\}$ the selected value of **Orchestration**
$k \in \{1,\ldots,5\}$ the selected value of **Space**
$l \in \{1,\ldots,5\}$ the selected value of **Mode and**
$m \in \{1,\ldots,5\}$ the selected value of **Augmentation.**

To ensure interpretability, each dimension is operationalized on a five-point ordinal scale. These scales are not intended to impose rigid categories, but to provide a common descriptive resolution that can be refined or extended in future empirical applications.

Table 3 presents the five values of the *Format (F)* dimension, which describe how learning is pedagogically organised, along with short definitions and indicative examples.

Code	Value	Description
F1	Lecture-based	Linear content delivery by instructor (e.g. amphitheatre lectures, PowerPoint-based teaching).
F2	Flipped classroom	Content studied individually; class time used for discussion and exercises (e.g. recorded lectures + in-class problem solving).
F3	Blended design	Planned mix of in-person and online learning activities (e.g. campus seminars + LMS assignments).
F4	Project / Inquiry-based	Learning organised around projects, cases or research problems (e.g. group projects, case studies).
F5	Experiential / HyFlex	Simulation-based or flexible-choice participation models (e.g. clinical simulations, HyFlex classrooms).

Table 3 - Format (Pedagogical organisation of learning)

Table 4 summarises the values of the *Orchestration (O)* dimension, specifying who or what primarily guides and structures the learning process.

Code	Value	Description
O1	Teacher-led	Instructor controls pacing, content and assessment (e.g. weekly lectures, fixed syllabus).
O2	Learner-led	Students self-direct goals and learning paths (e.g. self-paced MOOCs).
O3	Shared orchestration	Teacher and learners co-regulate activities (e.g. collaborative project courses).
O4	System-led	Platforms adapt sequencing using rules or analytics (e.g. adaptive LMS pathways).
O5	AI-led	AI provides tutoring or feedback (e.g. GenAI assistants, AI grading systems).

Table 4 - Orchestration (who guides and structures learning)

Table 5 defines the values of the *Space (S)* dimension, indicating where learning takes place and how physical and virtual locations are combined.

Code	Value	Description
S1	On-campus only	All activities in physical classrooms or labs.
S2	Campus-anchored	Campus is core with mandatory online tasks (e.g. lecture + LMS quizzes).
S3	Mixed-location	Simultaneous physical & remote participation (e.g. HyFlex).
S4	Remote-anchored	Mainly remote with required campus sessions (e.g. distance MSc with residential weeks).
S5	Virtual / immersive	Entirely digital or XR spaces (e.g. VR simulations, virtual labs).

Table 5 - Space (Where learning takes place)

Table 6 presents the values of the *Mode (M)* dimension, which capture the temporal structure of interaction in a digital learning space.

Code	Value	Description
M1	Fixed synchronous	All learning in real time (e.g. live lectures only).
M2	Sync with optional async	Live sessions plus optional recordings/forums.
M3	Designed temporal mix	Mandatory sync & async activities (e.g. lectures + graded forums).
M4	Async with optional sync	Asynchronous core with optional live Q&A.
M5	Fixed asynchronous	No real-time interaction (e.g. self-paced MOOCs).

Table 6 - Mode (Temporal interaction pattern)

Table 7 describes the values of the *Augmentation (A)* dimension, outlining the layers through which technology mediates and enhances learning.

Code	Value	Description
A1	Physical infrastructure	Digital Equipment but no digital platforms (Board, projector, Monitors etc)
A2	Core platforms	LMS (Moodle, Panopto), repositories.
A3	Communication & media	Conferences Tools (Zoom, Teams, etc)
A4	Data-adaptive layer	Learning analytics dashboards, adaptive platforms.
A5	Intelligent & immersive	GenAI tutors, chatbots, AR/VR/XR environments.

Table 7 - Augmentation (Technology mediation layer)

Operationalizing each FOSMA dimension on a five-point scale enables the framework to move beyond static labels and to describe digital learning spaces in a structured, comparable manner. Although a discrete 1–5 resolution is adopted for interpretability, the FOSMA model is inherently continuous and may be extended to finer-grained or continuous scales in future empirical applications.

This property allows DLS to be profiled, compared, and visualized, and facilitates quantitative analyses such as similarity measures, clustering, and configuration-based design support.

4.2 Examples of Learning Configurations through FOSMA

The FOSMA framework reframes terms that were traditionally used to describe learning spaces, shifting the focus from technology and location-centred labels to pedagogically meaningful dimensions. Distinct teaching scenarios reveal important pedagogical differences when viewed through the FOSMA dimensions. For example, in a conventional classroom[**], an instructor may use digital tools such as projected slides or on-screen code demonstrations to support face-to-face teaching, without altering the underlying pedagogical format. In contrast, teaching in a hybrid mode[††], in a digitally equipped classroom that incorporates cameras, microphones, and collaboration tools often involving a remote co-instructor introduces changes in orchestration, spatial configuration, and modes of participation, reflecting a qualitatively different learning arrangement.

The practical use of the FOSMA framework can be illustrated through concrete learning space configurations expressed as vectors.

L_trad = (F1, O1, S1, M1, A1): This configuration represents a traditional, fully face-to-face learning space with a lecture-based format, instructor-led orchestration, a physical classroom setting, synchronous interaction, and minimal technological mediation. It serves as a baseline configuration for comparative purposes.

L_hybrid_basic ≈ (F3, O3, S3, M3, A3): This configuration describes a basic hybrid learning space that combines on-campus and remote participation, synchronous and asynchronous activities, and moderate technological support. Although commonly labeled as *hybrid*, this configuration differs substantially from other hybrid practices in its pedagogical organization and orchestration.

L_hybrid_advanced ≈ (F3, O4, S4, M3, A4): This configuration represents a more complex hybrid learning space, characterized by increased spatial flexibility, more advanced orchestration (e.g., shared or system-supported), and enhanced technological mediation. Its complexity emerges from the interaction of multiple dimensions rather than from any single factor.

L_hybrid_extended ≈ (F5, O5, S5, M3, A5): This configuration illustrates an extended hybrid or digitally enhanced learning space with high flexibility across all dimensions, including system-level or AI-supported orchestration. It primarily functions as a theoretical upper bound within the FOSMA space rather than as a description of a standard institutional practice.

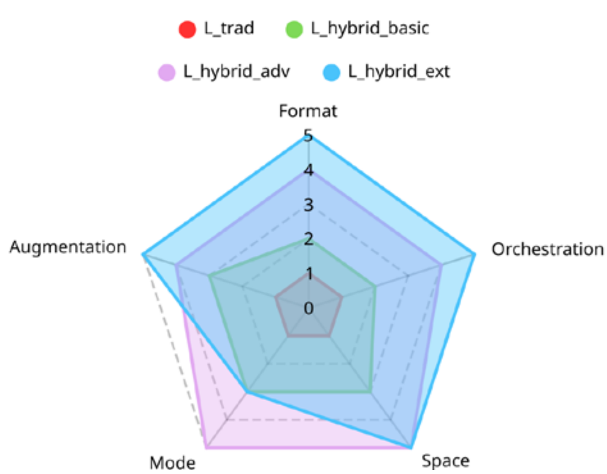

Figure 3 - Radar illustrating multidimensional learning space configurations across the FOSMA dimensions

[**] in-person learning is not defined simply by physical presence but corresponds to a specific configuration L=(F1,O1,S1,M1,A1)

[††] hybrid learning typically occupies a mixed-location and blended-temporal region L≈(F3,O2–3,S3,M3,A3)

Each configuration can also be visualized using a radar (spider) diagram (Figure 3), where the five axes correspond to the FOSMA dimensions and the resulting polygon represents the pedagogical and technological profile of the environment. However, it is worth noting that the radar chart is not a ranking or scoring mechanism, but a visual tool to illustrate multidimensional differences between learning space configurations. The purpose is not to evaluate *better* or *worse* learning spaces, but to make visible the multidimensional diversity, trade-offs, and design choices that characterize different digital learning spaces.

5 Discussion

In 2025, Aristotle University of Thessaloniki implemented the proposed layered approach in a pilot project comprising *15 hybrid digital learning spaces*. This pilot represents the first coordinated institutional application of a pedagogically driven framework to hybrid learning space design within the University, using FOSMA as a shared analytical reference. The framework contributed to clearer specification of pedagogical requirements during space design and reduced ambiguity between technical and academic teams, supporting more coherent decision-making in a large institutional context. Rather than focusing on specific tools, the framework positions technology as an enabler of pedagogical configurations, supporting flexible participation, orchestration, and augmentation across learning spaces. Building on this initial implementation, the institution plans to extend the approach to an additional *66 hybrid classrooms during 2026*, indicating both scalability and institutional commitment to a coherent digital learning transformation. Although not designed as an evaluative study, the pilot provided early qualitative evidence that a shared pedagogical language can significantly improve cross-unit coordination in digital learning space projects.

6 Conclusion

This study introduced FOSMA as a multidimensional analytical framework for mapping digital learning spaces in large Higher Education Institutions. Rather than defining strategies, systems, or space types, FOSMA clarifies how learning experiences are pedagogically configured across formats, orchestration models, spatial arrangements, participation modes, and technological augmentation. By positioning learning environments as configurations within a shared analytical space, the framework supports clearer communication, institutional coherence, and informed planning in complex digital and hybrid ecosystems. The FOSMA framework has been piloted in an institutional setting, demonstrating its practical feasibility and scalability. However, further empirical research is needed to systematically validate the framework, including studies on inter-rater consistency, instructional design support, and its impact on learning outcomes, student engagement, and institutional decision-making.

LLM Usage

Large Language Models (LLMs) were used only to support language editing, grammar correction, and syntax refinement during manuscript preparation. The authors retain full responsibility for the content, ideas, analyses, interpretations, and conclusions presented in this paper.

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Author Biographies

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