



# Hybrid 2.0: Advancing Learning Freedom at Aristotle University through the Institutional Digital Transformation of Learning Spaces for Innovation, Engagement, and Inclusion

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## Abstract

The rapid expansion of hybrid teaching during the COVID-19 pandemic prioritized continuity over coherence, often resulting in fragmented, instructor-dependent solutions. This paper presents the institutional response of Aristotle University of Thessaloniki, the largest university in Greece, serving approximately 100,000 students, through the design and implementation of Hybrid 2.0 Digital Learning Spaces (DLS). Building on extensive experience in large-scale audiovisual initiatives, the University moved from isolated deployments toward a standardized, scalable, and institutionally governed digital learning infrastructure. In 2025, the university implemented 20 Hybrid 2.0 DLS across diverse academic environments, using a layered architecture that integrates AI-enabled ceiling microphone arrays, distributed loudspeaker systems, PTZ video systems, IP-based control, and lecture capture functionality. Early three-month monitoring showed promising implementation outcomes, including 70% active instructional use, 0.20 incidents per space/month, and 80% positive faculty perception. The paper offers a transferable pathway for embedding hybrid capability into digital learning environments while supporting innovation, engagement, inclusion, and institutional resilience in higher education.

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## 1 Introduction

The COVID-19 pandemic accelerated digital adoption across higher education, forcing Higher Education Institutes (HEIs) to implement remote and hybrid teaching models rapidly (Akour & Alenezi, 2022; Bond et al., 2021; Broadbent et al., 2023). While these emergency responses ensured continuity, they often relied on fragmented, instructor-dependent solutions that lacked a coherent learning-space design (Alenezi et al., 2023; Khamitova, 2023).

As higher education entered the post-pandemic period, institutions faced a new challenge: moving beyond temporary solutions toward sustainable hybrid environments aligned with the demands of the digital era (Roussos et al., 2023; Roussos et al., 2025). At Aristotle University of Thessaloniki (AUTH), this shift prompted a strategic effort to improve learning spaces into integrated hybrid ecosystems capable of supporting both in-room and remote participation for Innovation, Engagement, and Inclusion.

This paper presents AUTH's institutional response to these emerging requirements through the design and implementation of Hybrid 2.0 Digital Learning Spaces (DLS) that advance learning freedom and its early institutional impact. Drawing on nearly six years of experience in delivering large-scale audiovisual (AV) initiatives, the Digital Governance Unit (DGU) has systematically optimised its implementation processes (Implementation → Standardisation → Scalability) in support of the academic community (Roussos et al., 2025). This institutional progress reflects a transition from isolated deployments to standardized, scalable hybrid learning environments (Roussos et al., 2025).

## 2 From No-Hybrid to Hybrid 1.0 and Hybrid 2.0 Learning

Hybrid learning has evolved through successive stages shaped by technological readiness and institutional priorities. Prior to the pandemic, digital tools mainly functioned as supplementary enhancements to face-to-face teaching rather than as integrated components of the learning environment (de Borja et al., 2020; Ellis & Goodyear, 2016; Moore et al., 2011; Pinto et al., 2020).

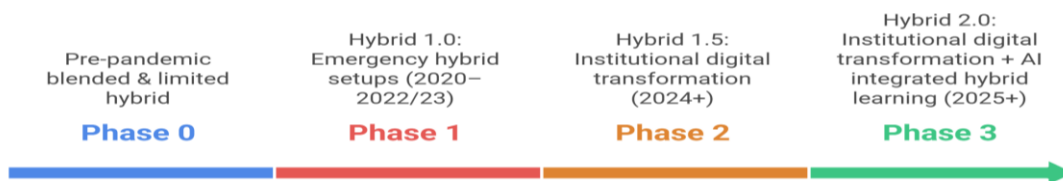
The pandemic triggered a rapid shift toward hybrid delivery, revealing both the potential and the limitations of emergency-driven implementations (Bond et al., 2021; Broadbent et al., 2023; Janahi et al., 2023). In the post-COVID period, institutions began transitioning from reactive setups to structured, scalable hybrid environments (Grassi et al., 2026; Kee et al., 2025; Ortega-Arranz et al., 2024; Roussos et al., 2025).

Approximately three years after the peak emergency phase, institutions entered a second stage of digital maturation (Bautista & López-Costa, 2025; Kee et al., 2025; Ortega-Arranz et al., 2024; Roussos et al., 2025). In this paper, this stage of institutional maturation is referred to as Hybrid 2.0<sup>†</sup> and reflects the shift from equipping individual rooms toward designing integrated hybrid learning ecosystems that combine physical presence with digitally supported interaction. We can divide this evolution into 4 distinct phases, and this section will shed light on them (Figure 1).

This shift does not constitute a new pedagogical framework but represents a transformation in the institutional orchestration of DLS. The emphasis moves from "equipping rooms" to "designing integrated hybrid ecosystems".

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<sup>†</sup>Hybrid 2.0 is used here to denote the post-COVID maturation of hybrid learning spaces characterised by institutional integration and AI-supported functionality.



**Figure 1 - From No-Hybrid to Hybrid 2.0 Learning**

Prior to the COVID-19 pandemic, this means before 2020, hybrid learning practices were neither systematically designed nor institutionally embedded except some specific cases as exceptions. Learning spaces remained primarily analog, with digital tools operating as external supplements rather than integrated spatial elements (Ellis & Goodyear, 2016; Neill & Etheridge, 2008).

During the pandemic, institutions rapidly deployed cameras, microphones, and videoconferencing tools to ensure continuity of teaching. These solutions were typically decentralized and platform-driven, prioritising operational survival. This emergency phase did not represent any pedagogical innovation but mostly a survival response to unprecedented disruption, with hybrid delivery emerging as an operational necessity rather than a strategically designed educational model (Al-Marouf et al., 2022; Broadbent et al., 2023; Pardo-Baldov et al., 2023; Ryoo & Winkelmann, 2021).

Following the emergency phase, universities began standardizing hybrid environments through governance-led upgrades of audiovisual infrastructure and lecture capture workflows. Hybrid classrooms increasingly became institutional assets rather than isolated technical solutions (Bautista & López-Costa, 2025; Khamitova, 2023; Tang et al., 2023).

The most recent phase, the Hybrid 2.0 phase, introduces artificial intelligence as an enabling layer within hybrid learning spaces. AI-supported systems enhance audiovisual performance, automate lecture capture, and facilitate interaction between on-site and remote participants. This stage reflects a transition from temporary hybrid solutions toward strategically designed environments aligned with institutional digital transformation (Bautista & López-Costa, 2025; Grassi et al., 2026; Roussos et al., 2025). The transition from 1.0 to 2.0 (Table 1) required shifting from "digitizing" old, broken processes to "transforming" them. It required a move toward institutionalization, where digital tools are not just temporary fixes, but deeply embedded, strategic components of the University's pedagogy (Boyarinov, 2021; Neill & Etheridge, 2008).

Aspect	Emergency Remote Teaching 2020-23 (Hybrid 1.0)	Hybrid Synchronous Learning 2023-2024 (Hybrid 1.5)	Structured Hybrid Learning 2025+ (Hybrid 2.0)
Nature	Reactive, crisis-driven shift to online	Simultaneous face-to-face and online synchronous	Deliberate, designed integration of online and face-to-face
Design	Minimal preparation, emergency adaptation	Requires intentional design to manage dual modalities	Thoughtful integration with pedagogical frameworks
Technology Use	Basic use of available tools, infrastructure-dependent	Complex use of synchronous tools, managing limitations	Use of LMS, digital platforms, and multiple tools
Student Experience	Increased academic performance but variable engagement	Challenges in communication, need for active design	Enhanced motivation, autonomy, satisfaction, and engagement
Faculty Support	Limited, often ad hoc	High cognitive load, need for support	Instructional design teams, training, and technical support
Institutional Maturity	Low, emergency response	Intermediate, experimental hybrid synchronous	High, strategic policies and sustainable frameworks

**Table 1 - Key Characteristics of Hybrid Learning Evolution**

The Hybrid 2.0 phase aligns with AUTH's broader institutional Digital Learning Environment or Ecosystem (DLE) strategy and the development of digital learning spaces. Within this context, the

transformation of classrooms into hybrid-enabled ecosystems follows the principles of the FOSMA model (Format–Orchestration–Space–Mode–Application), which we use internally to guide the pedagogically coherent integration of technology into learning spaces.

### 3 Designing Hybrid 2.0: Architecture and Institutional Implementation

Aristotle University of Thessaloniki, serving approximately 100,000 students, operates within a highly diverse instructional landscape that includes lecture-based delivery, blended learning, HyFlex formats, and experiential teaching practices (Roussos et al., 2023). At this scale<sup>‡</sup>, hybrid capability cannot remain decentralized or optional. Institutional resilience, inclusion, and international collaboration increasingly depend on structured digital learning infrastructures (Bygstad et al., 2022; Johnson et al., 2022).

In response to these emerging demands, AUTH initiated, for 2025, an additional centrally coordinated transformation program through the Digital Governance Unit. In 2025, twenty (20) fully standardized Hybrid 2.0 Digital Learning Spaces were implemented across campus, marking a transition from fragmented hybrid setups to institutionally orchestrated environments. An additional seventy (70) spaces are scheduled for completion in 2026, signaling strategic scaling rather than pilot experimentation.

The DGU, rather than introducing isolated AV upgrades, implemented Hybrid 2.0 digital learning spaces through a layered socio-technical architecture in which audio, video, control, and infrastructure operate as interdependent components of a unified hybrid ecosystem. This approach enabled consistency, scalability, and pedagogical flexibility across different room typologies, including amphitheatres, lecture halls, and flexible classrooms.

#### 3.1 Audio Layer

Hybrid parity begins with professional, high-quality sound, so AUTH adopted an audio-first design philosophy to ensure that both in-room and remote participants experience equivalent speech clarity.

Each Hybrid 2.0 digital learning space integrates ceiling microphone arrays with AI-supported beamforming, supported by wired and wireless instructor microphones. Distributed loudspeaker systems (ceiling or columns) are configured according to room geometry, while a centrally networked Digital Signal Processor (DSP) manages echo cancellation, gain control, and signal routing. This configuration ensures consistent in-room reinforcement and reliable remote transmission, reducing common hybrid disruptions such as feedback, uneven amplification, or latency.

#### 3.2 Video Layer

The video layer supports presence, interaction, and content delivery across physical and remote audiences. Hybrid 2.0 spaces integrate AI-assisted 4K PTZ cameras, projection systems, or 86" interactive displays, depending on room type, and lecture capture encoders supporting both live and asynchronous participation. Camera positioning enables simultaneous capture of instructor activity, board interaction, and audience presence, supporting visual parity between in-room and remote learners. In this configuration, hybrid classrooms serve as both teaching environments and institutional nodes for content production.

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<sup>‡</sup> The primary campus covers roughly 33.4 hectares (334,000 square meters) in the center of Thessaloniki. Additional facilities, including a university farm, forest reserves, and various research units, are located outside the main city campus. The institution includes 11 faculties and 41 schools departments, covering all disciplines (auth.gr)

### 3.3 Control and Signal Management Layer

Operational stability and simplicity were central design priorities in the Hybrid 2.0 DLS. Instructors interact with the environment through intuitive hybrid control interfaces, while the underlying orchestration is handled by AV control processors that synchronize audio, video, and recording workflows.

Each Hybrid 2.0 DLS integrates IP-based control systems, AV routing and switching infrastructure, and PoE-enabled network switches to support device coordination across the space. The combination of control processors and Dante-enabled audio networking enables real-time signal management, automated camera positioning, and seamless lecture capture activation.

### 3.4 Infrastructure Layer

The infrastructure layer of the Hybrid 2.0 DLS provides the computational and environmental stability required for reliable hybrid delivery.

Each digital learning space incorporates a dedicated mini-PC, centralized administration by DGU, structured network cabling, and, in some cases, acoustic treatment panels and optimized lighting conditions, designed to support both in-room visibility and camera-based transmission. These elements work in conjunction with the DSP-driven audio system and AI-assisted video capture to ensure consistent performance across synchronous and recorded sessions. In this context, infrastructure is not treated as background support but as an active enabler of hybrid parity and system reliability.

### 3.5 Architectural Integration Across Typologies

Although Hybrid 2.0 DLS deployed across diverse spaces and room types, including amphitheatres, lecture halls, and flexible classrooms, all spaces follow a consistent layered architecture that integrates key components such as AI-enabled microphone arrays, DSP-based audio processing, PTZ camera systems, lecture capture encoders, AV control processors, and hybrid computing nodes. This standardized integration allows each Hybrid 2.0 DLS to operate within a unified operational logic, enabling: a) consistent teaching workflows, b) simplified technical support, c) predictable hybrid performance, d) institutional scalability.

As a result, Hybrid 2.0 DLS functions not as isolated technical installations but as coordinated hybrid ecosystems aligned with institutional teaching and collaboration practices.

## 4 AUTH's Hybrid 2.0 Digital Learning Spaces

The Hybrid 2.0 Digital Learning Spaces were deployed across a diverse range of academic environments to ensure institutional reach and disciplinary inclusivity. The spaces presented here constitute representative examples drawn from the total of twenty (20) implemented Hybrid 2.0 environments. For example, some of them are located at the Center for Interdisciplinary Research and Innovation (CIRI) and within the Faculties of Sciences, Engineering, Agriculture, Forestry and Natural Environment, and Philosophy.

Figures 2 to 5 illustrate representative Hybrid 2.0 Digital Learning Spaces across different spatial typologies, including amphitheatres, lecture halls, medium-sized classrooms, flexible teaching spaces, and executive collaboration environments. Figure 5 especially illustrates the unified control environment through which Hybrid 2.0 DLS are operated.

Beyond architectural variation, the images highlight the consistent integration of core Hybrid 2.0 components such as AI-enabled microphone arrays, DSP-based audio processing, PTZ camera systems, interactive displays or projection, lecture capture capability, and centrally orchestrated control

interfaces. Together, these examples demonstrate how a common layered architecture enables hybrid teaching across diverse academic contexts while maintaining operational and pedagogical consistency.

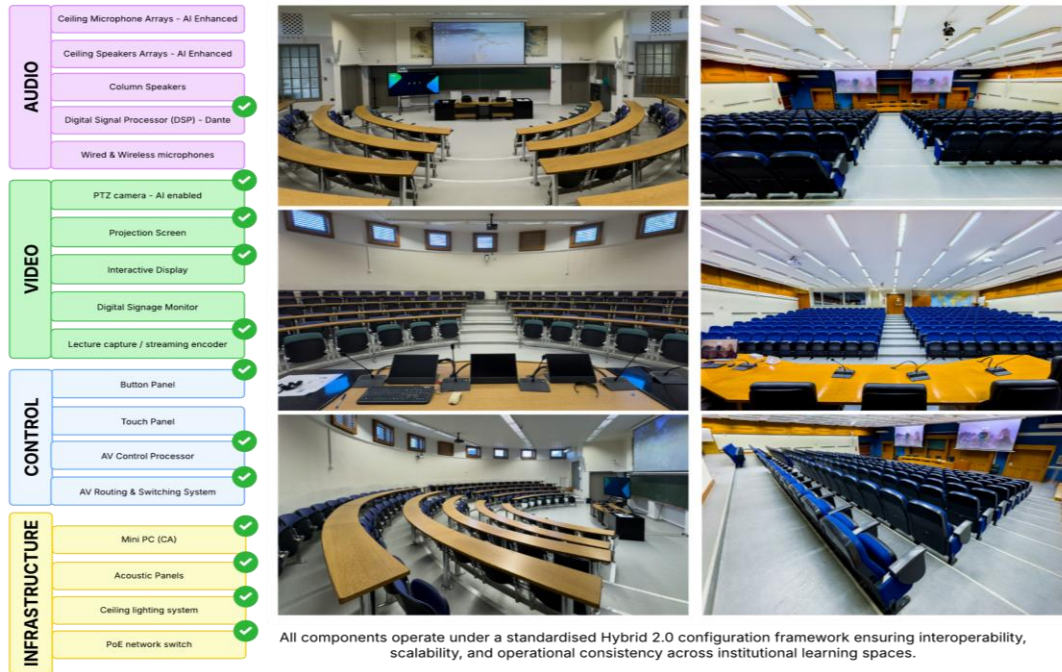


Figure 2 - Hybrid 2.0 Amphitheatres & Lecture Halls Configuration

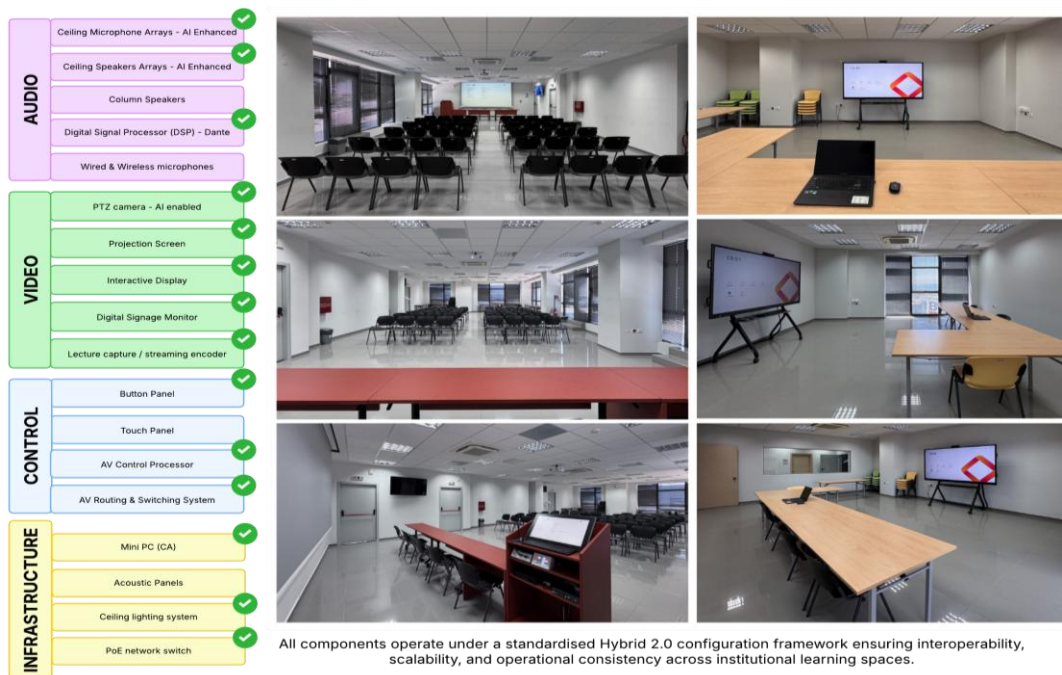


Figure 3 - Hybrid 2.0 Flexible Classroom Configuration

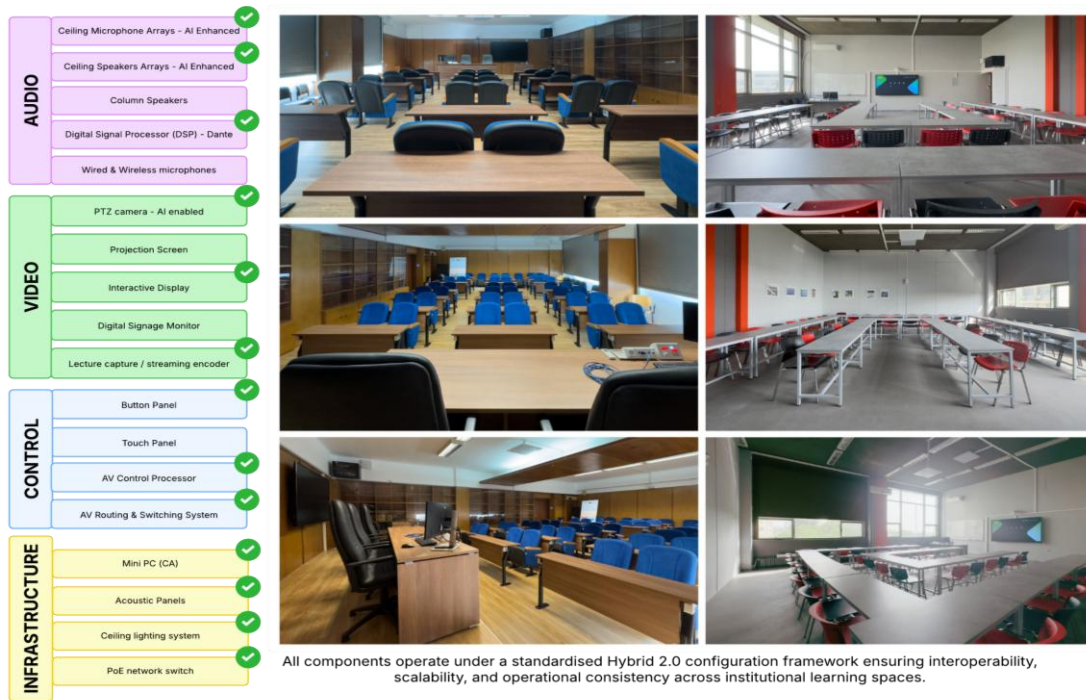


Figure 4 - Hybrid 2.0 Medium Classroom Configuration

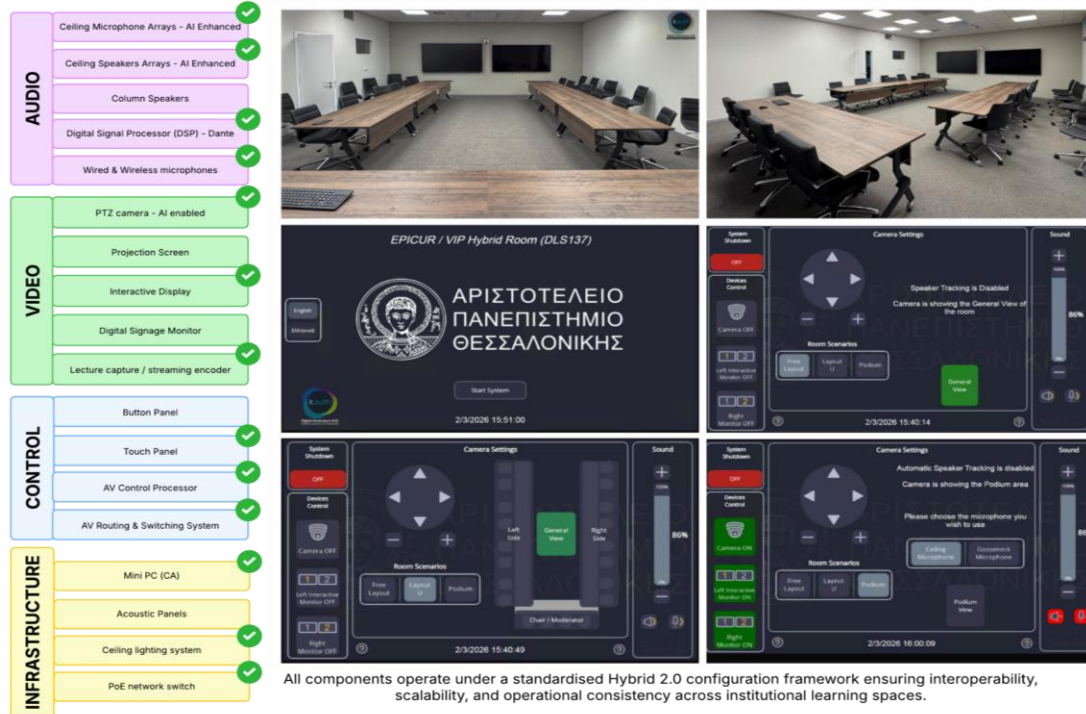


Figure 5 - Hybrid 2.0 Flexible Classroom Configuration

## 5 Evidence of Institutional Integration and Adoption

The following results reflect a structured three-month monitoring period at the end of 2025 following the phased activation of the Hybrid 2.0 DLS. The indicators presented below represent early operational evidence; however, even within this limited observation window, measurable patterns of institutional uptake, usage intensity, and operational stability are evident.

### 5.1 Growth and Scale of Hybrid 2.0 Digital Learning Spaces

By the end of 2025, twenty (20) fully configured Hybrid 2.0 digital learning spaces were operational. These spaces form part of a broader transformation program that has implemented more than 40 learning spaces across campus, with upgraded AV and network infrastructure.

Twenty DLS within a single calendar year represents a significant structural intervention in the University's learning infrastructure. In addition, this was not a pilot initiative confined to a single department but a centrally coordinated institutional deployment. Furthermore, the approved roadmap for 2026 includes the transformation of more than 70+ additional DLS. This planned expansion indicates that Hybrid 2.0 has transitioned from the implementation phase to the strategic scaling phase. Institutional commitment at this level signals organizational confidence in the model and confirms its alignment with long-term digital transformation priorities.

### 5.2 Use of the Digital Learning Spaces in Teaching and Collaboration

Within three months of activation, 14 of the 20 spaces were actively used for hybrid instruction, resulting in a 70% adoption rate. This level of uptake, achieved shortly after deployment and faculty onboarding, suggests rapid integration into academic practice.

Across all 20 spaces, the monitoring period recorded an average of approximately 2.5 hybrid sessions per day. The spaces supported a wide range of academic activities, including conventional lectures with remote participation, blended course sessions, guest lectures from international partners, inter-institutional research meetings, and hybrid seminars involving distributed audiences. Faculty were able to move seamlessly from presentation-based instruction to interactive hybrid discussion without reconfiguring technical systems. This diversity of use cases demonstrates that Hybrid 2.0 digital learning spaces function as both strong teaching support mechanisms and academic collaboration infrastructures.

### 5.3 Technical Stability and Support Performance

Operational reliability is critical in hybrid environments, where technical instability directly affects teaching continuity and student engagement. During the three-month monitoring period, an average of 4 technical incidents per month were recorded across all 20 spaces, for an incident rate of 0.20 per space per month. More importantly, the vast majority of issues were resolved within the next working day, and only in rare cases did resolution extend to 48 hours. These data suggest that the governance model and support workflow implemented alongside the technical deployment are functioning effectively. Hence, operational stability at this level is a prerequisite for institutional trust in hybrid teaching models.

### 5.4 Faculty Experience and Perceived Value

We conducted a structured pulse review to assess faculty perception during the first three months of operation. Of the 20 spaces evaluated, 16 (80%) were reported as positively impacting teaching practice, 3 (15%) were assessed as neutral, and 1 (5%) received negative feedback due to a technical problem that interrupted the educational process.

The initial positive responses suggest that the Hybrid 2.0 configuration aligns with faculty expectations and instructional needs. Qualitative comments indicated improvements in audio clarity, ease of session initiation, and greater confidence when engaging remote participants. Several instructors reported that remote students were more responsive and participatory compared to earlier hybrid setups implemented during the emergency phase. Although these observations remain preliminary and will require systematic longitudinal evaluation, they provide early evidence that Hybrid 2.0 may be contributing to improved engagement parity between physical and remote participants.

## 5.5 Summary of Early Indicators

The following indicators (Table 2) suggest that Hybrid 2.0 has moved beyond experimental implementation and is now functioning as an embedded component of institutional teaching practice. While annualized data are required to confirm long-term stability and scaling dynamics, the early results provide measurable evidence of emerging institutional operational maturity, faculty acceptance, and sustained instructional activity.

Category	Indicator	Result	Monitoring Basis
Infrastructure	Fully operational Hybrid 2.0 spaces	20	Completed 2025
Adoption	Active instructional use	70% (14/20 spaces)	3-month period
Usage	Average hybrid sessions	2.5 per day (all spaces)	3-month average
Reliability	Technical incidents	4 per month	All 20 spaces
Reliability	Incident rate	0.20 per space/month	Calculated
Reliability	Resolution time	Next working day (rarely $\leq 48$ h)	Service logs
Faculty feedback	Positive perception	80% (16/20)	Pulse review
Faculty feedback	Neutral perception	15% (3/20)	Pulse review
Faculty feedback	Negative perception	5% (1/20)	Pulse review

**Table 2 - Hybrid 2.0 Early Institutional Performance Indicators (3-Months)**

Beyond technical deployment and numbers, the point is that the Hybrid 2.0 Digital Learning Spaces implementation program represents a transferable institutional approach to designing scalable hybrid learning environments in HEIs and especially in large universities like ATh.

## 6 Discussion

The Hybrid 2.0 initiative demonstrates that sustainable hybrid capability in large public universities relies on governance-led orchestration rather than decentralized equipment deployment. The primary distinction of Hybrid 2.0 Digital Learning Spaces lies not in advanced devices, but in the systemic integration of architecture, signal management, and operational workflows within a unified institutional model. The evolution from Hybrid 1.0 to Hybrid 2.0 represents a broader shift from continuity-driven responses to strategically embedded digital learning infrastructures.

Within this context, advancing learning freedom is conceptualized as an institutional design outcome rather than simply a technological feature. Integrating hybrid capability into standardized digital learning spaces facilitates participation in both physical and remote contexts while preserving pedagogical stability. This structural transformation supports innovation through scalable infrastructure, increases engagement by enhancing parity of interaction, and promotes inclusion by minimizing spatial and logistical barriers to access. Lastly, these conditions establish a transferable pathway for large institutions seeking to transition from fragmented hybrid implementations to sustainable, scalable hybrid ecosystems.

## 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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**Christos Trantas** is the AV Systems Administrator of the Academic Technologies Support Office at the Digital Learning and Support Department of the Digital Governance Unit (DGU) at the Aristotle University of Thessaloniki (AUTH), Greece. He is responsible for the design, operation, and support of live streaming, recording services, and hybrid AV setups that enhance digital teaching, hybrid learning environments, and institutional communication. He specializes in video production, post-production, and technical support for educational and organizational content. His professional portfolio includes collaborations with the Thessaloniki International Film Festival, the Thessaloniki Documentary Festival, and the Drama International Short Film Festival. Drawing on this experience, he combines technical expertise to deliver high-quality video productions and digital media content.



**Antonios Dirchalidis** is part of the Academic Technologies Support Office at the Digital Learning and Support Department of the Digital Governance Unit (DGU) of the Aristotle University of Thessaloniki (AUTH), Greece, managing lecture theatre AV infrastructure, control systems, video-conferencing, hybrid teaching setups and end-user support. He is an accomplished AV Engineer with a BSc in Electronics Engineering and over 18 years of specialised experience in professional stage lighting. An expert in DMX, sACN, Art-Net protocols, LED systems, lighting console programming and large-scale event installations, he has delivered reliable, creative lighting solutions for theatres, concerts, festivals and corporate productions. Drawing on this experience, he combines technical expertise to deliver high-quality AV solutions for AUTH's technological needs.



**Eleni Tsakiri** works as an AV Architect and Support member at the Digital Governance Unit (DGU) of the Aristotle University of Thessaloniki, within the Digital Learning and Support Department. In her role, she is responsible for interpreting and analyzing architectural drawings and spatial documentation of university facilities. She focuses on mapping and correlating teaching spaces with AV systems and technical equipment, contributing to the strategic organization and upgrade of learning environments. Her work bridges architectural planning with technological infrastructure, supporting the efficient integration of AV systems in academic spaces. Alongside her professional responsibilities, she is a fifth-year student in the Department of Architecture at the same University, currently pursuing her integrated Master's degree, further strengthening her academic and technical expertise.