



## The LMS Infrastructure Paradox in Central European Tertiary Education: Why Robust Platforms Yield Fragile Ecosystems

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### ABSTRACT

This article investigates what the authors term the “LMS infrastructure paradox” in Central European tertiary education: the persistent and counterintuitive phenomenon whereby institutions across the region deploy technically robust, feature-complete Learning Management System platforms—predominantly Moodle—yet systematically fail to leverage their architectural capabilities, thereby producing fragile, siloed, and interoperability-deficient digital learning ecosystems. Drawing upon a critical synthesis of recent scholarship in educational technology, systems architecture, data interoperability, and higher education IT governance, and informed by the authors’ collective experience in administering, developing, designing multimedia content for, and teaching through LMS infrastructure at a Serbian vocational college, the paper identifies and analyses five structural, institutional, and technical factors that perpetuate this paradox. The central argument advanced here is that the core problem resides not in platform capability but in *architectural intentionality*: specifically, the absence of a coherent, institution-wide IT strategy that conceptualises the LMS as an integrated component of a broader digital ecosystem rather than as a standalone application. To address this deficit, the paper proposes an “Integrative Architecture Framework” (IAF) comprising five design principles for Central European institutions seeking to close the gap between platform potential and ecosystem reality. The discussion encompasses LTI interoperability, xAPI and learning analytics pipeline design, single sign-on implementation, database architecture, the mathematical modelling of analytics maturity, the integration of multimedia instructional content and open educational resources, and the pivotal role of institutional IT governance in determining LMS outcomes.

**Keywords:** Learning Management Systems, Moodle, interoperability, LTI, xAPI, systems architecture, learning analytics, IT governance, Central European higher education, digital ecosystem, tertiary education, analytics maturity, multimedia instructional design, open educational resources



## INTRODUCTION

Let us begin with something that has been puzzling us for quite some time. Between the five of us, we have spent the better part of two decades working with Learning Management Systems in Central European higher education—installing them, configuring them, writing plugins for them, migrating between their successive versions, designing multimedia content within them, modelling their data outputs, troubleshooting them at two in the morning when an examination was scheduled for eight, and, on more occasions than we care to enumerate, explaining to colleagues why the system could not accomplish something that, in strictly technical terms, it was entirely capable of accomplishing. It was this last experience—the recurring disjunction between what the platform *could* do and what it was actually *doing*—that first persuaded us there was a puzzle here worthy of systematic investigation.

The puzzle may be stated concisely. Moodle, which remains by a considerable margin the dominant LMS in Central European tertiary education (Turnbull, Chugh, & Luck, 2023; Bond, Bedenlier, Marín, & Händel, 2021), constitutes a remarkably capable piece of software. Its plugin architecture accommodates well over 2,000 community-developed extensions. It implements the Learning Tools Interoperability (LTI) standard, thereby enabling seamless integration with external applications. Its database schema, while not entirely free of idiosyncrasies, is thoroughly documented and readily extensible. It supports xAPI (Experience API) for granular learning event tracking, SCORM and cmi5 for content packaging, OAuth 2.0 and SAML for authentication federation, and a REST/GraphQL web services layer for programmatic access. Considered in architectural terms, Moodle is an interoperability exemplar—an open-source platform designed, from its foundational architecture upward, to interface productively with other systems.

And yet. Enter almost any higher education institution in Serbia, Croatia, Hungary, Slovakia, or the Czech Republic, and what one will typically encounter is Moodle operating as an isolated island: disconnected from the student information system, disconnected from the institutional authentication directory, disconnected from the library catalogue, disconnected from the video management platform, and very frequently disconnected from any coherent analytics pipeline (Ivanović & Putnik, 2022). The platform's interoperability features are present yet dormant. The architecture is capable yet underutilised. The system functions, in the narrow sense that it serves pages and accepts file uploads, but it does not *integrate*. It occupies, as it were, the centre of the institutional IT landscape, connected to nothing, communicating with no one.

It is this phenomenon that we designate the LMS infrastructure paradox, and it constitutes the subject of the present paper. Our purpose is threefold. First, we map the current state of LMS deployment in Central European tertiary institutions, drawing upon the available



literature and our own institutional experience at a vocational college in Subotica, Serbia. Second, we examine the technical, institutional, and governance factors that sustain the paradox, inquiring why capable platforms consistently produce incapable ecosystems. Third, we propose an Integrative Architecture Framework—a set of design principles intended to guide Central European institutions toward LMS deployments that exploit, rather than disregard, the platforms' native interoperability capabilities.

A note on scope is warranted at this juncture. The present paper is concerned with the IT infrastructure dimension of LMS deployment rather than with pedagogy or learning design per se. The pedagogical questions are important—vitaly so—but they have been extensively treated in the literature (Chapelle, 2023; Harmer, 2023; Motteram, 2023). What has received rather less sustained attention, particularly within the Central European context, is the unglamorous yet consequential matter of systems integration: the plumbing, if one will forgive the metaphor, that determines whether a Learning Management System operates as a living component of an institutional digital ecosystem or as an expensive, isolated web application. It is this plumbing that concerns us here. Our team's composition reflects this orientation: we bring together expertise in mathematical sciences and analytics modelling, computer science and systems architecture, industrial automation and project engineering, instructional design and multimedia educational technology, and applied linguistics and educational technology—a combination that, we venture to hope, permits examination of the paradox from perspectives that a more disciplinarily homogeneous team might overlook.

## **THE CURRENT STATE OF LMS INFRASTRUCTURE IN CENTRAL EUROPE**

To comprehend the paradox, it is first necessary to understand the landscape in which it arises. What does LMS deployment actually look like across Central European tertiary institutions? The picture that emerges, as we shall demonstrate, is simultaneously encouraging and deeply frustrating.

### ***Adoption: The Encouraging Dimension***

LMS adoption across Central European higher education is, by any reasonable measure, extensive. Moodle dominates the regional landscape, with deployment rates exceeding 80% in Serbian, Croatian, and Hungarian higher education institutions (Ivanović & Putnik, 2022; Dlab, Botički, Hoić-Božić, & Lovrenca, 2020). The COVID-19 pandemic accelerated adoption dramatically, converting even the most reluctant holdouts to some form of online platform engagement (Marinoni, van't Land, & Jensen, 2020; Bozkurt et al., 2022). By 2022, it had become exceedingly difficult to identify a tertiary institution in the region without a Moodle



instance—or, less commonly, a Canvas, Microsoft Teams, or Google Classroom deployment—in active use.

At our own institution, the College of Vocational Studies for the Education of Preschool Teachers and Sports Trainers in Subotica (VŠSSOVIT), Moodle has been operational since the early 2010s and received substantial investment in content development and course design during the pandemic transition. The platform is actively employed across study programmes, ranging from preschool teacher education to sports training to, more recently, the business informatics programme introduced in the 2021/2022 academic year and subsequently accredited for additional locations including Novi Sad. Assessed by the metric of adoption alone, the narrative is one of unqualified success.

### ***Integration: The Problematic Dimension***

The difficulty emerges the moment one looks beneath the adoption statistics and poses a straightforward technical question: to what is the Moodle instance connected?

In the majority of Central European institutions, the answer is: remarkably little. A survey of Serbian higher education IT infrastructure conducted by Stojanović and Mitić (2021) found that fewer than 15% of institutions had implemented Single Sign-On (SSO) integration between their LMS and student information system. LTI integrations with external tools were present in fewer than 20% of deployments. Automated grade passback from the LMS to the institutional records system was rare. Learning analytics pipelines—collecting xAPI or Caliper data from the LMS and routing it to an analytics platform for meaningful institutional insight—were essentially nonexistent outside a small number of research-intensive universities.

The pattern is remarkably consistent across the region. Dlab et al. (2020) reported analogous findings for Croatian institutions. Csibi and Papp (2021) documented comparable deficiencies in Hungarian polytechnics. Hrmo, Mikuš, and Tuček (2022) observed the same systemic disconnect in Slovak technical universities. The institutional specifics vary—some institutions have achieved SSO but not LTI; others have implemented partial grade passback but lack analytics—yet the overall picture is strikingly uniform: Moodle deployed, Moodle utilised, Moodle isolated.

At VŠSSOVIT, our own experience mirrors this regional pattern with considerable fidelity. Despite possessing in-house IT expertise sufficient to develop custom student web applications and maintain multiple production systems, our Moodle instance has, until recently, operated with minimal integration into the broader institutional IT infrastructure. Student authentication was handled locally rather than through federated identity management. Grade data was exported through manual processes. Analytics consisted of whatever Moodle's native



reporting could furnish, which is to say: activity logs of limited analytical utility. We possessed, in short, a capable platform performing unremarkable work.

## **THE PARADOX EXAMINED: FIVE CONTRIBUTING FACTORS**

Why does this situation persist? Why do technically sophisticated institutions deploy technically capable platforms and then systematically disregard their integration capabilities? Having conducted a thorough review of the literature and reflected extensively upon our own institutional experience, we propose that five interlocking factors sustain the paradox.

### ***1. The Installation-as-Completion Fallacy***

The first factor is cognitive in nature: the widespread institutional assumption that installing the LMS constitutes the terminus of the implementation process rather than its commencement. In software engineering, deployment is understood as one phase within a lifecycle that encompasses configuration, integration, testing, iteration, and ongoing maintenance (Sommerville, 2020). In Central European higher education IT practice, deployment is frequently treated as the conclusion. The Moodle instance is installed, a system administrator is designated (often as one responsibility among many), courses are created, and the project is considered complete.

This is, upon reflection, a rather extraordinary manner in which to treat an enterprise-grade application. No organisation would install an ERP system—SAP, for instance, or Oracle—and consider the project concluded before the system was integrated with finance, human resources, procurement, and reporting functions. Yet this is precisely what transpires with LMS deployments across the region, routinely and without evident discomfort. The LMS is treated not as enterprise software requiring integration but as a web application requiring hosting. The distinction, we would submit, matters enormously.

### ***2. The Skills-Architecture Mismatch***

The second factor is technical: a fundamental mismatch between the skills required for LMS integration and those available within institutional IT departments. Configuring Moodle's LTI consumer to interoperate with an external tool provider demands knowledge of OAuth signatures, tool configuration URLs, resource link parameters, and grade passback protocols. Implementing SAML-based SSO requires an understanding of identity providers, service providers, metadata exchange, and assertion attributes. Constructing an xAPI learning analytics pipeline necessitates familiarity with Learning Record Stores, statement structure, activity ontologies, and data visualisation tooling.



These are not esoteric skills—they constitute standard competencies in enterprise IT. However, Central European tertiary institutions, particularly smaller colleges and polytechnics, frequently staff their IT operations with personnel whose expertise resides in system administration and network management rather than in application integration and API-level interoperability (Grajek & Reinitz, 2022). The consequence is a skills gap that sits precisely at the juncture where the LMS's integration capabilities require activation. The platform possesses the capability; the institution's IT team, through no fault of their own, frequently does not.

This observation is not intended as a criticism of the individuals concerned—our own IT journey at VŠSSOVIT has taught us a great deal about the distance between knowing that Moodle supports LTI 1.3 and knowing how to make LTI 1.3 function reliably in a production environment with a particular constellation of external tools. The gap is real, and pretending otherwise serves no constructive purpose.

### ***3. The Funding Asymmetry***

The third factor is financial. In Central European higher education, funding for educational technology characteristically follows a boom-and-bust pattern tied to project cycles—European Structural Funds, national digitisation initiatives, Erasmus+ programmes, or, most recently, pandemic emergency funding (Marinoni et al., 2020; European Commission, 2022). These funding mechanisms are well-suited to initial acquisition—hardware procurement, software licensing, initial deployment—and poorly suited to the ongoing, unglamorous work of integration, maintenance, and iterative refinement.

The asymmetry is structural in character. A ministry will fund the deployment of Moodle across a university system; it will not fund the two-year process of integrating Moodle with the student information system, the authentication directory, the library catalogue, and the analytics platform. The former constitutes a project with a clear deliverable and a photogenic launch event; the latter constitutes a process with no obvious terminus and no ribbon to cut. Within the logic of Central European higher education funding, capital expenditure is fundable; recurrent integration work is not. The LMS is installed because resources exist to install it; it remains unintegrated because resources to integrate it are absent.

### ***4. The Governance Vacuum***

The fourth factor is organisational: the absence of coherent IT governance structures capable of assigning responsibility for LMS integration and holding accountable parties answerable for its outcomes. In many Central European institutions, the LMS occupies a governance no-man's-land between the IT department (which manages the server



infrastructure), the e-learning centre (which supports instructional staff), and the academic administration (which owns the student data). None of these units possesses unambiguous authority over the integration agenda, and none has clear incentives to pursue it.

Weill and Ross (2004), in their influential framework for IT governance in higher education, argued that effective technology governance demands clear decision rights, accountability structures, and alignment mechanisms. In the Central European institutional context, these structures are frequently absent or, where they nominally exist, oriented toward procurement and budgetary oversight rather than toward architectural coherence and systems integration. The consequence is that integration decisions—or, more precisely, the decision *not* to integrate—are made by default rather than by deliberate design.

We have witnessed this governance vacuum at first hand. At VŠSSOVIT, the establishment of formal quality assurance commissions, accreditation committees, and departmental leadership structures for the Business Informatics programme created an institutional infrastructure that *could* in principle support integration governance—yet the connection between academic governance and IT architecture governance was not, initially, rendered explicit. The committees reviewed curricula and staffing; no one reviewed the integration architecture. This was not negligence; it was simply a lacuna that the prevailing governance vocabulary lacked the conceptual resources to articulate.

### **5. The Interoperability Standards Knowledge Gap**

The fifth factor is epistemic: a widespread deficit of awareness, even among IT professionals operating within the sector, regarding the interoperability standards that modern LMS platforms support and the practical possibilities those standards create. LTI, xAPI, Caliper, SCORM, cmi5, QTI, OneRoster, SIF, Ed-Fi—the landscape of educational technology interoperability standards is, it must be conceded, formidable. The standards are promulgated by different organisations (1EdTech, formerly IMS Global; ADL; CEDS), documented at varying levels of accessibility, and implemented with varying degrees of fidelity across platforms (Griffiths, Brasher, Clow, Ferguson, & Yuan, 2023).

For an IT professional at a Central European college—an individual who may bear simultaneous responsibility for the network, the servers, the email system, the student database, and the LMS—the prospect of mastering this standards landscape is, understandably, daunting. The consequence is that interoperability features remain dormant not because they have been evaluated and found wanting but because they have never been subjected to serious consideration. The LMS's integration capabilities are, in practical effect, invisible to the very individuals charged with the LMS's operation.



## TOWARD AN INTEGRATIVE ARCHITECTURE FRAMEWORK

If the paradox is sustained by the five factors delineated above, then its resolution requires an approach that addresses all five in a coordinated manner. What we propose here is not a technical manual—though the principles carry technical implications—but a strategic framework for institutional decision-makers, IT leaders, and LMS administrators seeking to effect a transition from isolated deployment to integrated ecosystem. We designate this the Integrative Architecture Framework (IAF), and it comprises five principles.

### *Principle 1: Integration as a First-Class Requirement*

The first principle directly challenges the installation-as-completion fallacy: LMS integration with institutional systems must be specified as a first-class requirement from the inception of any deployment or major upgrade, rather than deferred as a future enhancement. In practical terms, this entails that the deployment project plan includes, from its first iteration, deliverables for SSO integration, SIS grade passback, and, at minimum, a foundational analytics data pipeline. The principle does not demand that all integrations be completed concurrently; it demands that they be *planned* concurrently and resourced commensurately.

Operationally, this translates to an institutional Moodle deployment that incorporates, at minimum: LDAP or SAML authentication integration with the institutional identity provider; automated enrolment synchronisation with the student information system; LTI 1.3 configuration for at least one external tool (such as a plagiarism detection service, a video platform, or an interactive content tool such as H5P); and xAPI event forwarding to a Learning Record Store, even where the analytics layer remains under development. These are not aspirational targets; they are achievable technical milestones that exploit capabilities the platform already possesses.

### *Principle 2: The Minimum Viable Ecosystem*

The second principle addresses the tendency toward paralysis induced by all-or-nothing thinking. Rather than attempting to construct a fully integrated digital ecosystem within a single project—an approach that is costly, high-risk, and frequently abandoned—institutions should define and implement a Minimum Viable Ecosystem (MVE): the smallest set of integrations capable of delivering a qualitative improvement in the experience of students and staff alike.

For the majority of Central European institutions, the MVE comprises three integrations: authentication (SSO), ensuring that students and staff authenticate once; enrolment synchronisation, ensuring that course memberships are managed automatically; and grade passback, ensuring that assessment results flow from the LMS to the student record



without manual intervention. These three integrations, taken in combination, eliminate the most consequential inefficiencies of the isolated LMS—duplicate credentials, manual enrolment, manual grade transcription—and establish the technical foundation upon which further integrations may be constructed incrementally.

This is, we believe, a point warranting particular emphasis. The perfect ought not to serve as the enemy of the good. An institution that successfully implements SSO and automated enrolment has achieved something of genuine significance, even where its analytics pipeline remains a prospective undertaking. The objective is not perfection but *momentum*: the establishment of integration as a sustained institutional practice rather than a discrete, time-bounded project.

### ***Principle 3: Standards-First Integration***

The third principle addresses the interoperability standards knowledge gap: all integrations should employ established open standards (LTI, xAPI, SAML, OAuth 2.0, OneRoster) wherever practicable, with proprietary or bespoke integrations treated as a measure of last resort. This stance reflects not merely an ideological preference for open standards—though we freely acknowledge such a preference—but a pragmatic strategy for minimising long-term maintenance burden and preserving institutional flexibility.

A custom PHP script that extracts grades from Moodle’s database and inserts them into the SIS functions, in the immediate term, just as effectively as a properly implemented LTI Advantage grade passback configuration. The custom script, however, is inherently fragile: it fails when Moodle upgrades its database schema, it requires institutional knowledge of both systems’ internals, and it generates a maintenance obligation of indefinite duration. The standards-based integration, by contrast, benefits from the support of both platforms’ development communities, survives version transitions, and can be maintained by any professional conversant with the standard. Within the resource-constrained environment characteristic of Central European tertiary education, this distinction is not academic; it is existential.

### ***Principle 4: Distributed Ownership, Centralised Architecture***

The fourth principle addresses the governance vacuum: integration architecture decisions should be centralised—vested in a cross-functional body possessing clear authority—while integration *implementation* may be distributed across organisational units in accordance with their respective expertise. The IT department configures authentication integration; the e-learning centre configures LTI tool connections; the academic administration specifies enrolment and grade synchronisation requirements; the quality assurance commission defines



analytics reporting requirements. The overarching architectural decisions—which standards to adopt, which systems to interconnect, which data to exchange—are, however, made collectively and documented in an institutional integration architecture document that serves as the authoritative reference for all stakeholders.

This principle draws upon the IT governance literature (Weill & Ross, 2004; EDUCAUSE, 2023) while adapting its prescriptions to the realities of smaller Central European institutions where dedicated enterprise architecture roles are uncommon. The cross-functional body need not be substantial—at an institution of our dimensions, four to five individuals convening monthly would suffice—but it must exist, it must possess genuine authority, and its determinations must be documented and observed.

### ***Principle 5: Analytics as Architecture, Not Afterthought***

The fifth principle addresses what we regard as the most consequential missed opportunity in contemporary Central European LMS deployments: learning analytics. The data generated by an LMS—login patterns, content access sequences, assessment performance trajectories, forum participation metrics, assignment submission temporality—is, in principle, of enormous value for institutional decision-making, early intervention mechanisms, and quality assurance processes (Tsai, Rates, Moreno-Marcos, Muñoz-Merino, Jivet, Scheffel, Drachsler, Delgado Kloos, & Gašević, 2023; Ferguson & Clow, 2022). In practice, these data are almost never collected in a structured, analytically tractable form.

The IAF conceptualises the analytics pipeline not as a future enhancement but as a core architectural component. At minimum, this entails configuring xAPI event forwarding from the LMS to a Learning Record Store (Learning Locker, Veracity, or a cloud-hosted alternative), defining an institutional activity ontology that maps Moodle events to meaningful learning activities, and establishing a foundational reporting layer—even where initial reports take the form of basic dashboards rather than sophisticated predictive models.

A mathematical perspective proves instructive at this juncture. One of us (Nikolić) has proposed modelling institutional analytics maturity as a function of integration depth, and we find this a clarifying exercise. If one defines an institution's Analytics Readiness Index (ARI) as a composite score across four dimensions—data collection infrastructure, data integration breadth, analytical capability, and governance maturity—then the paradox institutions we have described cluster at the lower bound of the first dimension and score near zero on the remaining three. The MVE, as specified in Principle 2, is engineered to elevate performance on dimensions one and two; Principles 4 and 5 address dimensions three and four respectively. The model does not, naturally, capture every nuance of institutional reality, but it furnishes a



useful diagnostic vocabulary: an institution can locate itself along the ARI dimensions and identify with some precision where the primary bottleneck resides.

The underlying principle bears reiteration: data collection infrastructure must be established early, even where analytical capability develops subsequently. Data that are not collected cannot be analysed retrospectively. This is a point that merits emphasis, for the temptation to defer analytics infrastructure until “we have determined what questions we wish to ask” is powerful and, in our experience, nearly universal. The questions will materialise; the data, if not collected, will not.

## **A CASE IN PROGRESS: VŠSSOVIT, SUBOTICA**

We include this section not as a success narrative—it is premature for that—but as a candid account of one institution’s attempt to apply the IAF principles in practice. The College of Vocational Studies for the Education of Preschool Teachers and Sports Trainers in Subotica is, in many material respects, representative of the institutions that the paradox describes: a mid-sized Serbian vocational college with an active Moodle deployment, a small but technically capable IT team, and a history of isolated platform utilisation.

The introduction of the Business Informatics study programme in 2021/2022 served as both catalyst and resource for integration work. The programme’s accreditation—a process in which several of the present authors were directly involved—brought to the faculty individuals possessing deep expertise in systems architecture, database design, mathematical modelling, and software engineering—precisely the competencies that the second factor of the paradox (the skills-architecture mismatch) identifies as critical. The subsequent accreditation of the programme’s extension to Novi Sad in 2024 further expanded the institutional constituency with a professional stake in integrated IT infrastructure. Equally important, the establishment of a dedicated Study Council for Business Informatics, with formal leadership and regular coordination, created the species of governance infrastructure that Principle 4 advocates, even though its initial mandate was academic rather than architectural.

Work is presently underway on four of the five IAF principles. Authentication integration via LDAP is in pilot testing. A custom student web application, developed in-house, has been designed with API endpoints intended to support automated enrolment synchronisation with Moodle. An initial xAPI event forwarding configuration is being prototyped, with Learning Locker as the target LRS. A preliminary Analytics Readiness Index assessment has been conducted, identifying data collection and integration breadth as the principal bottlenecks—a finding that accords with the framework’s predictions and has usefully concentrated the team’s priorities.



The governance dimension—Principle 4—has been addressed through a combination of formal and informal mechanisms. The Study Council for Business Informatics, the institutional quality assurance commission, and the Erasmus+ project coordination team have each contributed elements of integration governance, although a unified, formally constituted cross-functional architecture governance body has not yet been established. It is worth observing that the institution's considerable international research network—cultivated in no small part through the Horizonti interdisciplinary conferences and through extensive Erasmus+ project partnerships with institutions in Belgium, Austria, Greece, Poland, and Romania—represents an underexploited resource for benchmarking integration practices against those of peer institutions elsewhere in Europe. One of us (Hilčenko), through his editorial leadership of the Horizonti conferences and his advisory roles with international organisations including the International Community for Open Education at Beijing Normal University, has observed that the paradox we describe in the Serbian context is recognised, if not invariably named, by colleagues across the continent. The problem, in other words, is not parochial; but neither, we venture to hope, is the solution.

We report these developments in the spirit of honest practice rather than polished achievement. The work is ongoing, the challenges are genuine, and the outcomes remain uncertain. What we can affirm with a degree of confidence is that the IAF principles have furnished a useful strategic vocabulary for internal discussions that previously lacked a coherent framework: conversations concerning what to integrate, in what sequence, employing which standards, and under whose authority. That, in itself, represents a not insignificant advance over the pre-framework state of affairs, in which integration was not so much rejected as simply never discussed.

## **DISCUSSION**

The Integrative Architecture Framework advanced in this paper is, we are the first to acknowledge, more demanding than some institutions may find comfortable. It calls for resources that are scarce, skills that are unevenly distributed, and governance structures that do not yet exist in many Central European tertiary institutions. These are not trivial objections, and we do not treat them as such.

We would, however, offer two responses. First, the alternative—persisting in the deployment of capable platforms within incapable configurations—is not merely unsatisfying but actively wasteful. Every institution that operates an isolated Moodle instance bears the full cost of hosting, maintaining, and administering an enterprise application while deriving only a fraction of its potential value. The paradox is not without cost; it represents a systematic under-



return on institutional IT investment. In a region where higher education budgets are perennially constrained, this chronic under-return constitutes a matter of genuine concern.

Second, the IAF is explicitly designed to accommodate incremental implementation. The Minimum Viable Ecosystem concept—Principle 2—exists precisely to lower the threshold for initial engagement. An institution that achieves SSO and automated enrolment has addressed the two most consequential integration deficits at comparatively modest cost. The remaining principles may be pursued as resources permit, over timescales calibrated to institutional capacity.

A broader theoretical observation is warranted at this stage. The LMS infrastructure paradox, as we have characterised it, may be understood as a specific instantiation of a more general phenomenon in organisational IT: the gap between *tool capability* and *organisational capability*. This gap has been extensively theorised in the information systems literature (Orlikowski, 2000; DeSanctis & Poole, 1994; Leonardi, 2013) under the conceptual rubrics of structuration theory, adaptive structuration theory, and sociomateriality. Our contribution consists in documenting this gap within the specific context of LMS deployment in Central European tertiary education and in proposing a domain-specific framework for its amelioration.

The interdisciplinary composition of our research team has, we believe, constituted an asset in this endeavour. The mathematical modelling perspective contributed by Nikolić—the Analytics Readiness Index, the diagnostic scoring framework—furnishes a formal vocabulary that complements the qualitative, narrative analysis of institutional factors. The systems architecture expertise brought by Cvetković and Ličina grounds the framework’s technical recommendations in practical implementability. Hilčenko’s extensive experience in instructional design, multimedia educational technology, and international research collaboration—including his editorial leadership of the Horizonti conferences and his engagement with the International Community for Open Education—contributes a critical perspective on the intersection of integration architecture with content design and open educational resources. The applied linguistics and educational technology perspective contributed by Medić ensures that the framework’s integration principles remain anchored to the educational purposes that constitute the LMS’s *raison d’être*. We note this not to commend ourselves but to advance a methodological argument: the LMS infrastructure paradox is a genuinely interdisciplinary problem, and its investigation benefits materially from genuinely interdisciplinary teams.

A further dimension of the paradox warrants attention in this connection. The LMS infrastructure discussion has, understandably, concentrated on data plumbing—authentication, enrolment, grade passback, analytics. However, the integration of multimedia instructional content and open educational resources (OER) raises its own distinctive set of architectural



challenges. SCORM and cmi5 content packages, H5P interactive modules, educational animations, and multimedia instructional design objects all require standards-compliant packaging, metadata tagging, and repository management if they are to be shared, reused, and tracked across institutional systems. At VŠSSOVIT, where the development of didactic multimedia materials and educational software possesses a long institutional history—encompassing scientific monographs on instructional design, animated educational films, and didactic method manuals—these content assets exist in considerable abundance but have not, until recently, been managed through standards-compliant content repositories integrated with the LMS. The content is valuable; the infrastructure to manage and track its utilisation is not yet in place. This constitutes, in microcosm, the very paradox we have been articulating: capable assets, underconnected architecture.

There is, finally, a temporal dimension to the paradox that merits consideration. The accelerating integration of artificial intelligence capabilities into LMS platforms—AI-assisted content generation, automated feedback provision, predictive analytics, adaptive learning pathways—renders the integration imperative more urgent, not less (Zawacki-Richter, Marín, Bond, & Gouverneur, 2023). AI features are data-intensive; they perform optimally when supplied with rich, contextualised data drawn from multiple institutional sources. An isolated LMS, constrained to its limited local data, is poorly positioned to exploit these capabilities. An integrated LMS, connected to the student information system, the library infrastructure, and a structured analytics pipeline, is well positioned to do so. The institutions that resolve the infrastructure paradox in the present period will be those best equipped to derive benefit from the next generation of educational technology. Those that do not may find the gap widening rather than contracting.

## **IMPLICATIONS FOR PRACTICE AND RESEARCH**

For institutional IT leaders across Central Europe, the primary implication of this analysis is that LMS integration warrants the same degree of strategic attention presently accorded to LMS adoption. The adoption question has been substantially resolved; the integration question has scarcely been posed. We would urge institutional leaders to commission integration audits of their LMS deployments: systematic assessments identifying which interoperability capabilities are active, which remain dormant, and what the institutional cost of that dormancy amounts to in terms of staff time, data quality, and analytical capability.

For LMS administrators and IT professionals, the implication is that investment in interoperability standards knowledge—LTI 1.3, xAPI, SAML, OAuth 2.0—represents perhaps the highest-leverage professional development currently available. The distance between a system administrator capable of installing Moodle and an integration architect capable of



connecting Moodle to an institutional ecosystem is the precise distance that sustains the paradox. Closing this gap is a matter of targeted competency development, not wholesale organisational transformation.

For quality assurance commissions and academic governance bodies, the implication is that IT architecture belongs on the governance agenda. Accreditation processes routinely evaluate curricula, staffing ratios, and physical facilities; they seldom evaluate the integration architecture of the digital learning environment. Incorporating integration maturity into quality assurance frameworks—employing a diagnostic instrument such as the Analytics Readiness Index or a comparable tool—would generate institutional incentives for integration that are currently absent.

For the research community, the paradox opens several productive lines of inquiry. Quantitative surveys documenting the precise state of LMS integration across Central European institutions would provide the empirical baseline that the field currently lacks. Comparative case studies contrasting institutions that have achieved meaningful integration with those that have not would illuminate the enabling conditions and barriers in institutional terms. Design-based research developing and evaluating integration architectures for specific institutional profiles—small vocational colleges, mid-sized polytechnics, large research universities—would contribute directly to the practical repertoire available to institutional leaders. Formal mathematical modelling of the relationship between integration maturity and measurable institutional outcomes—student retention, administrative efficiency, analytics capability—would furnish the evidence base required for informed investment decisions.

## CONCLUSION

We commenced this paper with a puzzle: why do Central European tertiary institutions deploy technically capable Learning Management Systems and then systematically fail to exploit their integration capabilities? We have argued that the answer resides not in any single factor but in the interaction of five: the installation-as-completion fallacy, the skills-architecture mismatch, funding asymmetries, governance vacuums, and interoperability standards knowledge gaps. Taken collectively, these factors engender a self-reinforcing cycle in which isolated deployment becomes normalised, integration is perpetually deferred, and the platform's full potential remains unrealised.

The Integrative Architecture Framework we have proposed offers, we trust, a principled pathway out of this cycle. Its five principles—integration as a first-class requirement, the minimum viable ecosystem, standards-first integration, distributed ownership with centralised architecture, and analytics as architecture—are designed to be implementable incrementally,



within the resource constraints that Central European institutions actually confront. They constitute not a counsel of perfection but a counsel of strategic pragmatism.

Our own experience at VŠSSOVIT suggests that progress is achievable, if uneven and incomplete. The paradox is not destiny. Institutions that recognise it, name it, and commit to addressing it—however incrementally—can begin to close the gap between platform capability and ecosystem reality. The technology is ready. The standards exist. The architectural possibilities are thoroughly documented. What has been missing, we submit, is the strategic intentionality to act upon them. We hope this paper contributes, in however modest a measure, to supplying that missing ingredient.

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