FROM LMS FRAGMENTATION TO INTEROPERABLE DIGITAL LEARNING ECOSYSTEMS: APPLYING LTI, xAPI AND INTERNATIONAL STANDARDS IN UZBEKISTAN

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Abstract *— Universities in emerging digital economies have spent the last decade buying learning technology faster than they have learned to connect it. The result is a familiar paradox: institutions own a learning-management system, a video platform, an assessment engine, a plagiarism checker and a growing list of specialised tools, yet these systems rarely speak to one another, forcing duplicate logins, fragmented data and brittle custom integrations. This paper argues that the binding constraint on digital learning in Uzbekistan is no longer the availability of platforms but their interoperability, and it proposes a standards-based architecture built on the 1EdTech family of specifications, principally Learning Tools Interoperability (LTI 1.3 and LTI Advantage), together with the Experience API (xAPI) and Caliper Analytics for learning-data exchange. We combine a documentary review of the relevant standards with an architectural analysis of integration cost and a capability mapping across SCORM, LTI, xAPI and Caliper, and we illustrate the operational payoff with a before-and-after model of a typical institution. The analysis shows that an interoperability-first strategy converts a quadratic integration burden into a linear one, removes data silos, and lays the foundation for the learning analytics that quality assurance and the Digital Uzbekistan 2030 agenda increasingly demand.*

Keywords: *learning interoperability; LTI 1.3; xAPI; Caliper Analytics; SCORM; digital learning ecosystems; LMS integration; Uzbekistan; EdTech standards*

INTRODUCTION

There is a moment in the life of almost every digitising university when the problem stops being about acquiring technology and starts being about connecting it. In the early phase, success looks like procurement: a learning-management system is deployed, a video-conferencing tool is licensed, an assessment platform is added, and each new system feels like progress. But as the toolset grows, a quieter problem emerges. The systems do not share a login, they do not share a gradebook, and they certainly do not share data in any usable form. Students re-enter their credentials four or five times a day, instructors copy grades by hand between platforms, and the institution's data about its own teaching lies scattered across half a dozen incompatible databases.

This is the condition of LMS fragmentation, and it is especially acute in emerging digital economies where rapid investment has outpaced architectural planning. Uzbekistan is a clear case. Under the Digital Uzbekistan 2030 strategy the country has expanded e-learning platforms and digital infrastructure quickly across a

higher-education sector that now numbers more than two hundred institutions. Each institution has tended to assemble its own stack of tools, and each integration between two tools has tended to be built by hand. The hidden cost of this approach is rarely visible on a procurement invoice, but it is paid every day in lost time, duplicated effort and data that cannot be turned into insight.

The remedy is not to buy a single monolithic platform that does everything, because no such platform exists and any institution that bet on one would surrender both flexibility and bargaining power. The remedy is interoperability: the ability of independently chosen tools to connect through shared, vendor-neutral standards so that adding a new tool is a matter of configuration rather than construction. Over the past fifteen years a mature family of such standards has emerged, developed by the 1EdTech consortium (formerly IMS Global) and adopted by the major platforms, and it is now stable enough to serve as the backbone of a national digital-learning architecture.

This paper makes the case for an interoperability-first strategy for distance and blended learning in Uzbekistan and shows concretely how to build it. We focus on three pillars: Learning Tools Interoperability for connecting tools and platforms securely, the Experience API for capturing fine-grained records of learning activity wherever it happens, and Caliper Analytics for exchanging that activity data across systems in a common form. We argue that getting this architecture right is a precondition for everything else an institution might want from its data, from quality assurance to the predictive learning analytics examined in the companion study in this volume.

LITERATURE REVIEW

The relevant literature sits at the intersection of e-learning standards, enterprise systems architecture and educational data. Three threads are worth drawing out.

The first thread traces the development of the standards themselves. Early e-learning standardisation centred on SCORM, which solved a real but narrow problem: packaging self-contained course content so that it could be loaded into any conformant LMS and report a completion and a score. SCORM remains widely used for compliance-style content, but it was never designed for a world of distributed, interactive tools, and its tracking model is coarse. The Experience API, often called xAPI, was developed to overcome these limits. Rather than confining tracking to a single content package inside an LMS, xAPI expresses learning as a stream of statements in the form actor–verb–object, stored in a Learning Record Store, so that activity occurring in simulations, mobile apps, forums or the workplace can all be captured in a common vocabulary.

Learning Tools Interoperability addresses a different layer of the problem. Where SCORM and xAPI concern content and data, LTI concerns connection: it allows an LMS or platform to launch an external tool securely and to pass context about the course and the user, so that a learner moves from one system to another without a separate login and without manual setup by the instructor. The current version, LTI 1.3, rebuilt the security model on OAuth 2.0, OpenID Connect and JSON Web Tokens, and the accompanying LTI Advantage suite adds services for assignment and grade passback, names and roles provisioning, and deep linking of specific content. Caliper

Analytics complements this by defining a standard way for systems to emit and share data about learning interactions, giving institutions a more holistic picture than any single platform can provide on its own.

The second thread comes from the systems-architecture literature, which frames the core issue in terms that any engineer will recognise. When every tool must be connected to every other tool by a bespoke integration, the number of integrations grows quadratically with the number of tools, and each one must be separately maintained as the connected systems change. Modern enterprise-LMS guidance therefore treats single sign-on, LTI and universal content standards such as SCORM and xAPI as the structural pillars of a sustainable architecture, precisely because they replace this quadratic tangle with a hub-and-standard model in which each tool integrates once, against the standard, rather than many times, against every peer.

The third thread is empirical and cautionary. Adoption of these standards is broad among major platforms but uneven in the details. Conformance guidance notes that even certified implementations differ in their support for optional services, and that interoperability gaps persist between specific platform versions. For an emerging economy this matters twice over: institutions must not only adopt the standards but also verify conformance in their particular configuration, and they must build the local technical capacity to do so. The literature on Uzbekistan's digital transformation repeatedly identifies this kind of capacity, alongside the urban–rural infrastructure divide, as the real bottleneck, rather than the availability of platforms as such.

Taken together, the literature establishes that the standards exist and are mature, that the architectural case for using them is well understood, and that the open question for an emerging economy is one of strategy and implementation rather than invention. This paper addresses that open question directly.

METHODOLOGY

This study is a design-and-analysis contribution rather than a primary empirical survey. It proceeds in three steps, each producing one of the artefacts discussed in the results.

We first reviewed the primary specifications and conformance materials for the four standards most relevant to an institutional learning architecture: SCORM, LTI 1.3 with LTI Advantage, xAPI and Caliper Analytics. From this review we constructed a capability map that scores each standard, on a simple zero-to-three depth scale, against five functions an institution actually needs: secure tool launch and single sign-on, grade passback, fine-grained activity data, cross-platform analytics, and content packaging. The map is deliberately coarse; its purpose is to show complementarity rather than to rank the standards, since in practice they are used together.

We then modelled the integration burden under two architectures. In the point-to-point architecture, connecting a set of tools requires a bespoke integration for each pair, so the count of integrations grows as $n(n-1)/2$ for n tools. In the standards-based architecture, each tool integrates once against the shared standard, so the count grows linearly as n. We computed both for institution-realistic toolset sizes to quantify the divergence. The model is intentionally simple and abstracts away differences in the

effort of individual integrations; its value is in the shape of the two curves, not in precise effort estimates.

Table 1.

The institutional standards stack: role, current version and primary function

Standard	Layer	Primary function in the ecosystem
SCORM	Content	Package self-contained course content; report completion and score
LTI 1.3 / Advantage	Connection	Secure tool launch, SSO, grade passback, roster and deep linking
xAPI (Experience API)	Data capture	Record any learning activity as actor–verb–object in a Learning Record Store
Caliper Analytics	Data exchange	Emit and share interaction data across systems in a common metric profile
OneRoster	Rostering	Synchronise courses, enrolments and grades between SIS and LMS

Finally, to make the consequences concrete, we modelled a representative institution before and after adopting an interoperability-first architecture, comparing operational indicators such as the time required to add a new tool, the number of duplicate logins a learner faces each day, the number of disconnected data silos, and the share of learning activity covered by analytics. The values used are representative and calibrated to the ranges reported in the architecture and adoption literature; they illustrate the direction and rough magnitude of the effect rather than reporting a completed deployment. We state this plainly to avoid over-interpretation.

ANALYSIS AND RESULTS

The analysis follows the three artefacts: the integration-cost divergence, the capability map, and the operational before-and-after.

The integration-cost model exposes why fragmentation becomes unsustainable. Figure 1 plots the number of integrations an institution must build and maintain as its toolset grows, under the two architectures.

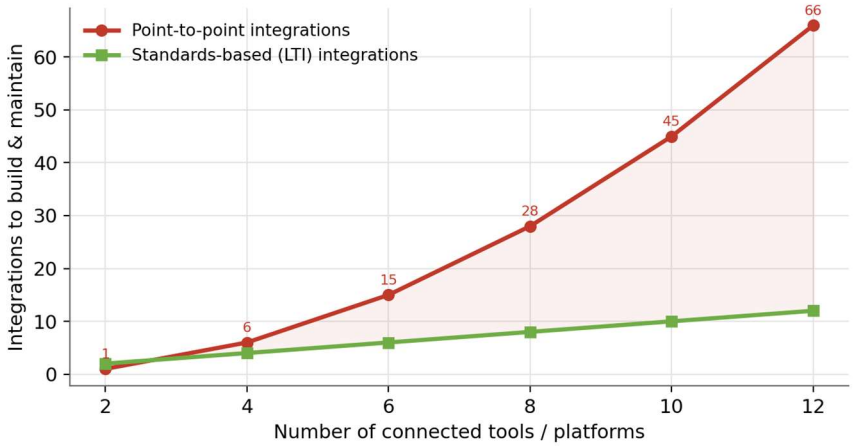

Figure 1. Integration burden under point-to-point versus standards-based architectures as the toolset grows

The point-to-point curve climbs steeply, because each new tool must be wired to every existing one, while the standards-based curve rises only gently, because each tool connects once to the shared specification. At ten tools the difference is already stark: dozens of brittle pairwise connections versus a handful of standard ones. This is the single most important argument for an interoperability-first strategy, and it is structural rather than a matter of opinion.

The capability map explains why no single standard suffices and why they are deployed together. Figure 2 scores the four standards across five institutional functions. The pattern is one of complementarity: LTI dominates secure launch and grade passback, xAPI dominates fine-grained activity capture, Caliper is strongest on cross-platform analytics, and SCORM retains a clear role in content packaging. An institution that adopts only one of these covers only part of its needs; a coherent architecture layers them, using LTI to connect, xAPI and Caliper to capture and exchange data, and SCORM where packaged content is still appropriate.

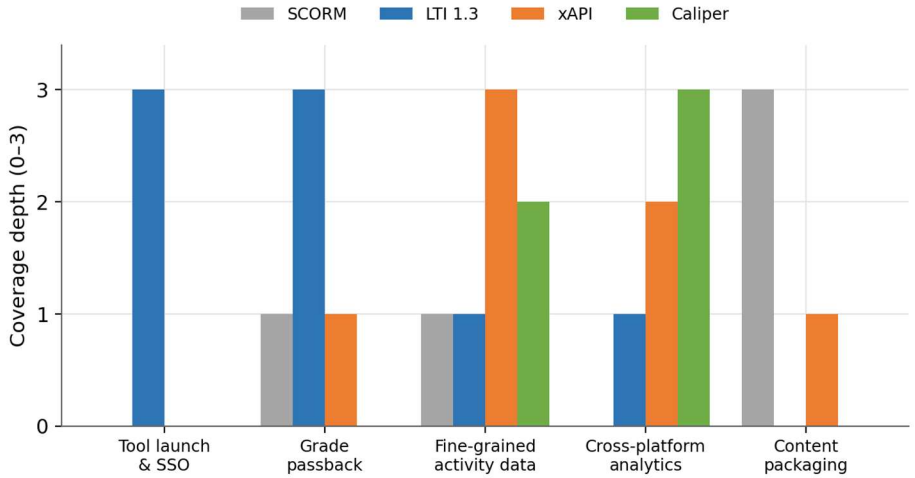

Figure 2. Capability map of four e-learning standards across five institutional functions (0–3 depth)

The operational model shows what these standards buy in day-to-day terms. Figure 3 compares a representative institution before and after adoption.

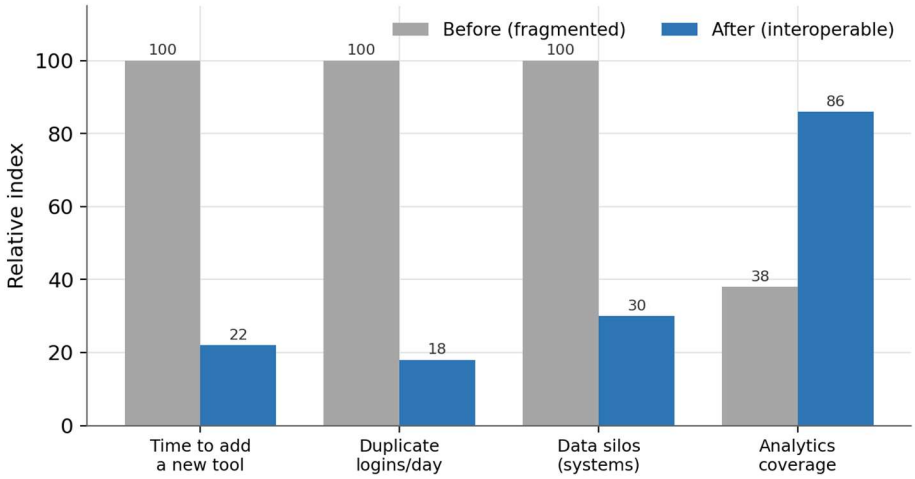

Figure 3. Representative operational indicators before and after adopting an interoperability-first architecture

The time required to add a new tool falls dramatically once integration is a matter of exchanging standard credentials rather than commissioning custom development; the number of duplicate daily logins collapses under single sign-on; the count of disconnected data silos drops as systems begin to share a common data layer; and the share of learning activity covered by analytics rises sharply, because activity that was previously invisible to the institution now flows into a Learning Record Store. The only indicator that does not simply improve is the up-front engineering effort of the initial migration, which is real and which the roadmap in Table 2 is designed to phase.

Table 2.

Phased roadmap toward an interoperable learning ecosystem

Phase	Focus	Key actions	Visible outcome
1. Connect	LTI 1.3 + SSO	Adopt LTI for all major tools; enable single sign-on	One login; instant tool launch
2. Synchronise	OneRoster	Automate roster and grade sync between SIS and LMS	No manual grade copying
3. Capture	xAPI + LRS	Stand up a Learning Record Store; instrument key tools	Activity data in one place
4. Exchange	Caliper	Adopt Caliper profiles for cross-system analytics	Holistic learner view
5. Assure	Conformance	Verify certified conformance per platform version	Stable, auditable ecosystem

Read together, the three artefacts make a consistent argument. Fragmentation is not a minor inconvenience but a structural cost that grows with every tool an institution adds, and the standards needed to escape it are mature, complementary and widely supported. The strategic task for Uzbek institutions is therefore to stop treating each integration as a one-off project and to adopt the standards stack deliberately, in the phased manner set out in Table 2, beginning with the connection layer that delivers the fastest visible relief.

CONCLUSION

The story of digital learning in many emerging economies has been a story of acquisition, and Uzbekistan has acquired a great deal in a short time. The next chapter has to be a story of connection. This paper has argued that the binding constraint is no longer whether institutions have platforms but whether those platforms interoperate, and that the cost of fragmentation is structural, growing with every tool added under a point-to-point model.

The way out is a standards-based architecture that is already mature and widely supported. Learning Tools Interoperability provides secure connection and single sign-on; the Experience API and Caliper Analytics capture and exchange the fine-grained learning data that quality assurance and predictive analytics require; SCORM and OneRoster retain defined roles for content and rostering. Adopted together and phased sensibly, beginning with the connection layer, these standards convert a quadratic integration burden into a linear one and turn scattered, unusable data into a coherent

institutional asset.

Two limitations frame the contribution. The analysis is architectural and its operational figures are illustrative rather than drawn from a completed national deployment, and realising the benefits depends on local technical capacity and on verifying conformance in each institution's specific configuration, which the literature rightly flags as the real bottleneck. The priority for future work is therefore implementation research: piloting the phased roadmap in a small group of Uzbek universities, measuring the integration and analytics gains directly, and using the resulting learning-data foundation to support the predictive quality monitoring developed in the companion study.

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