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IN.TUNE

Innovative Universities in Music and Arts in Europe

Inventory of LMS and Low Latency Systems

Seamless mobility for our students and staff (WP2)

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Document Details

Project number:	101124302
Alliance name:	IN.TUNE - Innovative Universities in Music & Arts in Europe
Acronym:	IN.TUNE
Call and topic:	European Universities – Development of new deep institutional transnational cooperation (ERASMUS-EDU-2023-EUR-UNIV-2)
Start / End date:	1 January 2024 / 31 December 2027
Work Package:	Seamless mobility for our students and staff (WP2)
Work Package leader:	Universitatea Națională de Muzică din București
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Deliverable:	**Inventory of LMS and digital low-latency systems (D2.5)**
Due date:	Month 12 (M12)
Type of document:	Document, report
Dissemination level	Public
Version / Status	Final
Date	20/12/2024

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Introduction to the Context

IN.TUNE

The European University Alliance IN.TUNE – Innovative Universities in Music & Arts in Europe brings together eight universities across the continent, committed to the development of a joint long-term strategy for excellence in education, research, innovation and service to society. This strategy is built on a shared perspective on our institutions' roles within society, a joint vision and approach towards deep institutional cooperation, and a shared dedication to the European values of diversity, democracy, social and human rights.

Through the establishment of IN.TUNE, we aim to:

- Build an effective, systemic and sustainable framework for deep institutional cooperation, drawing on our previous and existing collaborations to drive transformational change across our institutions.
- Strengthen, through this deep institutional cooperation, artistic and educational innovation and research, not only within our institutions, but also throughout the higher music education sector and the broader cultural and creative sector industries, providing students and professionals unique with educational opportunities that will improve their ability to access, create and maintain sustainable careers.
- Play an active role in shaping the future of our sector and our societies by addressing contemporary educational, professional, societal, technological and ecological challenges. Together, through the joint creation of forward-looking institutional environments, we will empower students and staff to engage with these challenges through their creative work, both at institutional and transnational level.

Work Package 2: Seamless Mobility for Our Students and Staff

The Seamless mobility for our students and staff (*Work Package 2*) focuses on developing IN.TUNE Mobility Framework aiming to enhance seamless mobility within the Alliance by creating advanced administrative and recognition arrangements for students and staff, promoting language support and linguistic diversity, and providing incentives for collaboration through teacher exchanges.

It will also develop a joint course database to facilitate flexible learning pathways. Furthermore, it aims to develop the IN.TUNE eLearning Policy focused on improving digital education skills by inventorying and connecting existing digital Learning Management Systems (LMS) and low latency systems, developing a unified digital education approach, supporting both technical and educational content advancements in collaboration with other work packages.

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Executive Summary

The *Inventory of LMS and digital low-latency systems (D2.5)* provides an overview of the existing Learning Management Systems (LMS), low latency systems, and non-low latency systems. The latter two are collectively referred to as *real-time audio/video systems*. This inventory describes the current usage, experiences and the state of readiness of these systems in Alliance institutions, while also identifying potential challenges that may limit their effective use. Furthermore, it offers both general knowledge of the systems and technical insights to guide future use and decision-making.

The practical definition of LMS in this inventory is intentionally quite broad, acknowledging a wide variety of digital solutions that can support educational purposes. In addition to the most commonly used Learning Management Systems, the inventory considers tools primarily designed for administrative work, but which can be adapted for teaching and learning as well.

Low-latency systems are particularly highlighted because of their specific application for teaching and practising music, where real-time collaboration over video is essential. However, recognizing that such systems are not always necessary, the inventory also examines non-low -latency real-time audio/video systems, here referred to as “standard systems”.

The inventory will serve as the basis for formulating a joint approach towards eLearning within the alliance. It will furthermore contribute to the development of the joint IN.TUNE eLearning Policy, which will additionally incorporate a proposal for the joint use of LMS and low-latency systems.

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IN.TUNE Inventory of LMS and digital low-latency systems

Deliverable 2.3, WP2 Seamless mobility for our students and staff

The IN.TUNE Inventory of LMS and digital low-latency systems offers a comprehensive analysis of the systems evaluated, detailing their functionalities, current usage across IN.TUNE Alliance institutions, and potential challenges to implementation. This document serves as a foundation for understanding how Learning Management Systems (LMS) and low-latency systems can enhance seamless mobility and foster innovative pedagogical practices in music and the arts within the Alliance.

The inventory was compiled by a working group that included at least one expert member from every institution, totalling nine members. While their primary expertise lay in technical matters, the group also brought valuable pedagogical, artistic, and teaching design knowledge.

Data for the inventory was gathered through questionnaires and direct inquiries directed at various institutional departments, including teaching staff, educational technology services, audiovisual and IT services. To organise the findings, the group created a detailed Excel document, dividing the data into sections for LMS and real-time audio/video systems.

The data collection process was structured to address the following key areas:

- LMS types, usage and login requirements: Documenting each institution's current LMS platforms, their intended use, and the extent of their adoption. This also included gathering information on system security and accessibility, typically through single sign-on (SSO) protocols.
- Real-time audio/video system types and usage: Documenting current applications, audiovisual equipment, studio facilities, involved support staff and the integration of these technologies within the institutional teaching practices.

The working group held regular discussions to review findings, share ideas, and document observations and insights throughout the process.

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Learning Management Systems

What is a Learning Management System?

A learning management system (LMS) is a digital platform or application used to manage, document, track and report on the usage of courses and other e-learning content during the learning process. The LMS provides an online environment where it is possible to create lessons and courses, organise and deliver content and assess student performance. There might be visual layout options, features that increase interactivity in learning and communication possibilities.

Usually, the LMS is tailored to be an internal platform in one educational institution. In some cases, the LMS can be shared between several institutions. LMSs are also used in the corporate world for employee training.

In a nutshell the LMS usually includes these key features:

- User and content management
- Learning resources and activities
- Assignments and assessments
- Feedback and communication
- Reporting and analytics.

From a learning perspective, the use of LMSs can be divided into two categories:

- Fully online courses
- Blended courses and workshops.

Both categories can include synchronous and asynchronous learning elements. Synchronous learning involves real-time, group-based activities, like in a traditional classroom environment. Asynchronous learning allows learners to progress at their own pace. Fully online courses are asynchronous, whereas blended courses combine face-to-face learning and learning activities in the digital learning environment and typically incorporate both synchronous and asynchronous elements. Although the courses in the LMS are usually aimed at the group, content can be personalised as needed.

The most common LMSs favoured by higher education institutions are Moodle, Canvas and Blackboard. Other popular solutions including the business world are Schoology, its learning, Google Classroom, 360Learning, iSpring Learn LMS, TalentLMS, SAP Litmos, D2L Brightspace and Docebo.

There are currently over 700 LMSs available in the market. This number includes a wide variety of platforms, each offering different features and capabilities to cater to diverse educational and corporate needs.

The use of Learning Management Systems in IN.TUNE institutions

The currently used learning management and similarly used systems among the IN.TUNE institutions are:

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- Canvas LMS (1 institution)
- Moodle LMS (5 institutions)
- Microsoft 365 (7 institutions)
- Google Classroom (1 institution).

Canvas is the standard solution for universities in Norway, and as such also the choice for *Norges musikkhøgskole (NMH)*. In Finland, *Taideyliopisto* (*Uniarts)* and all the other universities are Moodle users. It is also widely used in universities of applied sciences. In Austria Moodle is chosen for LMS in *Universität für Musik und darstellende Kunst Wien (mdw)* as well as in *Universitatea Națională de Muzică din București (UNMB)*.

Escola Superior de Música de Catalunya (ESMUC) has experimented with a combination of Moodle, Teams and Sharepoint with low latency connections in blended programs.

Microsoft 365 is used in almost every institution. Its administrative use for a variety of tasks is very common. Although it is not designed as an LMS, it is used in teaching to some extent. It is the only LMS substitute in *Stichting Hogeschool der Kunsten den Haag (HdK), Univerzitet umetnosti u Beogradu (UAB)* and *Conservatoire National Supérieur de Musique et de Danse de Paris (CNSMDP)*. In addition, the latter is planning to start developing a custom LMS.

Some institutions have dedicated staff to support LMS users in technical and pedagogical matters. A systematic approach for onboarding, user support, and competence development that contributes to teachers' ability to use the LMS in a way that further enhances study quality seems to be a prerequisite for successful implementation. This requires people with competence and time to carry out the work needed.

Usually, accessing the LMS requires the user to have an ID in the institution's IT system. The systems reviewed had varying login practices. Some institutions preferred the login method commonly used by higher education institutions in their country, others used the university's own login procedure, and some preferred a login method from a service provider (e.g. Microsoft).

Some examples of the current LMS usage in Alliance Institutions

This chapter provides examples of the current use of LMS in five institutions as of early December 2024. The results have been obtained from user surveys and LMS usage statistics.

The Moodle at *Uniarts* has over 3000 active users among students and teachers. The LMS hosts nearly 1300 active course areas. Since 2021, the university's Educational Technology team has held 500 personal support sessions for users, offering both pedagogical and technological support for the effective use of LMS.

The teaching staff has a positive attitude toward Moodle, which is mainly used for blended teaching and learning, although some courses are delivered entirely online. The subject areas cover a wide range of theoretical and practical topics. Uniarts also partners in the DigiCampus platform, a shared Moodle-based learning environment for Finnish universities offering common and open courses.

In the winter semester 2024, 381 Moodle courses have been active at *mdw*, with most carried over from previous semesters, and a smaller number created from scratch. Recent trends show an

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increase in Moodle course creation. Over 2000 students actively use the platform, underscoring its importance as an LMS for the institution.

During the first four months of the 2024-2025 academic year, *ESMUC* implemented 134 active Moodle courses covering both theoretical and practical subjects. The system is used for management, storage, and backup purposes. Additionally, Teams and SharePoint are widely used for communication and file sharing.

The primary barriers to LMS adoption within ESMUC include a lack of knowledge and experience with the system and a preference for in-person teaching. Nevertheless, there is an interest in using an LMS if it is user-friendly and can enhance student engagement. The training courses are seen as an opportunity to explore the potential of LMSs further.

A survey conducted in the *UNMB* showed that a great majority of respondents do not use an LMS. Among those that do, tools and platforms like Moodle, Canvas, Google Classroom or non-LMS applications, such as Microsoft Teams, OneDrive or Google Drive, are used for course storage and communication with students.

The main goals for improvement in using the LMS include fostering more (inter)active communication with students and enhancing their motivation to learn. The knowhow and ease of use are the main concerns hindering LMSs' adoption by faculty members. Additionally, there is a certain reservation among some teachers about its usefulness for teaching music, citing logistical or technological challenges in the implementation of such systems outweighing potential benefits. Despite these reservations, more than three quarters of respondents expressed their willingness to participate in LMS training if shown the potential advantages, especially for improving communication with students or teaching effectiveness.

The Canvas LMS at the *NMH* supports 1809 courses, 183 teachers, and 874 students. The extent of its use and the way it is applied are constantly evolving. In some music theory subjects, the system is used as a document archive, for communication and information, as well as for assignment submission and assessment. In an increasing number of theory subjects, the possibilities for dialogue and learning activities in the digital learning environment are being utilised.

In music performance subjects, the system is mainly used for communication and information sharing. A growing number of students and teachers are using the possibilities for asynchronous dialogue by exchanging audio and video recordings and other student-active learning forms in the digital learning environment.

Generally, interest in the system's pedagogical possibilities is increasing. Several courses are being developed to include blended learning, combining in-person meetings with interaction and activity in the LMS. An important driving force and prerequisite for positive development is that the NMH has a team for technology in learning and teaching, which is responsible for onboarding, user support, and competence development.

Summary of LMS usage

Overall, the institutions demonstrate diverse approaches to LMS usage, with varying degrees of adoption, challenges and plans for further development. The inventory reveals widespread use of Moodle as an LMS, with Microsoft 365 applications often serving as a substitute. Challenges include

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limited LMS familiarity and a preference for in-person teaching, though openness to training indicates potential for expanded LMS utilisation. Support and training are crucial in enhancing the effectiveness and acceptance of these systems.

Although many institutions use their LMS for blended or online learning, in-person learning is still preferred by both staff and students in many cases. This is natural, given the music and art education tradition, which has artistic expression at its heart. Teaching in numerous study programmes is still focused on individual one-to-one lessons with students, or guidance in small groups, leaving the added value of LMSs unexplored by many.

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Real-time Audio/Video Systems

What is a Real-time Audio/Video System?

Real-time audio/video systems can be divided in two categories: *standard systems* and *low latency systems*. Typical standard systems include applications like Zoom and Teams. They are mainly created to make spoken communication in the meetings with multiple participants possible. The audio quality in these applications is compromised, which is appropriate for speech but not suitable for music performance. The standard systems also include a short delay in data communication.

The low latency systems have barely noticeable delay in data communication, hence the name. The solution can be implemented in two ways: it can be a computer-based system or standalone unit. The first one needs a fast computer (often similar to those used in gaming), video camera, audio interface and a proper software application to make a high-quality connection. With a standalone solution no additional devices are needed to make the connection between participants. The combination of hardware and software handles the data processing and is embedded in a single unit. Audio and video signals along with the internet connection can directly be connected to the unit.

Both types are specialised technical setups with connections between two or multiple participants through a high-speed network. The network technology is optimised for ultimate transfer speed and high-quality audio and video connection. This type of connection usually requires identical systems on both ends.

For musicians and music educators, high-quality audio transmission is essential, as it forms the foundation of any meaningful remote musical interaction. While video adds important visual cues, especially in educational context, uncompromised audio quality and transmission are the key factors that make musical collaboration possible.

The real-time audio/video systems used in the institutions are:

- Low Latency – "LoLa" (6 institutions)
- Modular Video Transmission Platform – MVTP (2 institutions)
- Polycom (2 institutions)
- Zoom
- Teams

For low latency systems, LoLa is very commonly used, whereas two institutions have MVTP.[1] Among the standard systems, Zoom and Teams are also common. Polycom is used only at *Uniarts* and *mdw*. In addition, some other systems have been tested but not put into use yet.

[1] Modular Video Transmission Platform – MVTP System: Description of the Low Latency System Developed by Cesnet, accessed December 12, 2024, https://mvtp.cesnet.cz/.
Low Latency "LoLa" System: Description of the Low Latency System Developed by Conservatorio di Musica Giuseppe Tartini, accessed December 12, 2024, https://lola.conts.it/.

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What is a Low Latency System?

This section describes the technical aspects of low latency systems in detail. To understand the concept thoroughly it is important to include a deeper perspective on the matter.

The Fundamental Challenge of Latency

Remote musical collaboration faces a critical technical challenge: signal processing delay, commonly known as *latency*. Basically, it means the time delay between sending and receiving information. Producing a sound and hearing it is a typical example.

The time between signal capture and reproduction must be minimal for effective musical interaction. In this context even tiny delay counts. Delays exceeding 30 milliseconds (30 thousandths of a second) can greatly hinder an ensemble's ability to musically interact in a meaningful way during performance.[2]

Physical sound delay exists even without any technology involved. When two musicians play together at distance of 3 meters, the sound takes 9 milliseconds (ms) to travel between them, since sound covers 1 meter in 3 ms. At this short distance, the brain naturally compensates for this delay. However, when musicians are spread 10 meters apart, the 30 ms delay begins to challenge their ability to stay synchronised.

In remote music systems, the total time needed for audio signals to make a complete journey from one musician to another and back again, has to be considered. This is called the *round-trip time (RTT)*. When musicians collaborate remotely, they not only send their audio to their partner(s) but also hear their own playing returning from the distant location. This creates a doubled delay effect, since the signal must travel the full distance twice. For musicians to experience a truly responsive low-latency connection that feels natural, the round-trip time should remain under 30 ms. This is approximately the same delay they might experience playing 10 meters apart in the same room.

The total latency in remote music performance consists of three main components:

- network transmission time based on physical distance between the parties
- processing within network infrastructure
- signal processing at both endpoints of the connection.

Modern fibre optic networks can theoretically transmit signals at approximately two-thirds the speed of light. However, real-world network performance is considerably more complex. Data must pass through multiple routing points, each introducing its own processing delay. Network congestion, protocol management, and security measures further impact transmission times. These network-related factors typically remain outside institutional control and vary significantly based on geographic location and internet service infrastructure.

[2] The Haas effect and the echo threshold between 25-35 ms impede remote music performances. See: Owens, S., and Cunningham, S. 2018. "Auditory Masking and the Precedence Effect in Studies of Musical Timekeeping." *Proceedings of the Audio Mostly 2018 on Sound in Immersion and Emotion*, 1–4.
More on technical, performative and compositional perspectives of networked music: Hope, Cat. 2021. *Networked Music Performance*. Accessed December 12, 2024.
https://mutor-2.github.io/HistoryAndPracticeOfMultimedia/units/06/#carot

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The most promising area for latency reduction lies in the endpoint signal processing. At each endpoint the system must handle several things: signal capture, digitisation, compression, network formatting, and subsequent reconstruction. In traditional computing systems, each of these processing steps introduces some amount of delay. While network latency remains subject to infrastructure limitations, endpoint processing delays can be substantially reduced by using appropriate technical solutions.

General-purpose computing systems

Standard computer systems process audio and video signals through multiple software layers in a general-purpose computing environment. While these systems offer significant flexibility, their architecture introduces inherent latencies through operating system overhead, resource sharing, and buffer management. The resulting cumulative delay typically ranges from 10 to 30 ms, even in optimal conditions.

Achieving consistent low latency performance with general-purpose computers requires substantial computing power. Professional-grade processors, significant memory allocation, specialised audio interfaces, and high-performance network cards become necessary components. In practice, the result is a computer that is typically suitable for demanding gaming use. Consequently, the total cost of such optimised systems often exceeds initial estimates when accounting for all necessary hardware elements.

Dedicated hardware solutions

Specialised electronic circuits offer an alternative approach to general-purpose computing. These solutions implement signal processing directly in hardware, providing predictable timing behaviour and parallel processing capabilities. By dedicating specific resources to processing tasks, these systems minimise overhead and achieve more consistent performance.

The field of specialised circuits encompasses various technologies, from entirely fixed Application-Specific Integrated Circuits (ASICs), through moderately flexible Complex Programmable Logic Devices (CPLDs), to highly configurable Field-Programmable Gate Arrays (FPGAs). These technologies present different trade-offs between specialisation and adaptability.

Real-time music performance systems must address several key requirements:

- Network control including IP and firewall settings
- Simultaneous processing of audio and video signals
- Adaptation to various protocols and interface standards
- Potential for system improvements
- Implementation of complex processing chains.

When these factors are considered together, solutions based on configurable hardware emerge as particularly well-suited for low-latency music applications, achieving processing delays of 1-2 ms while maintaining adaptability to different usage scenarios.

Performance Implications

The impact of processing delay on musical performance varies significantly. At 3-6 ms, the delay corresponds to natural acoustic spacing (1-2 meters) between musicians and allows normal

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performance interaction. Delays of 10-30 ms (3-10 meters) may require performers to adapt their usual interaction patterns, while delays exceeding 30 ms present substantial challenges for synchronous performance.

Technical Considerations

The selection between general-purpose and dedicated hardware systems involves multiple operational factors. General-purpose systems offer lower initial hardware costs but may lead to higher total expenses when optimised for performance. They provide flexibility for updates but require ongoing maintenance and optimisation, while their performance characteristics can vary under different conditions. In addition, ensuring software and hardware compatibility can increase the workload.

Dedicated hardware systems, by contrast, provide consistent performance metrics and more predictable operational characteristics. Their purpose-specific optimisation typically results in lower long-term maintenance requirements and more reliable operation in demanding performance scenarios.

Global Adoption Trends and Implementation Patterns

Both technical approaches have found successful implementation in remote music performance systems. The choice between them typically depends on specific institutional requirements, existing infrastructure capabilities, and particular use case priorities. The growing adoption of dedicated hardware solutions often reflects institutional requirements for consistent, reliable performance, particularly when considering total cost of ownership and operational stability over time.

Also, usability plays a role here: if the goal is to have the users operate the remote systems independently, it is important to have easy-to-use solutions. It is also beneficial to consider the time spent by technicians in making settings, updating the system and resolving possible error situations.

For standard (non-low latency) systems, Zoom can be a viable solution when real-time playing together is not needed. It is possible to achieve decent sound quality for musical purposes, but this requires technical knowledge and appropriate equipment. In practice this means quality microphones, headphones or speakers, audio interface or mixer, wired (ethernet) connection and using the *Original Sound & High-Fidelity Music Mode* audio settings on Zoom. However, the outcome may vary depending on the operation of the network.

Teams is a functional solution for meetings, feedback, assignments, and other similar purposes. It is not a particularly good solution for musical purposes because it can be replaced by more suitable options. Features like file handling, chat, and integration to other M365 products can be valuable in teaching, though, especially when a real LMS is not available.

The working group's focus has been on exploring low-latency systems rather than further investigating standard (non-low-latency) systems. Low-latency systems are particularly interesting for higher music and arts education due to their huge potential in facilitating synchronous remote performing, virtual teaching, and learning in an international learning environment.

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Low Latency System Comparison and Test Period

The working group considered it important to compare low-latency solutions available on the market to help the Alliance make an informed choice for the system to be used. The systems considered were divided into two categories: standalone systems and computer-based systems.

The group developed a comparison framework of eight key criteria focusing on what matters most for music education institutions.[3]

1. **Latency** (Critical): How quickly does the signal travel from one location to another?
2. **Audio Quality** (Critical): How true is the sound to the original performance?
3. **Video Capabilities** (Important): How well can participants see each other?
4. **Transmission Reliability** (Critical): How stable and dependable is the connection?
5. **Usability** (Very Important): How easy is it to use in daily teaching?
6. **Data Security** (Important): How secure are the teaching sessions?
7. **System Durability** (Important): How reliable and future-proof is the system?
8. **Cost Analysis** (Very Important): Is the system financially viable across the Alliance?

Through systematic evaluation, several systems were eliminated for specific reasons:

- **Audio Processing Issues**: Teams, Zoom (use time-stretching algorithms)
- **Too Much Latency**: Koord, Jamulus, JammerNetz (server-based systems)
- **No Video**: Groovesetter, Jacktrip, Sonobus, Source-Connect, Cleanfeed
- **Reliability Issues**: JamKazam
- **Cost Prohibitive for Alliance**: Nimbra, Cleanfeed Cinema (exceeds sustainable investment level for some partners)
- **Uncertain Future**: Elk Live

After carefully evaluating various communication platforms against our stringent criteria for music education, including latency, video quality, transmission fidelity, cost, and long-term sustainability, the group's systematic assessment process identified two systems that truly meet Alliance's requirements: **LoLa** and **MVTP**. These systems emerged as the final candidates from rigorous evaluation, demonstrating the necessary capabilities for high-quality remote music collaboration.

Results from the Test Period

Since almost all institutions already had experiences with LoLa, the group chose to test the MVTP system in action to make a comparison. Alliance institutions *mdw* and *HdK* already had MVTP in place, which made test sessions with them a natural place to start[4].

[3] See: *Low latency system evaluation framework* document in the Annex.

[4] A case study by Daniela Peclová describes and analyses blended learning using MVTP for remote music masterclasses and rehearsals, conducted in collaboration between Janáček Academy of Performing Arts from Brno and the Royal Conservatoire The Hague. Peclová, Daniela. "Ultra-Low Latency Streaming Technology in Music Education." In *15th Annual ENCATC Education and Research Session: Book of Proceedings*, 33. Accessed December 12, 2024. https://encatc.org/media/7488-15th-annual-encatc-education-and-research-session_book-of-proceedings.pdf

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The MVTP system offers similar low latency functionalities as LoLa but is a standalone unit, whereas LoLa is a computer-based system. The MVTP manufacturer CesNet offer institutions the opportunity to borrow the unit and a video camera to test it.

The testing included both technical connection tests and real teaching situations. Several connections were made between institutions located in different parts of Europe. The distance between partners ranged typically from 700 to 1500 km.

The testing period gave promising results. In most cases the system worked very well: the sound quality was excellent, and the technicians found it easy to configure and use.

From a technical perspective, both LoLa and MVTP are viable solutions in terms of having good audio and video quality in remote music teaching and learning situations. It is worth noting that the quality of the network connection always affects the results regardless the system.

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Possible Constraints

No specific constraints were identified during the development of this deliverable. However, it is worth mentioning certain factors that could pose challenges to the successful and equitable implementation of LMS and low-latency systems across the alliance. These might include cultural differences, diversity in organisational practices, or limited resources, all of which should be considered when promoting new digital tools. Additionally, three key challenges were highlighted during discussions.

Challenge	Description	Key points to address
Level of digital and pedagogical skills	Importance of basic digital literacy and adaptation of pedagogical skills and teaching methods using digital tools	Creating functional support structures, regular training, and digital skills assessments
Technological and operational readiness to adopt and implement LMS and low-latency systems	Varying institutional resources and readiness levels	Investments in IT/AV infrastructure, giving time for adaptation of teaching practices, and expert support availability
Attitudes towards technology	Resistance to change, fear of failure, or reliance on traditional teaching methods	Simplify tools, show benefits as complementary methods, and promote gradual, non-threatening transitions

Figure 1: Main challenges and ways of addressing them

Sufficient digital skills of staff are the basis for using any system. The working group brought this up because it was seen as an essential topic to really enable the use of LMS and low latency systems. A possible lack of sufficient digital skills can generally reduce interest in using digital solutions.

The readiness of institutions to adopt a new LMS or low latency system may vary. Limited IT and AV resources, as well as the need for specialised expertise, can pose challenges. Additionally, the implementation of technological innovations inevitably brings changes to teaching practices, which can be time-consuming.

It is also natural to encounter some resistance to new digital tools. This may manifest as reluctance to change established teaching methods and habits, fear of failure, or misconceptions about the capabilities and limitations of these systems and tools.

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Discussion on the Final Outcome

The outcome of this inventory provides insights into how partner institutions are navigating the digital landscape in higher music education. These findings will directly inform the next steps and future tasks.

Learning Management Systems

The inventory shows that the use of LMSs and similar systems varies significantly in the IN.TUNE institutions. This is because of the different learning cultures at the institutions. Users need to be clearly explained what the LMS can be used for and what the benefits of using it are.

One of the key points is the utilisation of LMS, which means educational technology support for users. This should focus on both technical training and pedagogical support for the use of LMS. Properly targeted support measures play a crucial role in the use of an LMS. A case example at *Uniarts* sheds light on the situation in which the new LMS was introduced at the institution in 2021:

> *The students were dissatisfied with the way teachers used several different digital platforms. This led to students hoping for less systems and one common solution for educational use. At the same time, the old LMS was perceived as outdated in terms of usability and functions needed. The university decided to replace the LMS.*
>
> *After a new system was introduced, an extensive change in learning and teaching practices was initiated. There was a natural need for educational technology support. The development of this support was invested in. As a result, the number of LMS users increased rapidly.*

Low Latency Systems

The usage of low-latency systems in higher music education institutions has not been widespread, although the benefits of their use are many: less travelling (leading to a smaller negative impact on the environment), the ability for students to receive teaching and practice easily outside their institution, a wider audience and collaboration opportunities for teachers, and the promotion of international networking and musical performances, to name only some.

Therefore, the working group raised the question of how teachers and students could be encouraged to use these systems more. Several ideas were born:

- Identifying the needs and situations where low latency connections are most effective and emphasising the positive aspects.
- Organising activities or performances that demonstrate low latency systems to foster engagement.
- Scheduling regular time slots for students and teachers to connect for jamming and rehearsing together.
- Simplifying the technical processes to enable easy and independent use.
- Streamlining the practical aspects of planning and running lessons and events using low-latency tools.
- Securing high-quality partners with the same system who are committed to the development of this form of teaching and learning.

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- Having a more strategic approach towards incorporating this type of international experience into the curriculum.

The technical part of low latency sessions is relatively easy to implement, and the partners in the Alliance are generally well-equipped and skilled enough. The challenge lies in organising these sessions, since a lot of different functions within the schools are involved when an event using low latency tools is in the making.

This calls for a dedicated group including an AV and IT technician and a producer. A suitable studio room and necessary audio equipment are also needed. There must be coordination and communication between all the parties involved (IT and AV technicians, teachers, students) in the process at each institution. Also, studio reservations, rehearsal times and technical tests take time and may need a digital booking system.

Some of the institutions already have structures and procedures in place to accommodate requests for low latency sessions, and it is a goal for the Alliance that all partners will have this in place to facilitate a higher number of sessions in the future.

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Conclusion and Suggestions for Further Use of the Results

By systematically addressing the three main priorities described in this chapter, IN.TUNE can take one step closer towards creating a robust foundation for seamless mobility. Success will require sustained commitment to both technical implementation and cultural change across all partner institutions.

The working group recommends a continued focus on the following key areas and next steps:

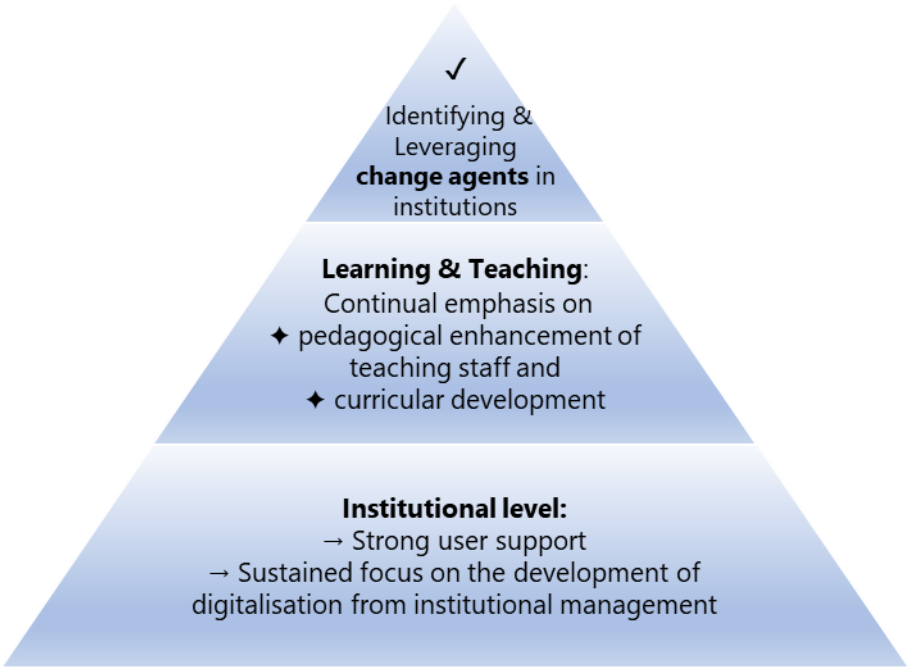

Figure 2: Key focus areas and approaches for the successful use of LMS and low latency systems in seamless mobility

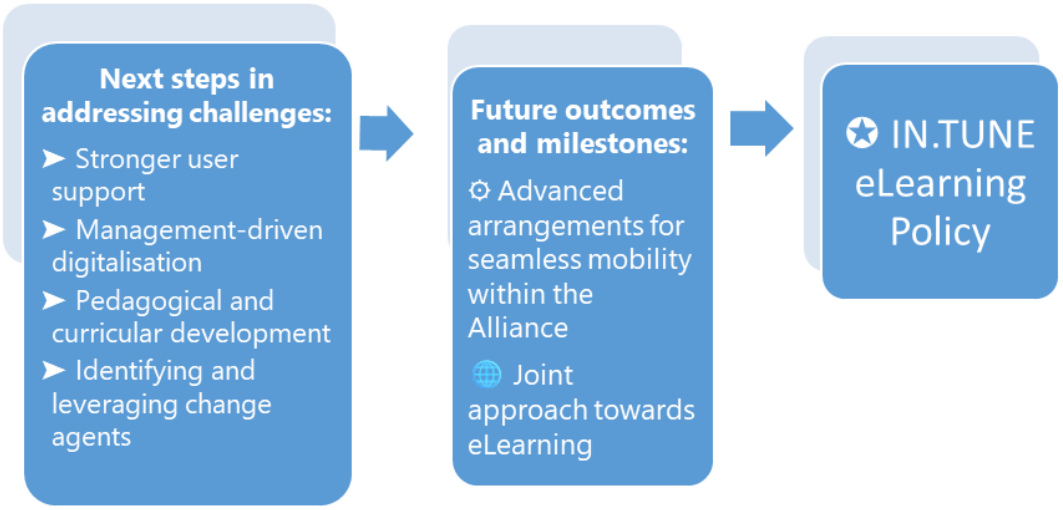

Figure 3: Next steps and future outcomes

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Development of LMS Usage

The current landscape of LMS adoption across institutions is diverse, ranging from basic to advanced implementations. While complete standardisation might not be the ultimate goal, the Alliance could focus on several key areas to collaborate and find appropriate ways for utilisation of the LMSs.

Another focus area of the alliance is to develop new educational formats, focusing on variations of blended teaching in new and innovative ways. The possible alignment of LMSs across the institutions will play a crucial role here. The institution must allow external students access to the LMS. Institutions have to be prepared to include students from other partners into their LMSs in order to create digital classrooms across the Alliance. This will require both a technical and pedagogical approach:

- Information about students will have to be shared to allow students access the other institution's LMS. In many institutions this is not automated now, which can create some challenges when the number of alliance students joining these courses increases.
- For the user (students and teachers in this context) it is of great importance that the digital classrooms have somewhat the same logic in the way they are structured. As a user it can be challenging to navigate digital platforms that you are not familiar with, and it will create a better user experience (and in turn a higher number of active users) if the digital classrooms of partner institutions have a familiar structure.
- The Alliance should investigate the use of EduGain or similar to provide unified and secure access, thereby simplifying the login process for users.

The working group has also identified key points for staff development in the efforts of developing the use of LMS in the Alliance:

- Institutions should ensure a robust system for user support and competence development regarding pedagogical use of LMS across the Alliance. It is not enough only to focus on the technical aspects of the LMSs. The teachers could use their pedagogical creativity in creating good solutions for the students.
- The Alliance could set up a system for sharing of best practices for supporting the teachers. This would enhance the overall user experience and contribute to staff development in all institutions.
- The Alliance could also consider setting up a network of *ambassadors*, meaning teachers with ideas and motivation to use the LMS in new and innovative ways, for instance in instrumental teaching or other practical subjects where LMS traditionally does not have a strong place.
- Creating guidelines for course design and content organisation to help maintain consistency and quality. Establishing minimum functional requirements for LMSs is essential to facilitate seamless student mobility between institutions.

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Development of Low Latency Infrastructure and Usage

The successful testing of the low latency systems demonstrated significant potential for expanding the use of this technology to complement the curricula in the Alliance institutions. To fully realise this potential, the Alliance could undertake several initiatives:

- → Create an Alliance network of dedicated studio spaces optimised for remote sessions is a priority, as these spaces will provide the necessary environment for high-quality remote teaching.
- → Establish technical standards, using the same system, and formulating unified protocols for inter-institutional connections will ensure smooth and reliable communication between institutions.
- → Develop support structures, including technical staff training and scheduling systems. This includes solving common challenges like using headphones in classical music education and positioning screens to support the physical health of the musicians.
- → Design pilot events to demonstrate the effectiveness of these systems, which could encourage wider adoption and showcase the benefits of remote music education.
- → Promote the opportunity as complementary to regular in-presence teaching, and not as a substitute. Low-latency tools can never fully replace the teaching situation where a student and a teacher meet live in the same room, and it should rather be seen as a tool to give the students even better opportunities to learn in an international learning environment.
- → Focus on guiding students and teachers in the musical parts of the sessions: How can you optimise that balance in the ensembles when hearing your fellow musicians through a speaker and not live?

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Next Steps Towards High Digital Capacity and Seamless Mobility

The findings in this inventory highlight the importance of prioritising the development of a systematic policy to enhance digital competencies and the use of low-latency tools and LMSs within the Alliance. The working group will continue its efforts to develop a joint approach to eLearning and formulate proposals for the shared use of these tools, aiming to address the following key issues in that process:

- Joint training programmes for staff: These will ensure that staff across the Alliance acquire the necessary skills to effectively utilise LMSs, low-latency systems, and other tools within the Alliance's digital environment. This includes establishing or strengthening support structures within all institutions and monitoring the development of digital literacy among staff.
- Empowering students as change agents: Students will be leveraged as a driving force for curriculum changes and the implementation of a more systematic use of low-latency tools and LMS in teaching.
- Creating a supportive environment: Providing a safe and encouraging space for both staff and students to become comfortable with integrating digital tools as a natural part of teaching and learning.
- Collaborating with other Alliance initiatives: Working in synergy with other projects, particularly the innovative educational formats outlined in Work Package 3, to support curriculum changes.
- Expanding the context of online learning: Contributing to the broader field of online learning in higher education by further developing low-latency systems as specialised and artistic tools, with potential applications in other artistic and academic disciplines.

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ANNEX

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Low-Latency System Evaluation Framework

The working group developed the following document to establish an assessment framework for low-latency systems.

Choosing a Low-Latency System for Music Education

Standard platforms like Teams and Zoom use audio processing algorithms designed to adjust timing to maintain a smooth conversation automatically. While effective for speech, these algorithms distort musical rhythm, making ensemble performance impossible. Musicians need both low latency (under 30 ms) and unprocessed audio to play together effectively – requirements that the video conferencing platforms are not designed to meet.

Our Evaluation Framework

The eLearning Working Group has developed eight key criteria focusing on what matters most for music education institutions:

1. Latency (Critical)

How quickly does the signal travel from one location to another?

- Connection type (direct peer-to-peer or through servers)
- Processing delay within the system itself
- Maximum tested working distance between locations
- Actual measured delay during musical performance
- Absence of time-stretching or audio processing that alters timing

2. Audio Quality (Critical)

How true is the sound to the original performance?

- Natural dynamics and full frequency range for all instruments
- Unmodified audio signal (no automatic processing)
- Multiple channel support for ensemble work
- Supported sample rates and bit depths
- Variety of audio connection options

3. Video Capabilities (Important)

How well can participants see each other?

- Synchronisation between audio and video
- Image quality sufficient for teaching technique
- Support for multiple camera angles
- Available resolutions and frame rates
- Video input/output options

4. Transmission Reliability (Critical)

How stable and dependable is the connection?

- Connection stability during extended sessions

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- Required internet bandwidth in each direction
- Network requirements (public IP addresses, firewall settings)
- Built-in tools for monitoring performance
- Maximum supported distance between locations

5. Usability (Very Important)

How easy is it to use in daily teaching?

- System type (standalone unit vs. computer-based)
- Required technical staff for setup and operation
- Typical preparation time needed for sessions
- Training requirements for teaching staff
- Adaptability to different teaching scenarios

6. Data Security (Important)

How secure are the teaching sessions?

- Connection encryption and access control
- Compliance with educational data protection requirements
- Network security implications
- Access management features

7. System Durability (Important)

How reliable and future-proof is the system?

- Hardware robustness and maintenance needs
- Regular technical maintenance requirements
- Manufacturer support and system longevity
- Availability of spare parts and upgrades
- Track record of reliability

8. Cost Analysis (Very Important)

Is the system financially viable across the alliance?

- Initial purchase and installation costs
- Ongoing maintenance and support
- Required facility modifications
- Network infrastructure upgrades, if needed
- Affordability for all alliance members

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