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An analysis of the state of interoperability across Higher Education systems in Europe (Synthesis report)

European Higher Education Interoperability Framework

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This publication was written by a consortium including the German Academic Exchange Service (DAAD, coordinator), Deloitte Consulting GmbH Germany, Deloitte S.L.U. Spain, Knowledge Innovation Centre (KIC), Stifterverband, SURF and EDEN, in collaboration with the members of the EDEH Higher Education Interoperability Working Group.

The European Digital Education Hub (EDEH) is an online community for practitioners from all sectors of education and training aiming to contribute to improving digital education in Europe. To achieve this goal, EDEH is not only a place for exchange and discussions but also offers a variety of different events and activities. These activities included a dedicated workgroup and a series of squads on higher education interoperability. This document is part of the results of these specific EDEH activities.

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Luxembourg: Publications Office of the European Union, 2025

Linguistic version:	*Media/Volume:*	*Catalogue number:*	*ISBN:*	*DOI:*
EN PDF	*PDF/Volume_01*	*NC-02-24-713-EN-N*	*978-92-68-18732-6*	*10.2766/556601*

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Table of Contents

Executive Summary 5

1 Introduction 15

1.2 Objectives 17

1.3 Methodology and data sources 17

2 Virtual campuses in Europe 19

2.1 Vision 19

2.2 Overview of use cases 19

2.3 Insights into the EU-A landscape 21

2.4 Roadmap to create a virtual campus 37

3 Virtual campuses in practice 38

3.1 Methodologies and strategies 38

3.2 Interoperability challenges and practical implications 47

4 European projects and regulations impact 57

4.1 Identity management 57

4.2 Credential issuing and recognition 64

4.3 Regulations 66

4.4 EIF Relation 69

5 Beyond the alliance level 70

5.1 Caveats on the proposed solutions 70

5.2 Way forward 76

Executive Summary

Purpose of this report

This synthesis presents key insights from the interoperability project within the European Digital Education Hub (EDEH). It aims to achieve the following objectives:

- First, it offers an overview of the status of European University alliances (EU-As) on interoperability. It also tracks progress in creating virtual learning environments and inter-institutional campuses. The report focuses on eight use cases that align with a typical learner's journey in Higher Education (HE). These use cases highlight key experiences requiring interoperability between HEIs.
- Second, it identifies common approaches, experiences, and strategies that address interoperability challenges.
- Finally, it examines the scalability of these strategies. This includes application within Alliances, between Alliances, and among individual Higher Education Institutions (HEIs).

This report stems from an inventory mapping and the associated detailed report that presents an inventory of standards and solutions used by EU-As to build interoperable virtual (inter-institutional) campuses. While the inventory gives insights into certain aspects of the technical landscape for technical experts at HEIs, this synthesis report looks at the bigger picture. It analyses the collected data and shows the overall state of interoperability among alliances. It also describes trends and patterns. This synthesis is a key reflection point in the European Higher Education Interoperability Framewor (HEIF) project. Its insights will inform the creation of tools that help implement the framework and interoperability efforts at alliances. These tools include resources for HEIs and a governance model for policy and decision-makers.

Context

Interoperability in HEIs aims to create a seamless learning environment for learners and stakeholders. The European Commission defines it as the "ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their ICT systems"[1]. Interoperability is essential for a learner-centred experience. It allows learners to build personal learning paths. It also allows for smooth mobility between institutions and countries. EU-As are collaborative networks of HEIs across Europe. They aim to pioneer cross-institutional HE experiences on a larger scale than ever before. However, achieving true interoperability is complex. Diverse HE systems pose many challenges to EU-As.

[1] European Commission (2017): New European Interoperability Framework. Promoting seamless services and data flows for European public administrations. P. 5. URL: https://ec.europa.eu/isa2/sites/default/files/eif_brochure_final.pdf.

This report uses EU-As as a model for the HE in Europe and for interoperability initiatives. It examines the challenges and key elements in HE teaching and learning systems. The focus is on the technical aspects of virtual interuniversity campuses, which all EU-As aim to establish. Building on previous inventories and mapping reports from the European Commission's Digital Education Hub's Higher Education interoperability framework initiative, this synthesis report aggregates data from over 40 EU-As[2]. It offers insights to guide future decisions and policies.

The European Higher Education Interoperability Framework

The HE interoperability framework developed under the interoperability project within the European Digital Education Hub (EDEH). It responds to the need for seamless digital teaching and learning across European borders, aligning with the European Commission's Digital Education Action Plan[3]. The framework reflects a shared vision and commitment from HE and policy stakeholders. Their goal is to harmonise digital processes and support student mobility throughout Europe.

The EDEH interoperability framework is built around the **reference architecture. This architecture** outlines the components required to achieve interoperability in core use cases, representing the learner journey. It acts as a central reference point.

To aid the use of the reference architecture, two key resources are available. First, there are implementation resources for HEIs. These resources focus on practical steps for applying the architecture. Second, a governance model designed for policy and decision-makers. This model addresses the broader governing environment.

The reference architecture is complemented by an **inventory mapping. This mapping** is a detailed view of standards and tools used in alliances. It is guided by a manifesto, describing the joint vision of the HE community.

[2] This includes the following EU-As: Arqus, CHARM-EU, CIVICA, CIVIS, E3UDRES2, EC2U, EDUC, ERUA, EPICUR, EU-CONEXUS, EU GREEN, EUGLOH, EUniWell, EUPeace, EuroTeQ, INVEST, NeurotechEU, T4EU, UNIC, UNITA, Unite! and other alliances that have preferred not to be named in reports or are in the process of giving permission to be mentioned.

[3] European Commission: Directorate-General for Education, Youth, Sport and Culture, Digital education action plan 2021-2027 – Improving the provision of digital skills in education and training, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2766/149764.

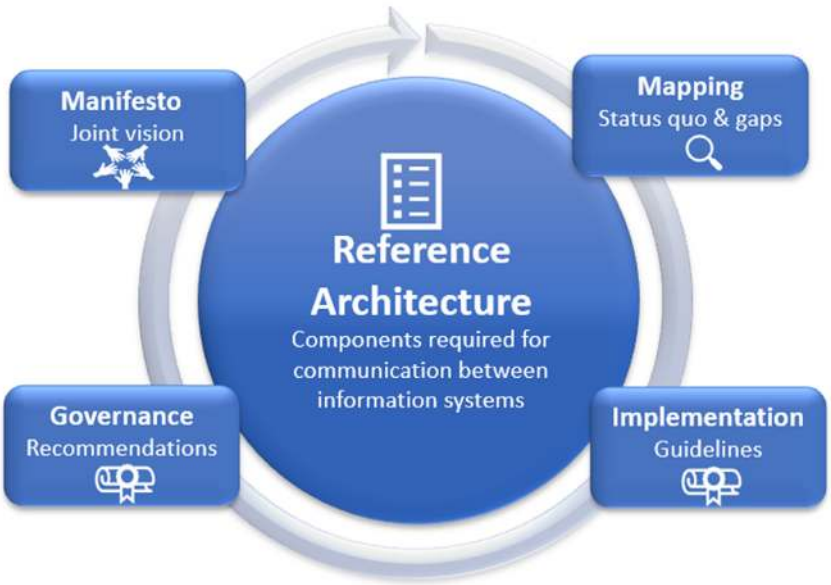


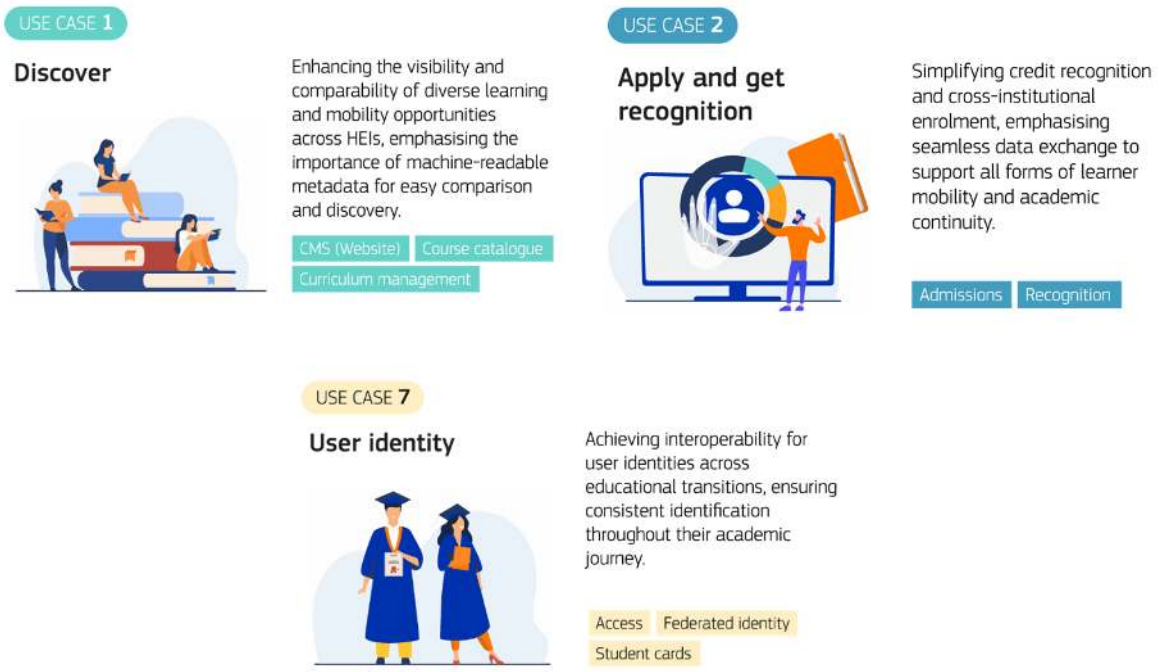
Figure 1 - Overview of the interoperability framework.
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Use cases along the learner's journey

Experts from various working groups collaborated in teams called use case squads. They defined the use cases' focus and scope, including high-level flows and architecture diagrams. From February to October 2024, these squads met regularly. Each squad session lasted three weeks. In total they developed eight well-defined use cases. These use cases follow the learner's journey, which include their entire educational experience across institutions. For example, a joint study programme, or taking courses from another alliance partner. Six use cases describe core experiences in this journey. The other two use cases support the core use cases and lay their foundation.

Key findings: use cases

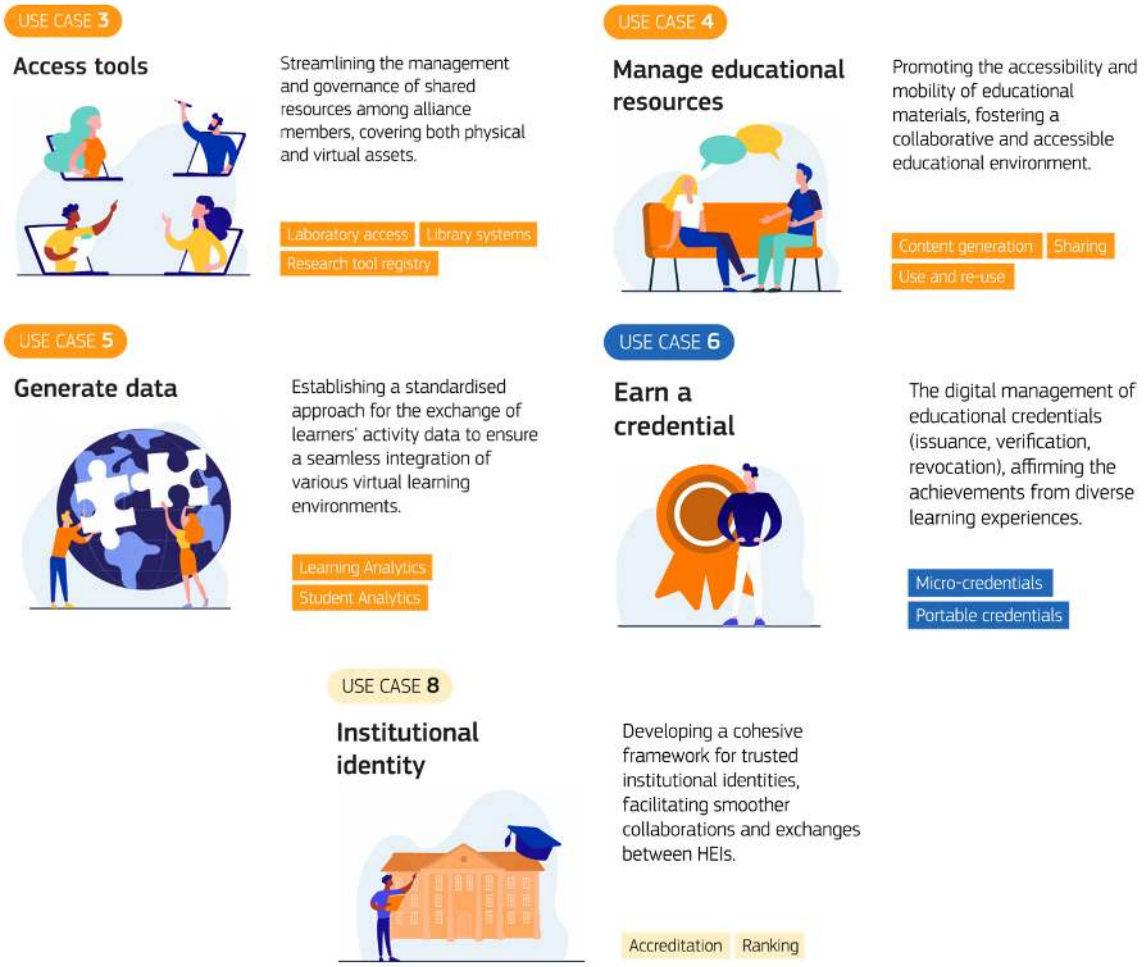
Alliances are committed to interoperability. They focus on key use cases that affect the learner's journey. Among the identified eight three stand out. First, **discovering learning opportunities** and **recognising prior learning and credits are crucial**. These align with the start of a learner's educational path. Next, **user identity is essential**. A cohesive and secure system for this supports core educational processes and enhance the overall learning experience.



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Another priority is **earning credentials** that affirm the achievements from learning experiences. **Institutional identity** is also a key underlying use case.

The last three use cases are: **1)** Co-create and **manage educational resources; 2) Share physical and virtual assets and tools** among alliance members; **3)** Analyse and share **learners' activity data.**



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Key findings: technical landscape and alliance approaches

Against the backdrop of the identified use cases, the state of EU-As was assessed by looking at existing solutions and standards across alliances. This overview of the technical landscape provides insights into potential solutions and guides an alliance's interoperability pathway. By mid-2023, there were 50 alliances with over 80% participating in this project. Through desk research information on the remaining alliances were gathered to provide a comprehensive overall picture. Since mid-2024, 14 more alliances have formed, and they can benefit from the resources developed.

From community sessions, about 400 data points were collected. These points cover solutions and standards used in planning by alliances. They include nearly 300 unique solutions and 50 data standards. However, not all records are complete or accurate. They only show what alliances shared. While there are still solutions not yet implemented, 93 tools and solutions are in progress, and there are 212 active tools.

Regarding licensing and ownership, alliances use a mix of tools. They use open-source, commercial, and self-developed tools, with each category having an equal share.

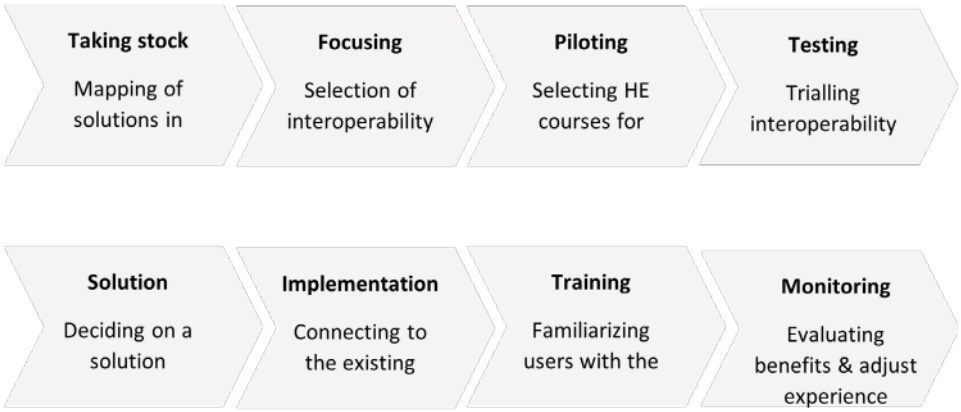
Alliances' journey towards interoperability

Three clusters of alliances show different paths to interoperability:

- **Emerging focus:** These HEIs are starting to approach interoperability. They are taking stock of their systems, defining next steps, identifying key priorities, and performing market analysis.
- **Strong focus:** Here, HEIs have launched pilot projects. They have chosen solutions to implement and set a clear direction to advance interoperability in their alliance.
- **Extensive focus:** Some HEIs have fully operational interoperable workflows for certain use cases. Pilots have progressed through several stages. HEIs are also ensuring that remaining workflows achieve the same level of interoperability.

Three-quarters of the 50 alliances demonstrate an emerging focus. They are familiarising themselves with interoperability and taking first steps towards collaboration. About 10% of alliances are front-runners, having extensively advanced interoperability across their institutions in one or more use cases.

The roadmap that alliances creating virtual campuses involves several steps. The process is not linear. It is agile and iterative, allowing for flexibility and to adaption to changing circumstances and new insights.



Key findings: interoperability challenges

Alliances encounter significant challenges in their journey towards interoperability. Data collection depended on online interactions with individual alliance members and their case studies, which could introduce biases. Additionally, the data only reflect a moment in time. Despite these limitations, the insights are valuable. They reveal the challenges alliances have encountered in achieving interoperability.

Interoperability faces many challenges from technical and legal issues, as well as organisational and semantic barriers. The EU provided resources for alliances to work towards interoperability, but these resources are limited. These financial limitations and a focused sticking to a work plan and completing deliverables often lead to work-arounds or provisional quick fixes, such as manual or semi-automated solutions. While these approaches can deliver quick results, they have considerable downsides: they are not scalable and are hard to maintain. Examples of these manual processes and provisional solutions include:

- **Manual Processes:** Alliances often upload content to course catalogues manually and converting Excel sheets. This process is labour-intensive when done repeatedly and prone to errors.
- **Provisional/Piloting Solutions:** A professor set up a new Moodle LMS for an alliance course collaboration. This was done without clear strategy or agreements on maintenance or data privacy.

To achieve true interoperability, these temporary solutions must consider how to scale up and maintain them sustainably. This approach will pave the way forward. The most pressing challenges leading to these workarounds are technical, legal, semantic, or organisational. Alliance report symptoms of these challenges as follows:

Technical interoperability: Challenges and key aspects to consider are found in:

- Diversity in existing and emerging technical systems across countries: Countries have different technical systems. Some are unique to HE in Europe, while others are specific to individual HEIs.
- Maturity and scalability of existing (sometimes legacy) solutions: Many existing solutions making it hard for institutions to adopt new systems. This is why alliances' virtual campuses strive for unity, with harmonised interfaces and smooth user experiences.

Security concerns: There are concerns about credential fraud, ensuring authenticity of credentials, and verifying the identity of those holding them.

Legal interoperability: EU-As navigate a complex web of legal and policy frameworks at European, national, and regional levels. Despite efforts at European harmonisation, differing implementation of regulations still hinders cooperation. This project's legal interoperability is limited to ensuring alignment with the existing European policy frameworks and agreements. However, certain legal challenges have arisen in collaborations with alliances. These include:

- Data protection and data sharing, especially regarding student information between institutions.
- Software licenses that may restrict sharing and access between teams.
- Intellectual property rights on educational materials which limits resource Sharing.
- Additionally, with the European Accessibility Act set to be implemented by June 2025, new requirements will emerge.

Semantical interoperability: Data models and standards vary across HEIs, complicating data translation between systems. EU-As in the EU lack common standards in key areas, although several widely used standards exist. A solution is to implement a translator component (mapper). This allows HEI data to be converted into standardised format at alliance-level. However, selecting and implementing these standards is challenging due to the diverse landscape. A shared data model depends on a vocabulary that is understood and agreed upon. This is essential for interoperability and for overcoming language barriers between national universities within an alliance.

Organisational interoperability: From an organisational perspective, EU-As are coalitions of institutions working together towards common goals. Each member remains independent, with their own traditions, processes, culture and specific needs. For interoperability, these institutions must align their administrative and educational processes. Developing and implementing solutions are significant challenges. Both require consensus among alliances, often exposing conflicting topics like resource shortages and local process alignment.

Alliances starting on interoperability often have one entity leading on behalf of the alliance. In contrast, alliances with more experience usually feature a central IT team collaborating on development. Outsourcing to a third party is another option, though it is rare. Regardless of the chosen approach, there are different options to select tools - using existing ones from member HEIs or creating new ones. A dedicated team of technical experts is essential in any case.

European projects impact in current interoperability HEI landscape

Several European projects help to address community-identified challenges, like managing identity, course define and recognise courses, and issuing credentials. They support educational institutions in achieving interoperability.

Touching upon several use cases, the European Student Card Initiative (ESCI) sets standards. It offers three key components for academic mobility. First, the European Student Card (ESC) lets European learners access services and facilities across Europe without additional verification. Second, the Erasmus+ App helps learners manage exchanges and find practical information about their destinations. It also offers specific benefits at each institution. Finally, the Erasmus Without Papers (EWP) network creates a digital link between HEIs. This eliminates physical documents and streamlines admissions, equivalence, and transcript processing.

Two additional tools enhance interoperability: the European Student Identifier (ESI) and MyAcademicID. The ESI gives learners a unique identifier, ensuring their data is recognised without duplication or conflicts. MyAcademicID simplifies authentication, allowing learners to access services across different institutions. It is based on the eduGAIN identity federation and connects identity management systems with Erasmus mobility systems, achieving greater efficiency. As part of these systems, the Identity Provider of Last Resort service allows institutions unable to join eduGAIN to join mobility programmes. This ensures that ESCI components are fully inclusive.

Looking ahead, self-managed and decentralised identities will give learners greater control over their data. The European Blockchain Services Infrastructure (EBSI) and its European Self-Sovereign Identity Framework (ESSIF) support this. It allows learners to maintain verifiable credentials on mobile devices, ensuring security and privacy. The EU Digital Identity Wallet (EUDI Wallet) will enable European citizens, residents, and businesses to securely store, manage and access identity, academic, and other digital credentials.

These initiatives align with the EIF and comply with GDPR and eIDAS regulations. They aim to create a secure, accessible, and efficient infrastructure for education and academic mobility in Europe. This alignment allows institutions provide a secure, reliable, and transparent digital experience for learners throughout their academic journey.

Lessons learned

The virtual mapping sessions with EU-As have been valuable for sharing experiences and building peer collaboration. Highlights include:

- **Standardisation:** Common standards and protocols are essential for interoperability across diverse systems.
- **Collaboration:** Sharing best practices is crucial to overcome interoperability challenges.
- **Resource Allocation:** Strategic allocation of resources, including budget and personnel, is necessary for scalable, automated solutions.

Proposed solutions

The main points in more detail:

1. **Solid agreements** are essential. Member institutions of an alliance need these to align with the alliance's goals. This prevents conflicts with their own systems and ensures mutual benefits.
2. Virtual mapping sessions with EU-As served a dual purpose. Besides collecting data, they allow alliances to **share experiences and information at a peer-level.**
3. Three main strategies have emerged: centralisation, decentralisation, and broadcast. Centralisation is the most common approach.
4. The decentralised approach is the most scalable. The other two strategies struggle to support scalability **beyond the alliance level.**
5. There are two approaches to implement mapping systems. One is a central access point with mapping capabilities. The other involves local systems at each institution.
6. For efficient and secure data exchange in educational institutions, several factors are crucial. These include protocol compatibility, adherence to data protection laws, and secure authentication and authorisation for managing student data.
7. Resource inequality poses challenges for smaller or less funded alliances in implementing interoperable solutions, risking a digital divide. Open-source tools can help to reduce these barriers.

Conclusion

Despite ongoing challenges, the commitment to interoperability in HEIs is strong. By addressing budget constraints, prioritising strategies, and building collaboration, a more connected and efficient European Education Area can be created. This will enhance educational quality and support the gradual integration of educational systems across Europe.

1 Introduction

Interoperability in HEIs is a transformative concept that aims to create a seamless and integrated learning environment. According to the European Commission, "interoperability is the ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their ICT systems."[4]

Interoperability is key to unlocking a unified educational experience, enabling institutions to collaborate, share resources, and enhance their learning process. By bridging the gap between different systems and platforms, interoperability ensures efficient and effective exchange of data and services. This not only enhances the quality of education but also fosters innovation and progress.

In the European context, efforts are being made to establish a comprehensive interoperability framework, paving the way for a connected and inclusive European Education Area.

This synthesis report takes a step back to consider the bigger picture. As such, it aggregates the rich data gathered from more than 40 EU-As, generates insights and draws conclusions for decision-making and the way forward in this project and beyond.

The report first sets the scene. Then, it outlines the global vision for virtual campuses in Europe, details the selected use cases, and provides insights into the landscape of EU-As, their priorities, and tools to enable interoperability. Finally, the report focuses on virtual campuses in practice, providing insights into methodologies and strategies applied by EU-As, challenges encountered and lessons learnt in their interoperability journeys, and opens the perspective beyond the alliance level.

By identifying patterns and trends, this report advances the collective understanding of the current state of interoperability across European HE, paving the way for next steps to advance virtual campuses.

[4] European Commission (2017): New European Interoperability Framework. Promoting seamless services and data flows for European public administrations. P. 5. URL: https://ec.europa.eu/isa2/sites/default/files/eif_brochure_final.pdf.

1.1 EDEH interoperability project context

At the core of the EDEH interoperability framework lies the development of a reference architecture, which outlines components required to achieve interoperability for selected use cases and serves as a central point of reference. This is complemented by an inventory mapping that provides an overview of standards and tools used across alliances. A manifesto guides these technical products are guided by a manifesto, outlining the shared vision of the HE community. To facilitate the adoption of the reference architecture, two key resources are provided: implementation resources that support HEIs at the practical implementation level, and a governance model, that addresses policy and decision-makers responsible for the broader environment (see 5.2 Way forward).

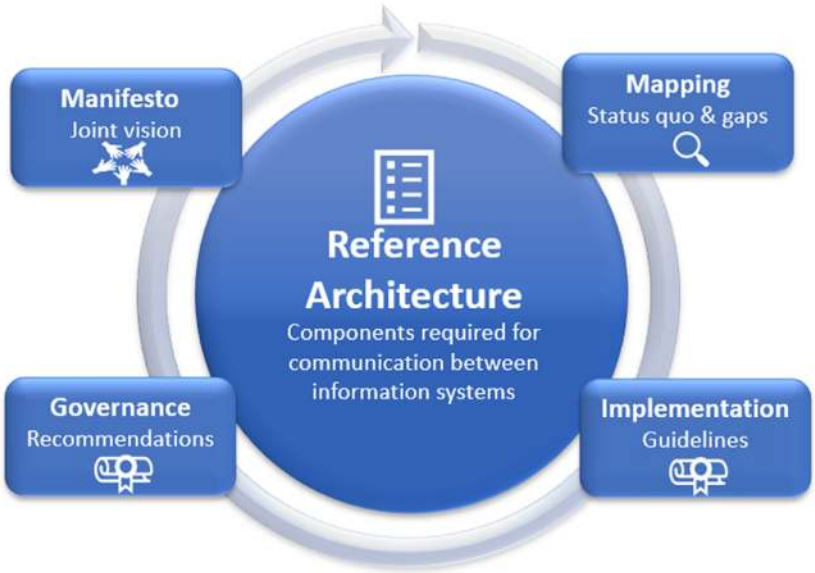


Figure 2 - Overview of the interoperability framework.
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The positioning of this report with the project's overall documentation is detailed below. This will help to clarify its context and significance.

1.2 Objectives

This report is drafted with regards to the following objectives:

- To provide an overview of the status of EU-As concerning interoperability and their progress towards developing and deploying virtual learning environments and inter-institutional campuses. The focus of the interoperability project and this report is on eight use cases, situated along a typical learner's journey within Higher Education (HE). These use cases represent key experiences of learners during their education journeys that require interoperability between HEIs.
- To identify common approaches, experiences, and strategies employed to address interoperability challenges.
- To consider the scalability of these strategies across various scenarios, including within alliances, between alliances, and among individual Higher Education Institutions (HEIs).

This report can guide decision-making in domains such as policy formulation, strategic planning, or research. It presents a comprehensive picture of the current state in the landscape of HEIs and pinpoints areas that need further investigation.

The findings of the draft synthesis report were disseminated in a webinar for participants from EU-As and other interested parties in the second half of June 2024.[5] Towards the end of June, a more in-depth, technically oriented one-day workshop was held in-person in Brussels. This workshop reviewed progress and discussed outcomes from the mapping exercise, this synthesis report, and the use cases. It aimed to align priorities and the way forward with experts and the community for the rest of this project, until end of February 2025.

1.3 Methodology and data sources

Data collection was conducted over 14 online mapping sessions from February to June 2024. During these sessions, participating alliances shared insights into their current status regarding interoperability, planned projects, roadmaps, and challenges faced.

Additionally, data collection was supplemented by a) alliances providing original documents, such as their technical documentation, development plans, and other documents for review and b) alliances providing direct input into the mapping sessions, shared with them through the European Commission's Teams platform. This data collection file asks for qualitative information, such as their priorities regarding use cases, tools and standards used or investigated and planned to be used.

[5] Webinar: Overcoming interoperability challenges in European higher education - European Education Area (europa.eu)

Out of a total of 50 alliances established by mid-2023[6], more than 80% (41) have been involved in this process in one or more ways[7]. Since mid-2024, a further 14 alliances have been established[8] that can benefit from the developed guidelines and resources going forward.

Across the eight use cases, data collection resulted in approximately 400 data points. They covered solutions and standards implemented or planned by alliances, which translated to almost 300 unique solutions and approximately 50 data standards. The available data was analysed for this report to identify patterns and trends in line with the objectives outlined above. Key insights and conclusions are presented and supported by data visualisations.

The mapping report's insights were challenged and refined at the online and in-person events with experts. They were also refined by feedback received on the report and an analysis of the feedback as noted above.

The mapping report's insights were challenged and refined at the online and in-person events with experts. They were also refined by feedback received on the report and an analysis of the feedback as noted above. To ensure common understanding, key terminology used in the context of this project and report is elaborated upon. Additionally, a comprehensive glossary of terms is provided.

[6] Cf. 50 European Universities to cooperate across borders and disciplines | European Education Area (europa.eu)
[7] This includes the following EU-As: Arqus, CHARM-EU, CIVICA, CIVIS, E3UDRES2, EC2U, EDUC, ERUA, EPICUR, EU-CONEXUS, EU GREEN, EUGLOH, EUniWell, EUPeace, EuroTeQ, INVEST, NeurotechEU, T4EU, UNIC, UNITA, Unite! and other alliances that have preferred not to be named in reports or are in the process of giving permission to be mentioned.
[8] Cf. New funding for additional European Universities alliances will boost cooperation in higher education | European Education Area (europa.eu)

2 Virtual campuses in Europe

For context, the following chapters begin by outlining the vision for virtual campuses, as stated in the project's manifesto. They continue with an overview of the eight key use cases. After this, the results of the data analysis are presented. Patterns are highlighted, and insights into the priorities set by EU-As are offered.

2.1 Vision

At the start of this project, the HEI community set out to develop a shared vision across alliances for creating an interoperability framework and virtual campuses. This resulted in a publicly published manifesto[9], which was widely shared within and beyond the community. By utilising technology, the framework will eliminate barriers, streamline processes and solutions, and provide orientation, enabling HEIs to refocus on their core activity of educating learners. While building on existing foundations and creating interlinkages, alliances remain open to individual solutions. EU-As envision an ecosystem of virtual campuses that promotes a vibrant and diverse landscape, characterised by transparency, interaction, and interlinkages between HEIs, policymakers, and the private sector. In the long term, interoperability will extend beyond HEIs to include primary and secondary education, vocational training, and adult education, adopting a comprehensive and learner-focused approach to lifelong learning.

2.2 Overview of use cases

Defining concrete use cases was the main objective of the first stage of the assignment. Experts explored, in several meetings of the HE Interoperability Workgroup and the Core Expert Group, the goal of supporting inter-university campuses. From the learner's perspective, they identified key points in a learner's HEI journey that required interoperability. The first Design Thinking workshop (January 2024) concluded this discovery stage, resulting in eight use cases, as displayed and described in the following overview.

This overview breaks down the learner lifecycle into six core use cases (use cases 1 to 6), covering orientation, application, education, and certification. Additionally, two supporting use cases (use cases 7 and 8) were identified, describing transversal capabilities essential to several core use cases.

The initial use cases were further developed, detailed, challenged, and refined in use case squads. A series of consecutive squad sessions was organised for the eight focus use cases, running from February to October 2024. These squads were led by an expert from the consortium and supported by a squad co-lead selected from the core expert group. Members of the wider group were invited to join as many squads as they wish to test, validate, and propose changes to high-level flows and architecture diagrams in a series of working

[9] Higher-Education-Interoperability-Manifesto_December-Draft.pdf (daad-brussels.eu)

sessions held online. Each squad run over a period of three weeks, with a start and a closing session with the squad members in weeks one and three. Internal refinement work was conducted in between. This resulted in eight well-defined use cases.



Figure 3 - Overview of use cases.
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For each use case, experts identified a set of concrete user stories from the perspectives of learners, educators and administrative staff, which further flesh out the use cases.[10] The squad meetings have facilitated the development of high-level workflows, clearly defining the main business processes for the use cases. Additionally, with the expertise of professionals in the field, architecture diagrams and reference architectures have been modelled to represent interoperable solutions applicable to current infrastructures.

2.3 Insights into the EU-A landscape

A stock-taking exercise was carried out to assess the current situation at EU-As and to inventory existing solutions, set against the backdrop of the identified use cases (see chapter 1.3 Methodology and data sources). Analysing the collected data revealed key insights into EU-As' interoperability status, their priorities, and the tools they use. It also outlined their roadmap for establishing virtual campuses.

Alliances' focus on interoperability

Using an inductive approach in data analysis, three clusters emerged. They reflect different intensities in alliances' focus on achieving interoperability.

- **Emerging focus:** HEIs within alliances are approaching the topic of interoperability. They are conducting system inventories, defining next steps, identifying key points to prioritise, and performing market analysis.
- **Strong focus:** HEIs have launched some interoperable pilot projects. They have decided which solutions to implement and how to advance interoperability within their alliances.
- **Extensive focus:** Fully operational interoperable workflows can be observed at HEIs within alliances, with some pilots having progressed through several stages. Also, HEIs are actively working to ensure that the remaining workflows reach the same level of interoperability.

[10] More details on all eight use cases can be found in the European Higher Education Interoperability Framework, Publications Office of the European Union, 2025, https://data.europa.eu/doi/10.2766/851374

As can be observed from the collected data[11], the vast majority of EU-As demonstrate characteristics for having put an emerging focus on interoperability, as defined above. Existing solutions are being explored for evolution, systems are being inventoried, or efforts are being made to determine how to adapt their current situation to new digital tools available. Slightly less than 20% of alliances can be described as having put a strong focus on interoperability efforts. Around 10% of alliances can be described as front-runners, having focused extensively on advancing towards interoperability across their member institutions in one or several use cases.

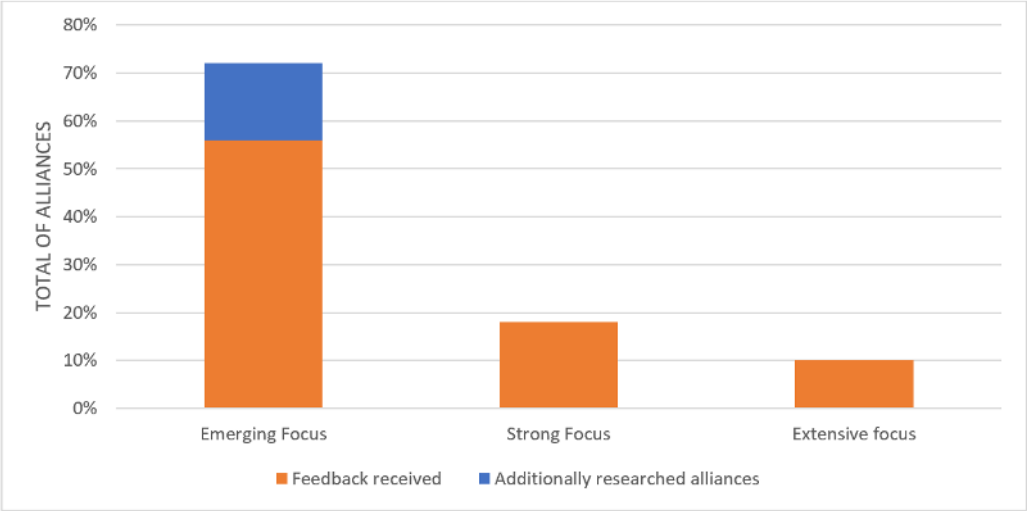


Figure 4 - Current interoperability status landscape.
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While alliances have made significant efforts to enhance interoperability between their institutions, five alliances have placed extensive emphasis on interoperability as described above. For instance, two alliances from the first cohort of EU-As will provide further insights into interoperability in action, enabling virtual inter-university campuses.

[11] To arrive at an overall picture that is as comprehensive and complete as possible, the data for this instance includes data collected from the 41 alliances that took part in the mapping exercise. In addition, desk research was conducted on the remaining nine alliances. For the sake of transparency, the two different categories of data collection were clearly distinguished in Figure 4.

The European Partnership for Innovative Campus Unifying Regions (EPICUR) has developed the Virtual University Registrar System (VURS) based on the open-source Universis software, providing a comprehensive Student Identity System. This system features essential components, including course discovery, applications, course content management, and class management. It delivers numerous services in various ways, such as student applications and a course catalogue portal. Several alliances have reported that EPICUR serves as a reference for them, highlighting its influence and contribution to other alliances.

The University Network for Innovation, Technology and Engineering (Unite!) connects nine universities. Unite! has fully implemented existing solutions like Moodle, OpenBadges, and eduGAIN, which cover the use cases described in our project. They have also developed the necessary components for deeper interconnectivity, such as plugins for their existing solutions, integration with others, or incorporating Learning Tools Interoperability (LTI). Many of the solutions in place in this alliance are open-source tools, making Unite an interesting case to explore. The alliance has conducted a thorough analysis of the challenges ahead and partially identified solutions. For instance, regarding the differences in copyright rules across European countries and the cross-country use of materials, a solution could be using Open Educational Resources (OER) or further investing in technical means.

While acknowledging the importance to advance interoperability and deploy and develop infrastructures, EU-As are faced with the complexity, challenges, and concerns that the process brings with it. Tight digitisation schedules, resource constraints and the uncertainty of budget availability to allow for long-term planning, the need to standardise business processes between institutions within an alliance, and the different regulatory frameworks in each country can lead to situations where functional solutions are favoured over interoperable ones due to their lower time and resource demands. This often results in the adoption of solutions and standards that are tailored to the immediate needs of the institutions and might be of ad-hoc, provisional or semi-manual nature. As a result, the range of solutions implemented becomes wide, leading to fragmentation within the European HE ecosystem and underlining the importance of this EU-level project. (see 3.2 Interoperability challenges and practical implications).

Priorities

Based on the data collected from EU-As, certain priority themes and topics have emerged. These are detailed in the following analysis, which illustrates and describes the current landscape of interoperability.

Focus areas

When it comes to data collection for each use case, alliances can be grouped into three categories. Firstly, some provide information on the tools and standards used for the use case. Secondly, some explicitly mark a use case as non-priority, giving a reason. Lastly, some do not provide any feedback on the use case at all. The information provided across the use cases varies, offering interesting insights into the alliances' priorities.

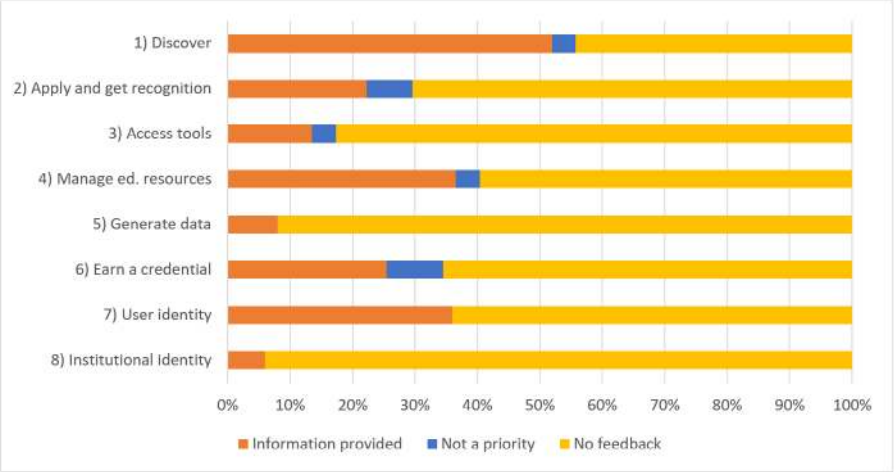


Figure 5 - EU-A feedback received on use cases.
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Following the results from the mapping sessions, alliances give the most attention to use case 1 (discover), with half of the participating EU-As providing information on the discover use case and detailing their use of tools and standards. This might be because the discovery phase of learning opportunities is at the beginning of a learner's journey, making it a natural starting point for advancing interoperability. Next, around a third to nearly half of alliances provide information on use cases with a strong learner focus: 2 (apply and get recognition), 4 (manage educational resources), 6 (earn credential), and 7 (user identity), which supports the core use cases with a learner focus.

In contrast, indications of use cases not being a priority are clearly in the minority. This mainly concerns use cases 6 (earn credential) and 2 (apply and get recognition), and to a smaller extent, use cases 1 (discover), 3 (access tools), and 4 (manage educational resources).

The lack of feedback on use cases suggests that the concerned use case is not a current priority for the alliance, although not as strongly as explicitly labelling it a non-priority. Deprioritising use cases does not equal their importance, but might be due to limited resources, such as personnel, time, and budget, which require active allocation (see chapter).

Future plans

Some alliances reported on plans to use some tools and solutions to improve interoperability within their alliance. These plans and concrete ways ahead also give indications for the alliances' priorities with regards to use case implementation. The top three use cases for alliances to focus on are, in order: managing educational resources (use case 4), user identity (use case 7), and discovering learning opportunities (use case 1). Data generation (use case 5) is a close fourth.

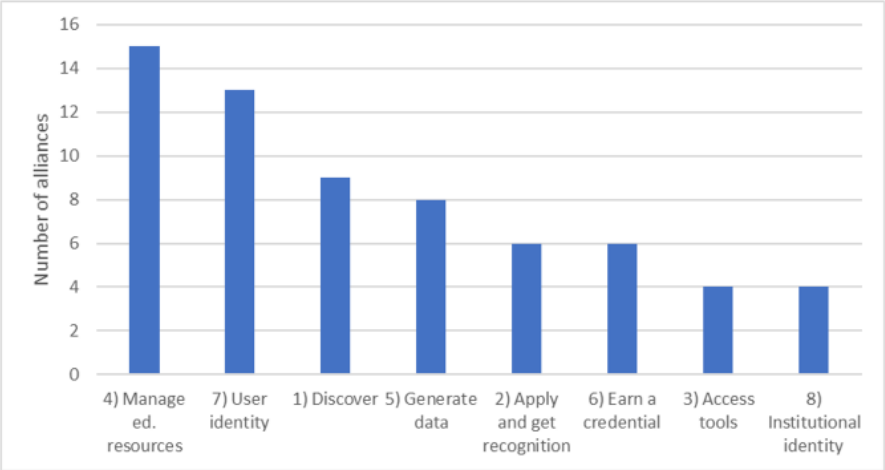


Figure 6 - Future priorities of alliances based on tools planning.
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These initial results on use case prioritisation have been further discussed during the in-person event in Brussels in June 2024 and participants were asked to vote on the use cases. Each participant had three votes in total: one for the highest priority use case and two for use cases they consider at the second highest priority. To the broad extent, the results from the voting exercise confirm the initially outlined priorities.

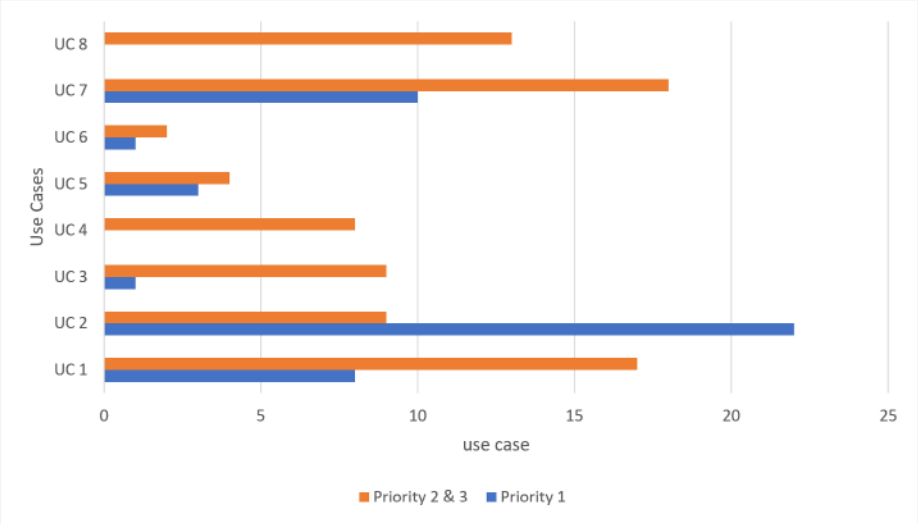


Figure 7 - Use case prioritisation at the Brussels event.
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With regards to priority one, the top three ranked use cases, in order of priority votes received, were use case 2 (Apply and get recognition), use case 7 (User identity), and use case 1 (Discover). The latter two use cases also received very high second and third priority votes, clearly highlighting their importance. Combining all voting categories, including priority one, two, and three, shows a similar picture. The same top three use cases are followed by use cases 6 (Earn credential) and 8 (Institutional identity).

These results highlight the importance that alliances place on serving learners by providing a smooth start and end to their HE mobility journey. They also demonstrate a forward-looking perspective, taking care of the foundational layer required as a prerequisite for many core use cases.

From the info in the use cases, future plans, and the vote, we can derive these interpretations:

Discover (use case 1):

At the start of the learner's journey, learners get their bearings and find out about learning opportunities. Alliances have made this use case a priority, focusing on both implementation and future planning. They mainly use central catalogues to showcase their educational offerings, attracting new learners and research staff. This use case involves cataloguing and standardising course data to create efficient ways of aggregating data in a central catalogue.

Apply and get recognition (use case 2):

Despite the challenges of integrating different student information systems (SIS), this use case has clearly emerged as a top priority. This is because it encompasses all student mobility plans, along with the challenges associated with agreements and the subsequent recognition of qualifications. Furthermore, its interdependence with other use cases beyond the foundational ones (use case 7 and use case 8) adds to its importance. Use case 1 is closely related to this case, as defining courses and learning outcomes becomes crucial when creating mobility plans and aligning courses from different institutions. Similarly, use case 6 is linked through the recognition of the generated credentials.

Access tools (use case 3):

This use case deals with shared access to physical and digital tools and resources, posing challenges such as reservation systems and identity federation. As one of the least prioritised use cases, it does not form a basic part of the learner's journey. It rather may be reserved for advanced stages of interoperability.

Managing educational resources (use case 4):

Sharing and collaborating on educational resources is a very common scenario where interoperability is necessary. This use case has the highest number of alliances reporting plans for tools to enable interoperability. The associated challenges include, for instance, copyright aspects.

Generate data (use case 5):

Although no alliances have explicitly marked this use case as low-priority, it is one of the two use cases for which only a very small number of alliances have provided information. This may be due to challenges with this use case in different fields. These include intellectual property, sharing sensitive learner data, and the effort to standardise and interconnect systems. As more alliances improve their interoperability, this use case will likely become a priority.

Earn credential (use case 6):

This use case is crucial in a learner's journey. Although around 40% of alliances provide information, it is a focus area. However, it is also the most deprioritised use case. Alliances mainly deprioritise it because they plan to focus on it later, showing they understand the importance of earning credentials for learners. Specifically, eight alliances report having tools planned for implementing this use case.

User identity (use case 7):

As a supportive use case, user identity lays the foundation for many core use cases, such as enrolment processes and access to educational tools. It is no surprise, then, that this use case ranks second highest, both in the voting exercise and in terms of the information it provides for inventory mapping.

Institutional identity (use case 8):

The picture that emerges for use case 8 is very similar to that of use case 5 on data generation, where only a small percentage of alliances have provided information. One reason for the low overall prioritisation of this use case might be the number of alliance members. Currently, the average number of HEIs per alliance is nine. With such a small number of institutions, close trust-based relationships can form the basis for cooperation and be managed manually, without an urgent need for automated, scalable approaches to verification and proof of institutional identity.

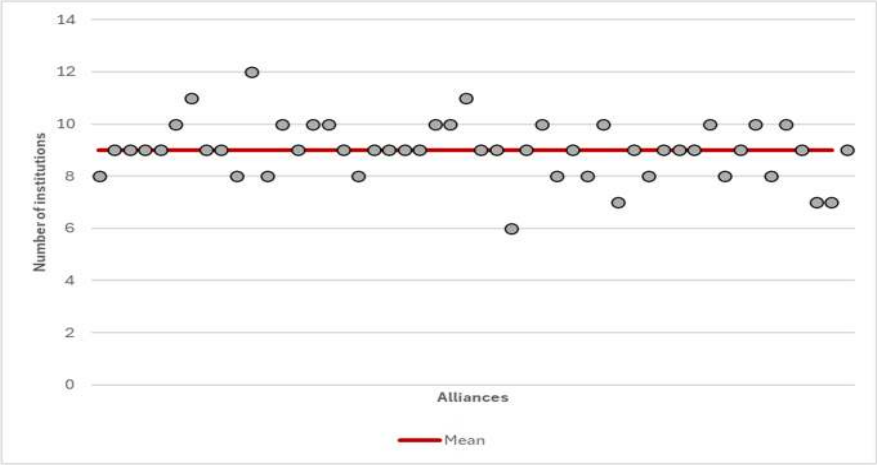


Figure 8 - Number of institutions per Alliance.
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Yet, although the average number of institutions per alliance is relatively small compared to the total number of institutions, it is sufficient to create a diverse ecosystem within an alliance. This ecosystem confirms the alliances' main concerns about interoperability.

As cooperation in the European HE landscape expands, i.e., moving from intra- to inter-alliance cooperation and interoperability, this use case will become increasingly important and relevant for ensuring secure partnerships and smooth cooperation with recognised institutions.

As cooperation in the European HE landscape expands - widening the scope from intra- to inter-alliance cooperation and interoperability - this use case will become crucial. It will ensure secure partnerships and smooth cooperation with recognised institutions.

Tools

The following chapter offers insights into the tools and systems alliances use to achieve greater interoperability.

Tools in numbers

Across all use cases, alliances reported using or considering over 300 tools, including those applicable to multiple use cases. When we look at the distribution of tools across use cases, a striking picture emerges. Nearly 100 distinct tools are actively used or planned for use in use case 4(testing and resource management), followed by over 60 tools used or planned for use case 7 (user identity).

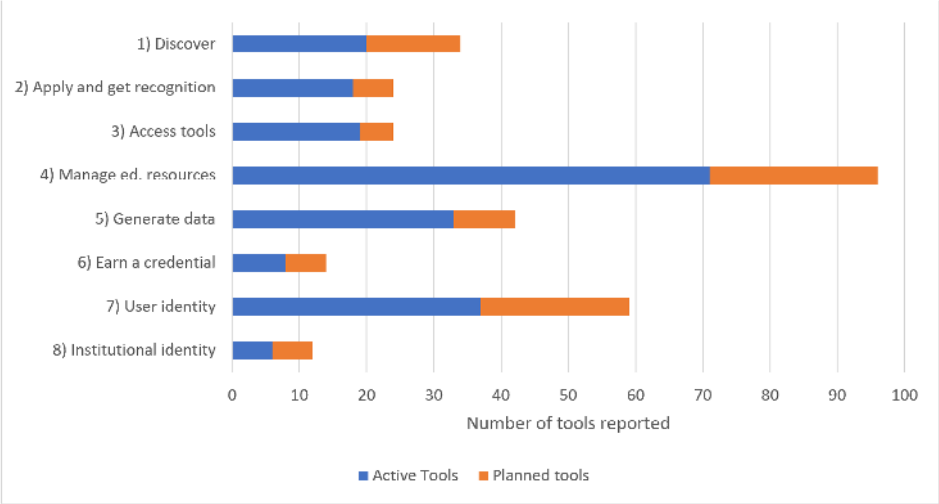


Figure 9 - Number of distinct tools reported by alliances across the use cases.
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These results could be due to various reasons, such as the availability of many tools and solutions that meet the particular use case's requirements. However, it could also imply the opposite: the use case may have very specific needs that are not clearly addressed by one tool or solution, requiring the combination of several tools and/or the development of custom tools.

On the other hand, across all use cases, alliances reported nearly 50 unique standards, either in use or being considered for implementation. The most numerous standards were those on identity and courses. They were, respectively, use case 7 (user identity) and use case 1 (Discover).

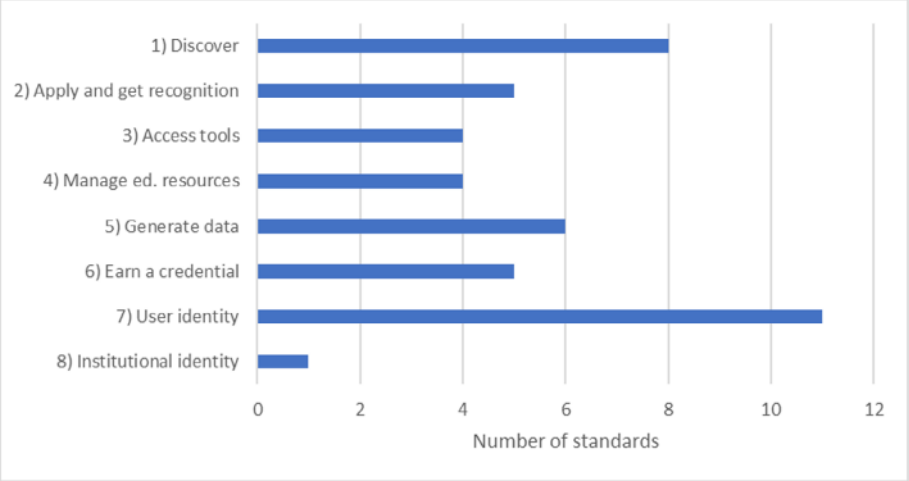


Figure 10 - Number of standards per use case.
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As with the tools, the standards reveal a limited number of elements dedicated to use case 8 on institutional identity. Although the mapping sessions do not cover the entire landscape of standards, the information provided by the alliances appears to represent some of the most popular or versatile standards, as they can be applied to multiple use cases.

During the mapping sessions, Open Badges was one of the most frequently mentioned standards, primarily used in use case 6 on credential generation, but also in use case 2 on apply and get recognition. In addition to Open Badges, the alliances most commonly reported LTI and LOM, as they are useful for several different use cases.

Licences

Regarding their licensing and ownership, tools and systems were sorted into three categories: a) commercial/ proprietary tools that require purchasing closed licences, b) open-source tools with a cost-free open licence, and c) tools developed by the alliances themselves.

The values of community, collaboration, and co-creation are embodied in the concept of open source. Moreover, open-source tools only incur underlying costs related to hosting, systems management, etc., with

no purchase fee involved. This makes them easily accessible, suggesting that open-source tools might be a favourable option for alliances. Self-developed tools are customisable. Though, they take time to develop. They need dedicated IT staff to maintain them, which adds costs.

Across all use cases, open-source tools are the most prominent ones. However, the proportions between open-source, commercial, and self-developed tools are very similar. Each takes around a third of the overall share, although open-source tools predominate.

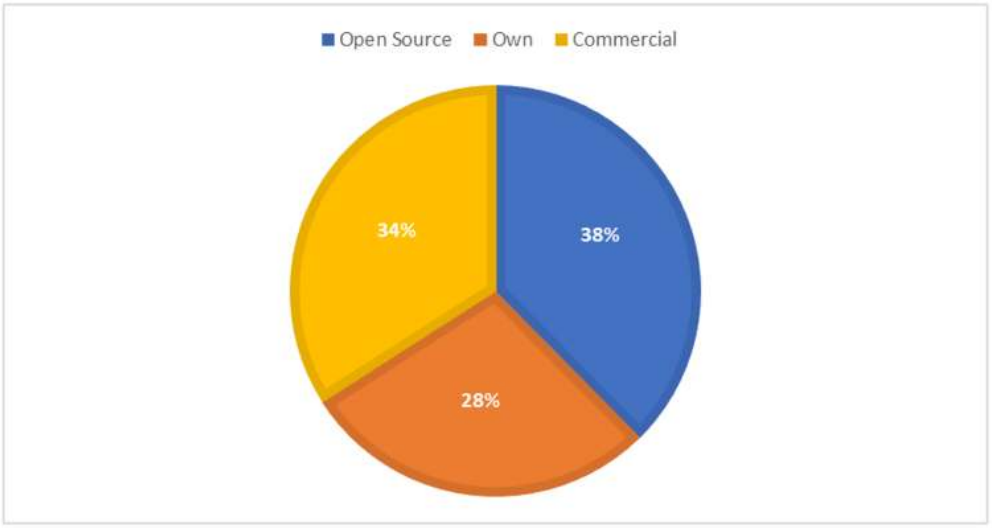


Figure 11 - Breakdown of types of tools used by alliances.
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To facilitate a better understanding, the tools used will be categorised and broken down according to their individual use cases. This will provide insights into how alliances address interoperability. It will also show the solutions they are using to create efficient, connected virtual campuses.

The distribution of commercial, open-source, and self-developed tools across the use cases is as follows:

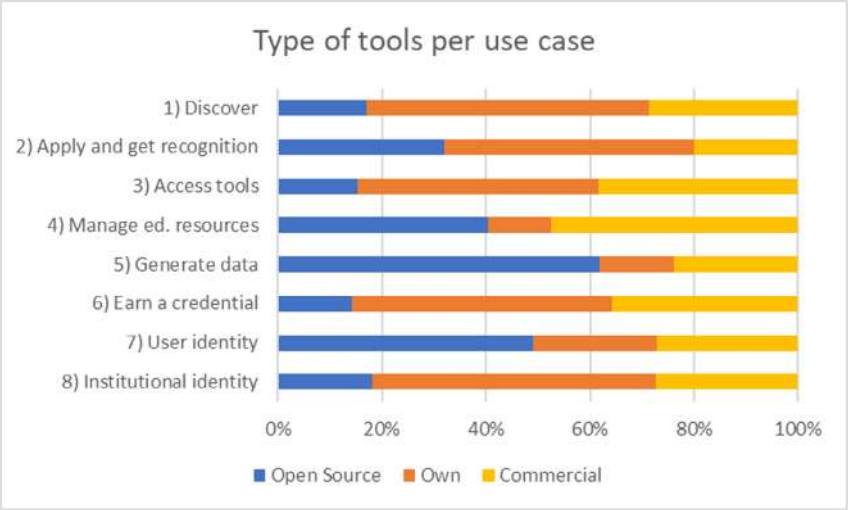


Figure 12 - EU-A feedback received on used tools per use case.
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Across the use cases, the picture of tools used is rather heterogeneous. Use cases 4 (manage educational resources) and 5 (generate data) show the clearest use of tools available on the market, both commercial and open-source. Those are closely followed by use case 7 (student identity). Nearly 90% of the tools used for the first two use cases are either commercial or open-source; for the latter use case, their share is around three-quarters.

For five of the use cases - 1 (discover), 2 (apply and get recognition), 3 (Access tools), 6 (Earn credential), and 8 (Institutional identity) - around half the tools used are the alliances' own developments.

This might indicate a lack of available tools in both the commercial and open-source markets. Alternatively, it may suggest that the challenges arising from the heterogeneity of systems within institutions can only be resolved with highly customised tools.

For the individual use cases, the following interpretations can be derived:

Discover (use case 1):

Around half of the tools in this case are own developments from the alliances. This large share can be explained by the challenges this use case presents regarding data standardisation for subsequent grouping and filtering in the central catalogues of virtual campuses. As they are tailored to specific requirements, custom solutions can address homogeneous standards more precisely.

Tools insights:

- **Open source:** The most chosen open-source solution is EduXchange.
- **Commercial:** There is no single commercial tool that predominates in this use case. Popular commercial tools used include Fullfabric, ILIAS, and Vortex.
- **Own:** Several internally developed tools for this use case are based on UniverSiS technology, which is an open-source project.

Apply and get recognition (use case 2):

Roughly half of the tools are developed in-house by the alliances. The proportion of open-source tools is higher than in the previous use case, with about a third of tools being open-source. Achieving compatibility between catalogues, student information systems, and application forms is challenging due to different data models. Many alliances have created forms for students to apply for courses in their catalogues, while others have adopted integrated systems that automate and digitise the entire process. In the current solution landscape, many application processes are still handled manually and outside of system interfaces.

Tools insights:

- **Open source:** The most commonly used open-source tool in this use case is EduXchange.
- **Commercial:** As use cases 1 and 2 are closely related, some commercial tools reappear, covering some of the needs of this use case, such as Fullfabric.

  LimeSurvey, stands out for its frequent use in this case, utilised for collecting user data during the enrolment phase. This is also a good example of a "hybrid" case: LimeSurvey is open-source software and also has a commercial hosted offer ("software as a service") with additional features.
- **Own:** As referenced in the open-source section, many tools developed by the institutions themselves are built on EWP. UniverSiS is also used here, as in use case 1.

Access tools (use case 3):

The mix of systems causes issues in identity management and resource allocation. This leads to the development of custom tools. Their share is similar to the previous use cases, at around 50%. This time, commercial solutions also take a significant share, with over 40% of tools reported.

Tools insights:

- **Open source:** Although they do not have a big share in this use case, alliances using open-source tools make use of tools such as Mahara, Crownlab or Edu-sharing.
- **Commercial:** The identified commercial tools include Bloom Hub. It is a platform that supports HEIs by centralising information and improving operational efficiency.

- **Own:** There are many self-developed tools. They range from databases that expose certain tools to custom CMS implementations using WordPress, adapted to the alliances' needs.

In all three cases, the eduGAIN federation is often used for implementing cross-institutional Single-Sign-On (SSO) systems. Institutions can use various – commercial, open source or own – tools to connect to the eduGAIN network.

Managing educational resources (use case 4):

In use case 4, self-developed tools account for the smallest share across all use cases. This is due to the wide range of educational resource management solutions available on the market, which cover most of the needs identified for this use case. Over the years, there has been a demand for such solutions, resulting in a multitude of offerings, both commercial and open-source.

Tools insights:

- **Open source:** Among open-source tools Moodle stands out as the most used tool by alliances in this use case. Its free basic version covers the needs for this use case, although it offers some paid features. Nextcloud is another frequently mentioned tool, allowing for sharing and collaborating in the creation and management of resources.
- **Commercial:** Blackboard is perhaps the most well-known alternative to open-source Moodle in the commercial space. Additionally, alliances use tools like Microsoft Teams or Zoom for this use case. Although not Learning Management Systems (LMSs) and general-use rather than education-specific tools, they offer functionalities that prove useful for this use case.
- **Own:** Internally developed tools in this use case represent barely 10%. These tools have similar functionalities to those mentioned earlier but are tailored to the specific methodologies and internal processes of the alliances.

Generate data (use case 5):

In this use case, the proportions of market vs. self-developed tools are similar to those in the previous use case. The introduction of Learning Record Stores (LRS) explains this similarity, as they may be integrated into the LMS itself in some cases. As a result, many tools relevant to use case 4 are also suitable for this use case. Here, tools are as important as the standards they support, since it is crucial that generated data can be stored and shared in a standardised way. This use case has the highest presence of open-source tools, with approximately 60% of tools falling into this category.

Tools insights:

- **Open source:** As in the previous use case, Moodle continues to be the prevailing open-source tool. Moreover, it is compatible with data standards like SCORM and xAPI, which makes it easier to integrate with other systems
- **Commercial:** In the commercial tools category, in addition to Blackboard, which supports the xAPI standard, there are others like Canvas LMS, which is compatible with the SCORM standard.
- **Own:** Since both commercial and open-source markets offer a wide range of solutions for this use case, self-developed tools are scarce. In this regard, self-developed tools have been specifically created for generating content, like tests/exams or repositories, where users' results can be directly stored.

Earn credential (use case 6):

This use case has the fewest reported tools. The low priority given to it by alliances may be the reason, as it represents a later stage in the learning path and may not be a current priority. Of the reported tools, around 40% are self-developed, and around a third are open-source.

Tools insights:

- **Open source:** As an open-source tool, UniverSiS appears again, helping to implement support for micro-credentials. OpenBadges also appears, a widely followed standard that brings many benefits in terms of interoperability. The European Digital Credentials for Learning (EDC) is used by several alliances, and it comes with an open-source tool for issuing compliant credentials.
- **Commercial:** As a commercial implementation of OpenBadges, Bestr offers sufficient capabilities to meet the needs of this use case in terms of credential interoperability.
- **Own:** Edubadges is the platform for digital certificates, including micro credentials, for the Dutch education sector. It is also based on the OpenBadges standard.

User identity (use case 7):

In this use case, the challenges of user identity across different learning platforms and systems overlap with those in many other sectors. As a result, the range of available open-source solutions can cater to most of the needs that may arise from this use case. This is evident in the number of open-source tools registered for this use case, which make up half of the total registered tools.

Tools insights:

eduGAIN is by far the most used existing network to manage identity federation. Given that most HEIs in Europe are already connected through their national federation (NREN), it is not surprising that the use of eduGAIN is a straight-forward solution.

- **Open source:** Different open-source tools are used in connection with eduGAIN. Although less commonly used, another open-source tool registered for this use case is RegApp.
- **Commercial:** Among commercial tools, Microsoft AD (Active Directory) stands out because it is frequently mentioned. It is Microsoft's solution for managing user identities.
- **Own:** In the area of self-developed tools, custom implementations of the European Student Card (ESC) and identity federation systems are prevalent. These systems are interconnected within alliances, enabling access to resources among member institutions.

Institutional identity (use case 8):

This use case has collected the fewest tools. This aligns with the priorities section, where it was mentioned that this use case currently has one of the lowest priorities among alliances. There are a few open-source tools in this case, and nearly half of the registered tools are internally developed.

Tools insights:

- **Open source:** As in the previous case, the eduGain inter-federation appears again. This is because eduGAIN and national federations manage institutional identity as a pre-requisite for federated user identities.
- **Commercial:** For this use case, the commercial tools mentioned mainly refer to their public-facing identity, as seen on their website, e.g. WordPress and various database software.
- **Own:** As mentioned before, this use case is still at a very early stage of maturity, so there are not many self-developed tools available yet. However, the registered tools align with the institutional authentication and validation processes required for this use case.

2.4 Roadmap to create a virtual campus

Based on the data gathered and the exchanges with alliances, patterns emerged regarding the steps alliances took to create virtual campuses. This chapter outlines the general steps alliances followed in their journey to advance and achieve interoperability. Note that this process is not linear. It involves agile and iterative elements that allow for flexibility and adapt to changes in circumstances and new insights that arise during the process.



Figure 13 - Steps to create a virtual campus.
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On a more general note, every change process, like the one described above, should be built on continuous dialogue and transparent communication with stakeholders. This involves keeping learners informed about their course being piloted and tested for potential new solutions that enable enhanced interoperability. Crucially, this communication ensures all stakeholders are on board and understand that initial teething problems may arise.

3 Virtual campuses in practice

3.1 Methodologies and strategies

Building on the current landscape, this report presents the strategies employed in practice for implementing virtual campuses of alliances. Three main strategies can be observed: a) centralisation, b) broadcast, and c) decentralised. These strategies represent different ways of meeting the same needs in situations where a range of resources need to be shared. As such, they can be applied to the defined use cases to create an interoperable solution. Moreover, they can be used as a basis to modify and adapt them to the specific needs of institutions, even creating hybrid solutions.

Sessions with alliances have shown that the most common strategy for applicable use cases is centralisation (either full data centralisation or metadata centralisation). This strategy is quite popular as it can adapt to many different scenarios during implementation. For instance, it is common in alliances with limited budgets, as it can be combined with manual or semi-manual processes. For example, transferring course data from a local system to the alliance‘s centralised system for the discovery use case avoids the need to map the data to a compatible standard (such as those in the semantic layer, which section 3.2 will address in more detail) or to develop a service that makes requests to a central repository or to other repositories within the alliance. Another reason why the centralised strategy (specifically for sharing metadata) is very common is that by storing only the metadata centrally, it allows compliance with privacy, data protection, and intellectual property regulations, since the actual content does not leave the local system.

a) Centralisation

Approach 1: Centralisation of full data

In this strategy, a central system stores a full copy of every piece of information, along with its metadata. When an end user needs to access a particular piece of content, they send a query to the central system, which then returns a copy of the local content. Another point to consider with this strategy is that the central system is also responsible for deciding whether the user has permission to access these resources.

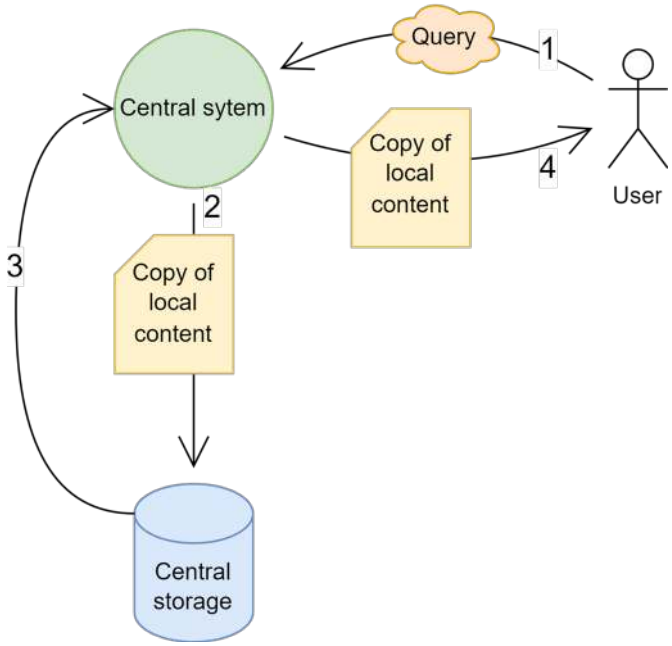


Figure 14 - Centralisation strategy.
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Approach 2: Sharing of metadata

This strategy is a variation of the centralised approach. It avoids data duplication by storing metadata from different local systems in a central system, which facilitates the user's search process. When a content query is made, the central system sends the metadata of the original data, along with the required content attributes, to end users, allowing them! to access local copies. The central system redirects to the local system, which only delivers the content after verifying the user's access permissions. This approach is more efficient in terms of storage and space management. It also provides advantages in terms of data protection and intellectual property, as it does not share all local system content with third-party systems (central

server). Centralising metadata in a well-organised repository makes it easier for users to discover, access, and understand available data, improving data retrieval and utilisation efficiency and facilitating more effective decision-making processes.

This strategy lets institutions improve interoperability by using standardised metadata. This enables different systems to communicate and exchange data more effectively, leading to more seamless integration and collaboration.

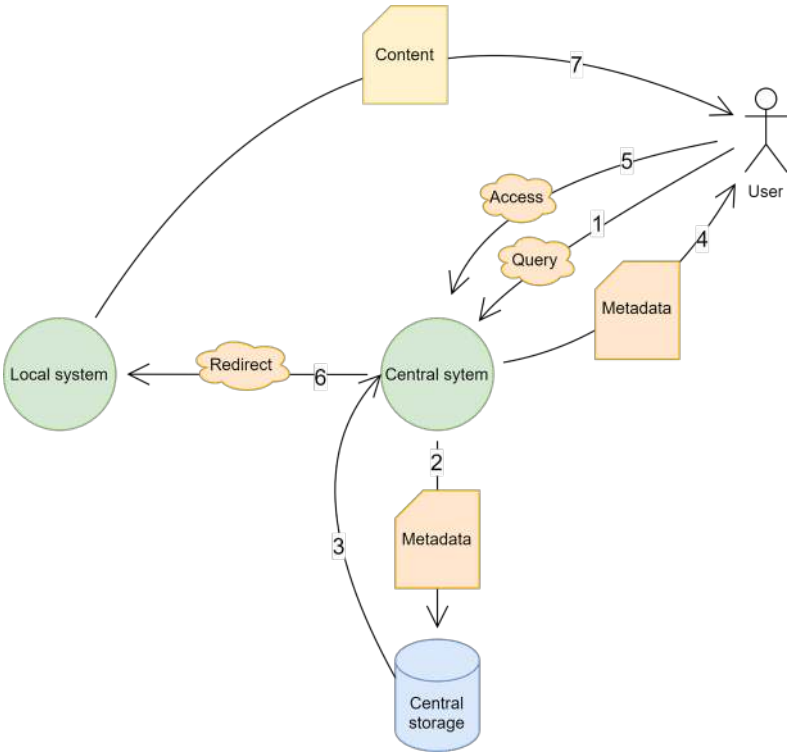


Figure 15 - Centralisation of metadata strategy.
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Underlying approach: Synchronisation of data

The centralised strategy raises a series of considerations about data synchronisation. A crucial point to consider is the version mismatch between different systems, which can lead to undesired issues. To address these challenges, we have identified two ways to handle synchronisation between local systems and the central system.

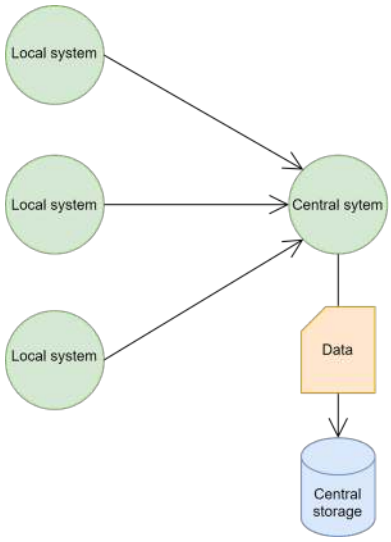


Figure 16 - Central system synchronisation - approach 1.
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The first approach involves local systems sending new data to the central system, known as a „push" update. This can be done at a set time to avoid disrupting normal traffic to the central system, or on-demand. If updates are scheduled, it's worth noting that the data on the central server may become outdated during those intervals.

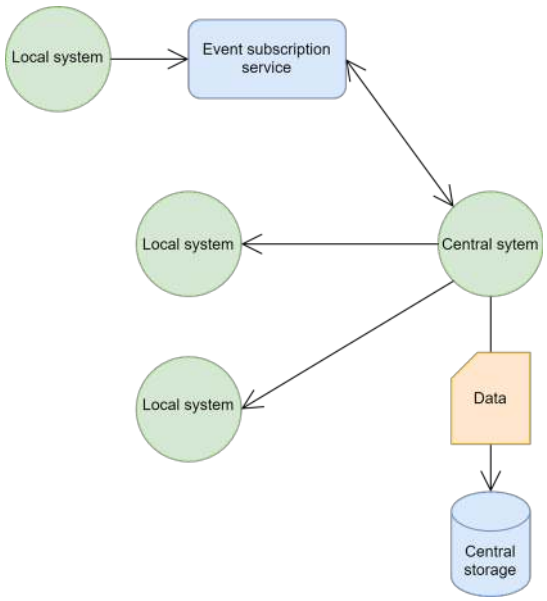


Figure 17 - Central system synchronisation - approach 2.
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In the second approach, the central server manages data updating, needing to be aware of all systems it must contact to obtain information, known as „pull“. This can also be done as a periodic task. One thing to note about this implementation is that if the central server is responsible for obtaining new data without a reactive system, a user may try to access data on the central server before it is loaded. As shown in the graphic above, the first local system has a reactive implementation, where the server subscribes to a series of events through a service exposed by the local system. This enables automatic updates, avoiding synchronisation issues in this case.

Scalability challenges

Central systems must ensure they can scale to handle the expected load of data storage communications. This applies whether they store only metadata or whole data. It should be capable of supporting as many requests as the number of learning records generated and stored.

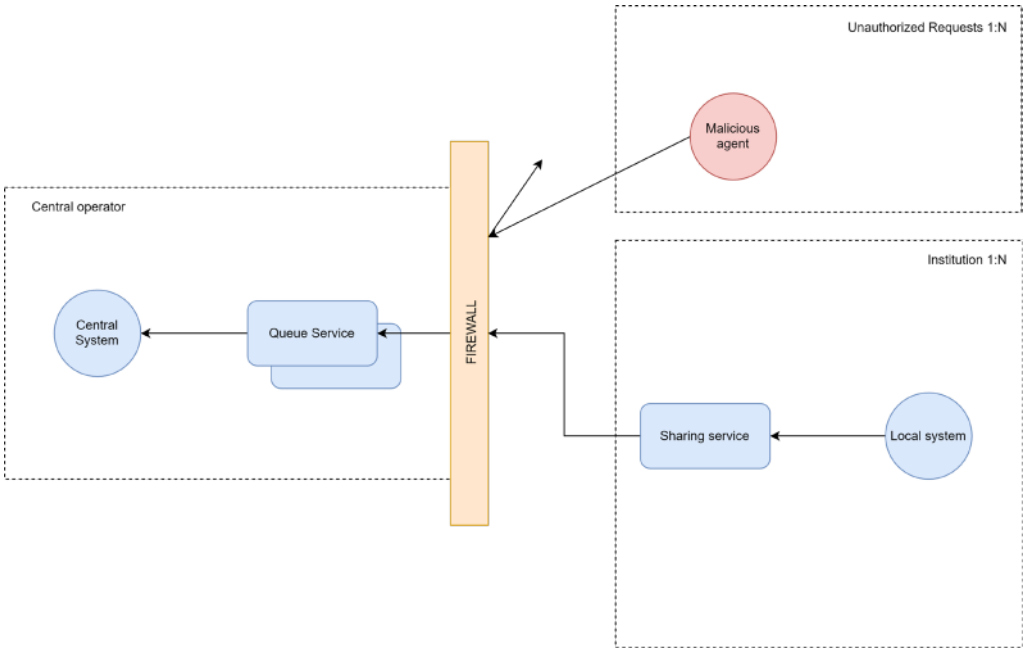


Figure 18 - Addressing scalability challenges in handling peaks.
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The above scheme offers a potential solution for handling extremely high peaks of requests to the central system, as well as potential DDoS attacks. By implementing strict firewall rules, it ensures that only requests from the institutions‘ sharing services are accepted. This allows a scaled queue system to control the intake of data received from all institutions, maintaining system stability during peak activity periods.

An alternative to the queue system is to perform periodic and scheduled transfers of data from local systems to the central one. Although this approach ensures stable communication, it introduces a delay between data generation and its availability for consultation.

b) Broadcast

This strategy, like centralised and decentralised approaches, emerged from various working sessions with the alliances, aimed at developing and refining generic solutions tailored to their needs. This strategy is called „broadcast“ because it spreads data. It sends locally stored data in each institution to other local systems whenever this data is created, modified, or deleted.

As a result, the alliances might deploy a central access point, allowing end users to access any content, or allow users to access content from all institutions through their existing local access points. When a content query is made, each institution‘s system can answer the query and deliver the content to the end user.

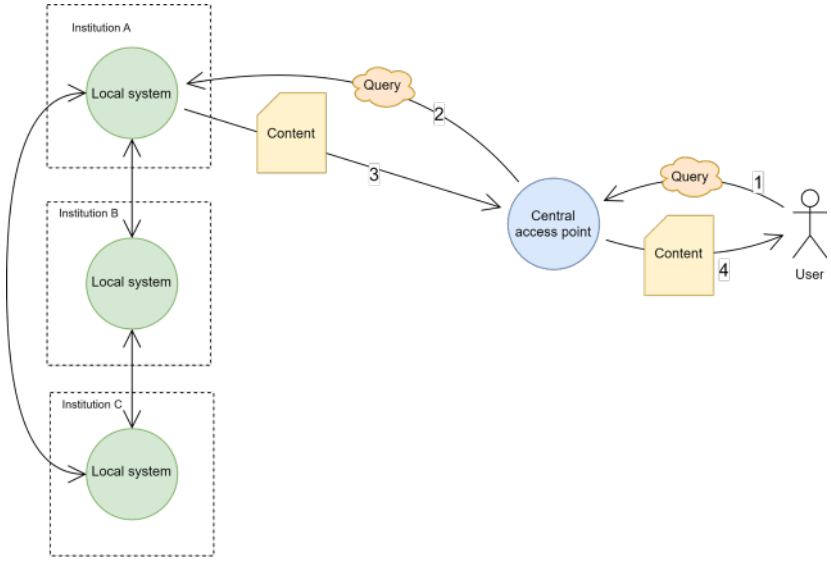


Figure 19 - Broadcast strategy.
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Alliances that adopt this strategy have a single access point for all their content needs, making the user experience simpler. Furthermore, this strategy reduces complexity for users, as they do not need to navigate multiple HEI systems independently. It can use either a central access point or their local one.

The broadcast strategy does not rely on central repositories or storage systems, as content is stored in the local HEIs' systems. Since information from local systems is redundantly stored among them, high data availability can be achieved; if one system fails, data can be accessed from any other. However, having data in multiple locations can cause sync issues. This may create different versions of the same content due to system communication problems. Moreover, storing complete data across systems can lead to conflicts regarding data protection, as data might travel between institutions in different countries.

Scalability challenges

In implementing this strategy, several scalability challenges arise. As more local systems are added, the central access point's load increases, leading to potential bottlenecks and latency. To alleviate this central point overload, several solutions are possible, including: a) distributing requests among multiple central access point instances through load balancing, and b) reducing the central access point's load with caches. These options are not mutually exclusive and can be implemented together, as shown in the following diagram.

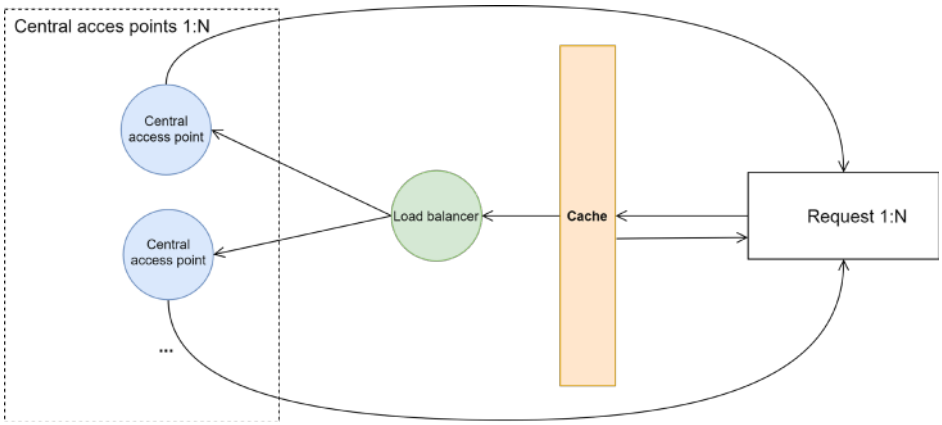


Figure 20 - Load balancer with cache mitigation approach.
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c) Decentralised

As with the broadcast strategy, the decentralised approach does not rely on a central system to store data. Instead, it provides an interface that retrieves data from all involved systems as needed, making it the most privacy-friendly approach. This strategy also sidesteps synchronisation issues, but it does shift the responsibility for service stability to the various local systems it depends on. Each institution must implement a service. It should extract data from its local systems, convert it to a common standard, and send it to the central access point for aggregation and processing.

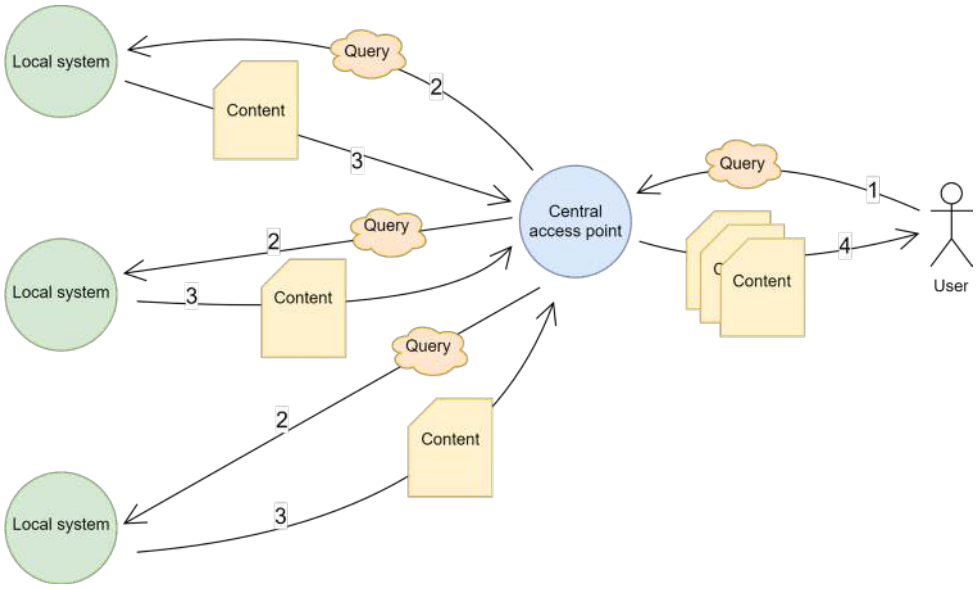


Figure 21 - Decentralised strategy.
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In the diagram above, an example is shown of a flow querying information from a central catalogue. The central access point directly calls each involved system, which then returns the necessary information to be displayed to the user, avoiding any unnecessary storage and synchronisation issues. The returned data can be either the actual content or, similar to the centralised strategy, metadata that represents the content.

Scalability challenges

Both this strategy and the previous Broadcast approach share a common foundation. As a result, they both wrestle with similar scalability challenges. The previously mentioned solution, featuring load balancers and caching, shines here too. The real triumph of this strategy lies in its scalability edge. It deftly sidesteps concurrency and synchronisation woes, as well as pesky performance penalties, by avoiding data replication across local systems.

Mapping data

Regardless of the chosen strategy—centralisation, broadcast, or decentralisation—a mapper is essential for facilitating the exchange of standardised data. If the mapper is integrated into the central system under a centralised strategy, it must be able to transform data from various institutions. This raises a scalability concern: as new local systems and institutions are incorporated, the number of mappings will need to increase correspondingly.

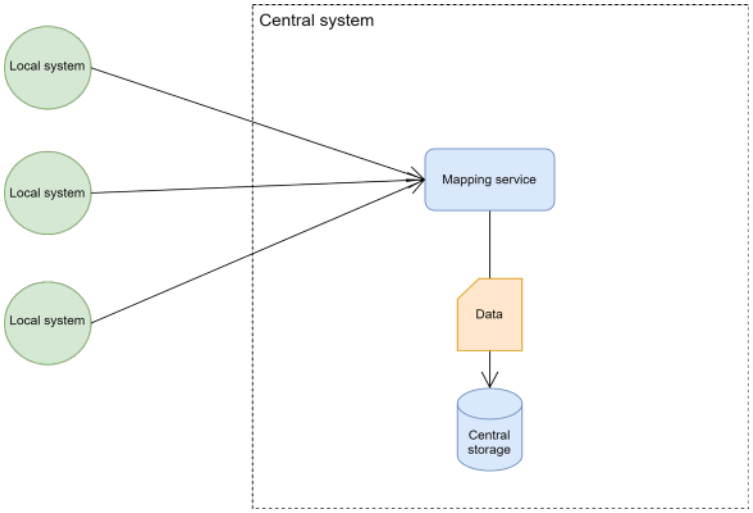


Figure 22 - Central system mapping approach.
© 2025 European Union

In a centralised strategy, local systems can manage data mapping, which lightens the load on the central system, simplifying the process and addressing scalability concerns. It is essential for each institution to agree on common standards for the mappers to ensure consistent data aggregation in the central system.

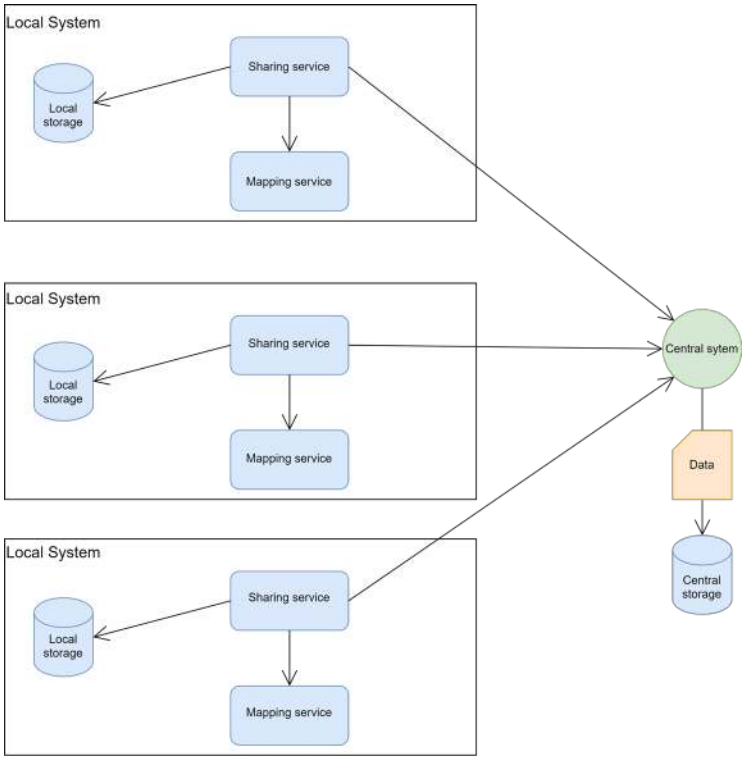


Figure 23 - Local system mapping approach - Centralised strategy.
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With a broadcast and decentralised approach, a common, agreed data standard is useful so that the sending institution can handle the mapping, maintenance, and updating, keeping the solution scalable. This means each institution implements a bi-directional mapping service between their local data standard and the common one. If the receiver were responsible for mapping, each institution in a network of N institutions might need to implement N – 1 different mapping services in the worst-case scenario.

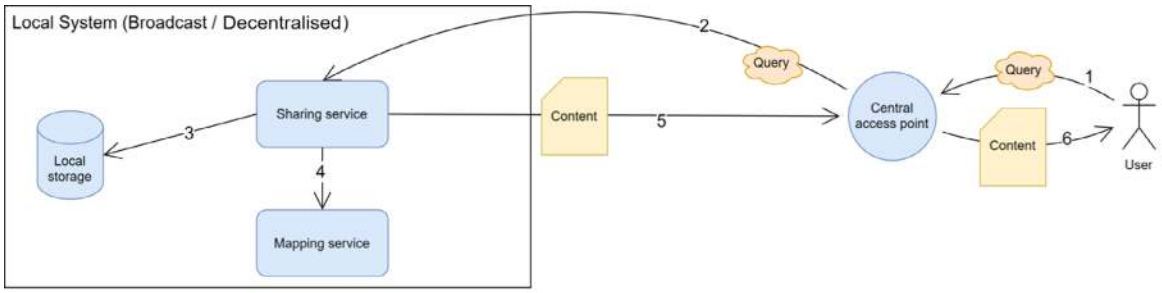


Figure 24 - Local system mapping approach - Broadcast and decentralised strategies.
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3.2 Interoperability challenges and practical implications

During the exchanges and sessions with EU-As, several concerns and challenges related to interoperability have become apparent.

Data collection, among other things, relied on online exchanges with individual representatives from alliances and their specific case studies, which might be subject to biases. Moreover, the data provide a snapshot of the point in time of data collection. The data, despite its limits, can still provide insights into the challenges alliances have faced in their interoperability journeys.

To provide a comprehensive overview, a word cloud has been created, featuring the most frequently raised challenges. The larger the font, the more often the concern was raised by alliances.

The most frequent concern is of a technical nature, focusing on the interconnection of existing technical systems across institutional boundaries. For instance, difficulties arise when trying to connect the different SIS of an alliance or integrate the various platforms of the institutions. The top challenges are standards, budget, and related issues. These include a lack of dedicated IT staff and GDPR legal concerns.

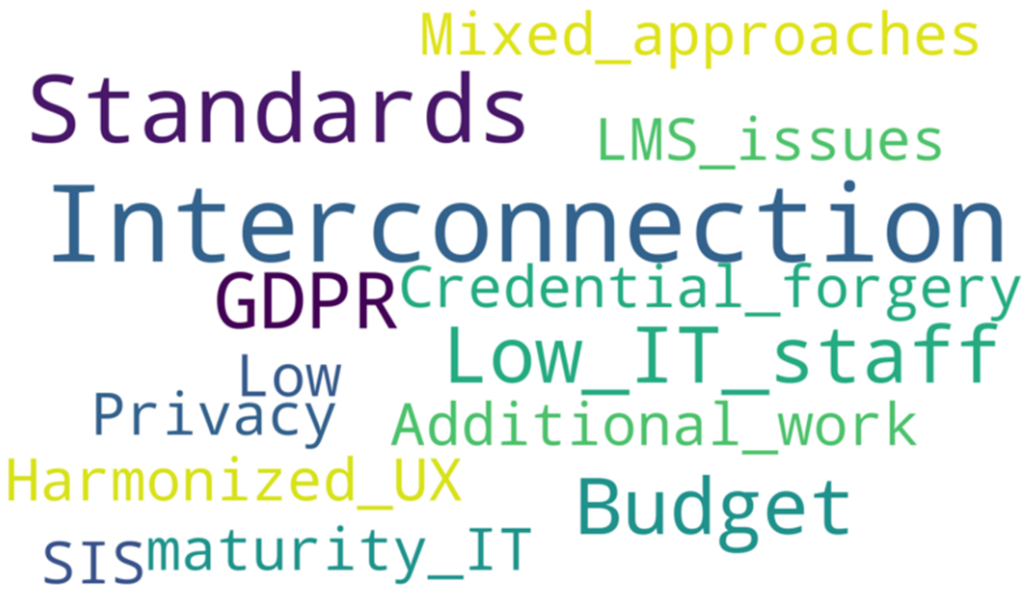


Figure 25 - Principal alliances concerns gathered from workgroups.
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To structure these challenges, the different interoperability layers of the European Interoperability Framework (EIF)[12] will be used. The EIF provides a common approach, helping public administrations, businesses, and citizens interact across borders. It focuses on practical implementation of interoperability principles and models.

The EIF is crucial. It lays a foundation for a digital, efficient EU. It promotes growth, improves public services, and supports citizens' rights and mobility. This enables the EU to function as a unified entity in the digital age, catering to the needs of its diverse member states.

The EIF consists of four interoperability layers, which the project and its deliverables will tackle as follows:

Layer per EIF	Project components addressing this layer		Examples of existing agreements or standards
Legal Interoperability	Alignment with existing frameworks and agreements is ensured, even if not tackled directly.		EHEA[12] and EEA[13] policies (e.g., European Degree), GDPR[14], and others
Organisational Interoperability	High-level flows	Implementation guidelines and governance recommendations	Standardised Erasmus+ agreement (Inter-Institutional Agreement, Learning Agreement)
Semantic Interoperability	Architecture for data standards		ELM[15], ECTS[16], EQF[17], ESCO[18]
Technical Interoperability	Architecture for standardised services		ESCI[19] (incl. EWP[20]), EDC[21]

Figure 26 - Interoperability layers in focus of this project.
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The following sections will analyse each of the four interoperability layers and their impact on the current landscape.

Legal Interoperability

As per EIF: "Each public administration contributing to the provision of a European public service works within its own national legal framework. Legal interoperability is about ensuring that organisations operating under different legal frameworks, policies and strategies can work together. This might require that legislation does not block the establishment of European public services within and between Member States and that there are clear agreements about how to deal with differences in legislation across borders, including the option of putting in place new legislation."[22]

[12] European Higher Education Area: https://www.ehea.info/
[13] European Education Area: https://education.ec.europa.eu/
[14] EU General Data Protection Regulation: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02016R0679-20160504
[15] European Learning Model (https://europa.eu/europass/elm-browser/index.html)
[16] European Credit Transfer and Accumulation System (https://education.ec.europa.eu/education-levels/higher-education/inclusive-and-connected-higher-education/european-credit-transfer-and-accumulation-system)
[17] European Qualifications Framework (https://europass.europa.eu/en/europass-digital-tools/european-qualifications-framework)
[18] European Skills, Competences, Qualifications and Occupations (https://esco.ec.europa.eu/en)
[19] European Student Card Initiative (https://erasmus-plus.ec.europa.eu/european-student-card-initiative)
[20] Erasmus Without Paper (https://erasmus-plus.ec.europa.eu/european-student-card-initiative/ewp)
[21] European Digital Credentials for Learning (https://europass.europa.eu/en/europass-tools/european-digital-credentials)
[22] European Interoperability Framework EIF, https://ec.europa.eu/isa2/sites/default/files/eif_brochure_final.pdf

EU-As operate within a complex interplay of legal and policy frameworks established at the European, national, and regional levels. As universities in Europe largely refer to the national level, EU-As must comply with multiple regulations simultaneously due to their cross-national nature.

While there is no EU regulatory competence over education, various European initiatives aim to harmonise national higher education policies and regulations. Notable are the European Higher Education Area (EHEA) and the European Education Area (EEA). Despite this harmonisation, variations in regulations at national and regional levels hinder cooperation. They make it harder to execute joint projects.
This project does not focus on legal interoperability. It cannot propose changes to specific national regulations or European policies. But, it will align with existing European policies and agreements. Specifically, the framework established by European Union instruments (e.g., Council Recommendations) and EHEA tools serves as a common denominator.

Legal challenges

During the exchanges with alliances, some legal challenges emerged. First and foremost, compliance with data protection and privacy frameworks is essential, particularly GDPR and related national legislation. This becomes especially challenging in cross-border collaborations between institutions, where varying and strict rules govern sensitive data handling. Other frequently mentioned legal frameworks concern licenses and intellectual property (IP) in resource exchange.

The following three main aspects of legal interoperability were highlighted by alliances during the exchanges:

1. **Data protection and data sharing:** In HEIs' context, data sharing means sharing student information between institutions, like their academic history and grades. This raises questions about the level of detail in the data to be shared (e.g., learning records details vs. results only) and the need to obtain the data owner's consent before sharing their data.
2. **Software licenses:** Legal interoperability ensures that various software systems can work together within the boundaries of legal frameworks. However, restrictive licenses often hinder this by limiting how software can be shared, accessed, and used across different teams and tasks. The use of software solutions that facilitate interoperability and cooperation, such as text processors, design tools, or cloud drives, often encounters legal obstacles due to licensing rules. When multiple users need access to a software for coordinated work, licensing can pose legal challenges. For instance, some licenses restrict the number of users, requiring the purchase of further licenses, which inhibits further sharing beyond those already granted access. Other licenses may be time-bound, only valid

for a specific period, after which they must be renewed. Moreover, licenses may permit usage for specific tasks but prohibit other uses, particularly in professional settings. These restrictions can hinder efficient collaboration and the seamless integration of software tools within an organisation or alliance.

3. **Intellectual property rights:** Sharing educational materials can affect third-party rights. For instance, movies, short films, and other resources often have restrictions that limit their use, sharing, or access. These limitations can create significant barriers to sharing and using educational content smoothly, making it harder to achieve legal interoperability within educational environments.

Organisational interoperability

Organisational interoperability, as understood per EIF, "refers to the way in which public administrations align their business processes, responsibilities, and expectations to achieve commonly agreed and mutually beneficial goals. In practice, organisational interoperability means documenting and integrating or aligning business processes and relevant information exchanged. Organisational interoperability also aims to meet the requirements of the user community by making services available, easily identifiable, accessible and user-focused."[23]

From an organisational perspective, the EU-As are coalitions of individual entities collaborating to achieve common goals and visions. Each member university remains an independent organisation with its own traditions, established processes, and specific needs. Some member universities may collaborate with other partners, nationally and internationally. This requires consideration of the partnerships' organisational requirements.

Interoperability requires that institutions establish a mutual understanding of their relevant administrative processes (e.g., admission, enrolment, credits) and align them where necessary. This might take the form of agreements between institutions. They should also cover the semantic and technical elements in the following sections. For example, they should regulate which standards, controlled vocabularies, and data models to use.

[23] idem

Data gathered and insights from exchanges with EU-As indicate three approaches to organising the development and joint work to advance interoperability.

1. One HEI will take on the developer role on behalf of the alliance.
2. Some alliances have opted to have their HEIs jointly develop such processes.
3. The responsibility could be outsourced, with development delegated to a third party, such as a company.

It can be observed that the approach where one institution takes the lead on behalf of the alliance is popular in alliances with an emerging focus on interoperability. This might be due to the low barriers to implementing this approach, which requires a relatively small budget. Most alliances that have strongly emphasised interoperability and gained more experience have opted for the joint development approach, led by a central IT team. Approach 3 is not very common, likely because outsourcing requires a dedicated budget allocation and creates further dependencies.

The alliance may, regardless of the approach, use tools from one or more HEIs as a starting point. Alternatively, it may create a new tool for the alliance.

Also, the alliance‘s experience shows that co-operation in technical development is essential, no matter the chosen strategy. Alliances argue that there is a need for a dedicated team of technical experts to work on interoperability between institutions.

Organisational challenges

Exchanges with EU-As highlight two major bottlenecks in interoperability: solution development and implementation. Both require the alliances to agree on a joint way forward - and here multiple problems arise. The **budget** is a concern that reflects the occasional lack of resources to carry out the necessary transformations and ensure continued maintenance. Closely related is the challenge of having too few IT staff to support these processes. Often, the budgets and staff from the institutions are insufficient or incompatible with maintaining the alliances‘ tools.

Differing development capacities within the alliances is another challenge reported. Some alliances put development within their member institutions on hold to support the technical development of the alliance. Another problem is reaching and aligning agreements on joint processes. Local processes are often

incompatible with each other. Often, the requirements of the alliances contradict institutional interests. Once interregional cooperation across Europe comes into play, the difficulty increases exponentially: the nature of local processes heavily depends on the country. This can range from manual to automated processes, as well as legal or governmental requirements.

Semantic interoperability

Data models and standards often vary across HEIs, which makes it challenging to translate data between different systems. To overcome this, a set of common standards needs to be agreed upon.

Due to the differences in data between HEIs, there are two main options for applying these standards:

1. Modify all local systems within the institutions to adopt the agreed standards, or
2. Implement a component that translates data between systems, converting each HEI's local data into standardised data that follows a shared model understood across the EU-A or even beyond.

Given the effort required to change an institution's entire data structure, implementing a mapper component seems easier and more feasible. Therefore, the focus will be on this approach, which can be illustrated as follows:

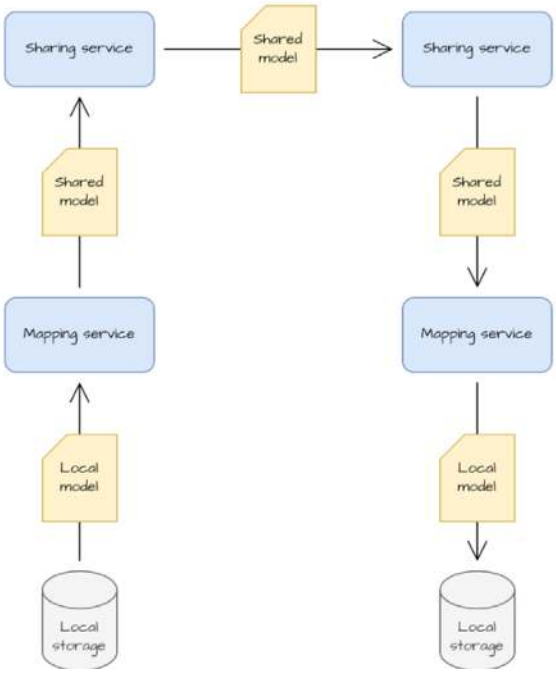


Figure 27 - Achieving semantic interoperability by means of implementing a mapping service.
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In this approach, a mapping service converts individual data models into a shared one. The data to be shared is then sent to a sharing service, which distributes it to another institution's sharing service. Once the requester receives the content, it is converted back into the requesting institution's local data model.

Without a shared data model, each local model must be mapped to every other. This becomes increasingly burdensome as the number of institutions grows, with complexity increasing quadratically.

Semantic challenges

A crucial aspect of a shared data model and semantic interoperability is having a vocabulary that is commonly understood and agreed upon. This is true for interoperability and, more generally, for language barriers between the national universities in an alliance. In interoperability, controlled vocabularies are key. They ensure consistent, precise, and clear communication across systems, organisations, and domains. Controlled vocabularies are standardised sets of terms and phrases that have specific, agreed-upon meanings. Forms can include taxonomies, dictionaries, and others.

The selection and **implementation of standards** in HEIs' diverse environments has been a major challenge. This is due to difficulties in selecting and applying standards at all levels. Evidence suggests that the lack of coordination at the European level increases the diversity of the technological landscape and developments, rather than reducing it. For example, parallel efforts to develop standards for describing course material (like OOAPI vs. Edu-API) and poorly-aligned Member State initiatives create technological silos. This hinders interoperability.

Technical Interoperability

"This covers the applications and infrastructures linking systems and services. Aspects of technical interoperability include interface specifications, interconnection services, data integration services, data presentation and exchange, and secure communication protocols."[24]

Technical interoperability in European HEIs is a key focus area. It involves creating interconnected virtual learning environments and campuses that enable joint enrolment processes, virtual mobility experiences, virtual exchange, and others, with the most prominent ones reflected in the selected use cases for this project.

The technical design builds especially on the organisational layer. It can only lead to meaningful results when combined with it, as all technical design elements need to be agreed upon and documented.

[24] idem

Technical challenges

The **diversity of technical systems, both existing and emerging**, across countries is one of the main technical challenges. Over time, diverse technological approaches have been adopted, resulting in a complex and varied technological landscape. Some of these approaches are unique to European HE systems, while others are unique to individual universities. When HEIs decide to develop institution-specific solutions or acquire commercial tools, this gap widens. Although these two types of solutions aim to offer the best capabilities or experience for the HEI, they might not align with standards or best practices that benefit the alliance.

During the mapping sessions, a preference emerged for all institutions within an alliance to agree on common tools and then interconnect them, rather than trying to connect different tools. Here, the heterogeneity among alliance systems becomes a factor again. Since each institution has implemented its own solutions or commercial solutions, standardisation becomes a costly problem in terms of both time and budget.

From the alliance's virtual campus perspective, a concern that still matters despite being infrequent is **harmonising interfaces and user experience**. The virtual campus aims for unity, and a key usability concern is providing visitors with a seamless experience. To achieve this, we need to maintain a consistent style guide across all platforms accessible from the campus.

Another concern raised in the exchanges with alliances and experts relates to **security**. Once a credential is issued, there is a risk of fraud, which is a significant security concern. Digital credentials are not just files; they must be linked to several elements that authenticate their validity. One of the primary methods to ensure the authenticity of a digital credential is through digital signatures. Each credential should be digitally signed by the issuing authority, which employs cryptographic techniques to ensure the credential has not been tampered with and to verify the issuer's identity. This adds a layer of security, as any alteration to the credential would invalidate the signature. In addition to digital signatures, verifying the credential holder's identity is crucial. This process should involve robust identity verification mechanisms at the time of issuance.

User identity management presents significant challenges due to the evolving nature of identities throughout an individual's academic life. Changes such as role transitions, personal information updates, and name changes make it difficult to maintain accurate, secure, and consistent identity data across institutions. Interoperability becomes particularly challenging, as these changes must be recognized and validated across multiple systems. Efficient role management is essential to ensure continuous access to resources while preventing security issues. Additionally, ensuring the traceability and recognition of credentials, even when

linked to previous identities, requires robust solutions that balance immutable and flexible identity attributes. The development and adoption of interoperable standards are crucial to support academic mobility and international cooperation in European education.

Also, the European Accessibility Act took effect in April 2019. It must be implemented by June 2025. A series of capabilities must be added to ensure services are accessible.[25]

Though not strictly mandatory, this should be considered in the short to medium term.

[25] See the Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services (Text with EEA relevance).

4 European projects and regulations impact

In this chapter, key European projects that are driving progress towards interoperability within Higher Education Institutions across Europe are presented, together with their impact on the current landscape. These projects, for instance, are vital. They create a more connected and efficient ecosystem. They help transnational educational alliances collaborate. They also make processes smoother and more harmonised. Each project is detailed, with a focus on its relevance and specific application to the use cases identified in the final mapping report.

4.1 Identity management

User identity management has emerged as one of the primary challenges on the path to achieving interoperability among HEIs. Use case 7, which specifically addresses this issue, has become a key priority for the alliances consulted.

The second squad meeting on this use case, given the complexity of designing an architecture that accommodates the diverse identity management systems in use by institutions, led to a strategic shift. Efforts shifted from the architectural aspects to defining the essential minimum attributes a user identity must have. This definition aims to address not only the specific needs of each use case but also the necessary level of assurance for different scenarios. As a result of this strategic adjustment, the dependencies between the use cases and use case 7 were made more explicit, to be considered. The revised report now outlines the identity requirements needed for proper and effective implementation, ensuring the proposed solutions are consistent and aligned with the varied needs of each use case.

User identity management has proven to be a significant challenge, especially when considering the mutability of identities. Throughout an individual's academic and professional life, their identity may undergo numerous changes. For instance, a student may become a member of academic staff, which requires changes to their roles, permissions, and access to resources. Similarly, users may change their name due to personal circumstances, such as marriage, or update other relevant personal details.

These changes greatly complicate identity management, as systems need to accurately reflect and update them without putting data integrity or security at risk. Interoperability between institutions is especially affected, since identity changes must be recognised and validated across multiple entities while keeping consistency across all systems. Efficient role management is crucial. Systems must adjust user rights

and permissions based on new roles or statuses. This ensures users can access essential resources while preventing security breaches.

In addition, ensuring the traceability and proper recognition of credentials issued over time adds another layer of complexity. For instance, a credential issued under a previous name must remain identifiable and linked to the user's current identity. This requires robust identity solutions that include both permanent, immutable attributes and flexible handling of those that may change. It is essential to define and adopt interoperable standards to tackle these challenges. They are key to supporting academic mobility and cooperation in Europe's education system.

Selected reference projects

Among European projects, the **European Student Card Initiative (ESCI)** stands out for its widely used tools and success stories, as reported by the community and expert squad meetings.

ESCI's goal was to create an interoperable system, enabling smooth student mobility between HEIs and ensuring secure, hassle-free access to academic services across Europe. A key contribution of the project has been introducing the **European Student Identifier (ESI)**, a unique identifier assigned to each learner.

The project has also promoted high standards for data security and privacy, ensuring the ethical management of learner identities in line with European regulations, including the GDPR. This has enhanced the safeguarding of personal data while enabling more efficient and transparent identity management.

ESCI has also promoted interoperability among identity management systems across various institutions. This is crucial for creating a more connected digital education environment. As a result, learners benefit from an integrated and enhanced experience when engaging in academic mobility.

MyAcademicID part of ESCI, makes it easier for learners in the European Higher Education Area to access digital services. It provides a secure way to use a single academic identity across Europe. Based on recognised standards, it offers an authentication system. Learners can log in using their home institution's account through the eduGAIN service. This project also connects their academic identity to their personal identity by integrating with national eIDAS nodes.

eduGAIN is a global initiative that offers a technical framework to connect federated identity systems in academia and research. It aims to provide secure, seamless access to online services and resources. Additionally, eduGAIN fosters international collaboration among education and research institutions worldwide.

eduGAIN allows digital identities managed by an educational institution to be recognised and used for accessing services offered by other institutions, both nationally and internationally. This is achieved through a federation of identity systems. It allows institutions to authenticate users and share info with service providers. This eliminates the need for users to create multiple accounts or manage extra credentials. This service has become one of the most widely used.

MyAcademicID and the ESI work together to let learners verify their identity securely. This integration makes processes like Erasmus+ mobility, course enrolment, and accessing digital resources much easier, eliminating the need for multiple credentials. The European Student Card (ESC) acts as a physical counterpart to the digital MyAcademicID system, greatly improving the experience for learners. While MyAcademicID offers a secure way to authenticate and access academic services with a standard digital identity, the ESC provides a simple and effective physical means to access resources.

The ESC is a well-known student card in Europe. It lets students access libraries, sports facilities, and local services at their home institution and during mobility programmes. They can also enjoy discounts. There's no need for multiple registrations or extra admin steps, which cuts down on bureaucracy and makes things easier for students.

The ESCI second phase, known as **ESCI II**, introduces new features. One main proposal of ESCI II is to adapt to the new **eIDAS 2.0** regulation. It creates a framework for secure, harmonised electronic identification and authentication across Europe.

This will enhance the security and reliability of digital identification processes for learners, facilitating their access to educational services and resources beyond national borders with greater legal assurances.
Furthermore, ESCI II also introduces capabilities for the ESC, expanding its functionality and leveraging the improvements of the European digital ecosystem.

Another key feature is the **'last resort' mechanism**. GÉANT manages this, serving as a backup to ensure learners can access essential services. If technical or procedural issues disrupt the usual authentication and verification processes, this contingency plan kicks in. It's vital for maintaining the reliability and usability of the **European Digital Student Service Infrastructure (EDSSI)** framework. This framework operates across various institutional and national contexts, where connectivity or system compatibility can sometimes be challenging. Some alliances are interested in this resource because it offers a balanced approach to achieving interoperability. They see it as a reasonable investment of resources to reach their goals in a timely manner.

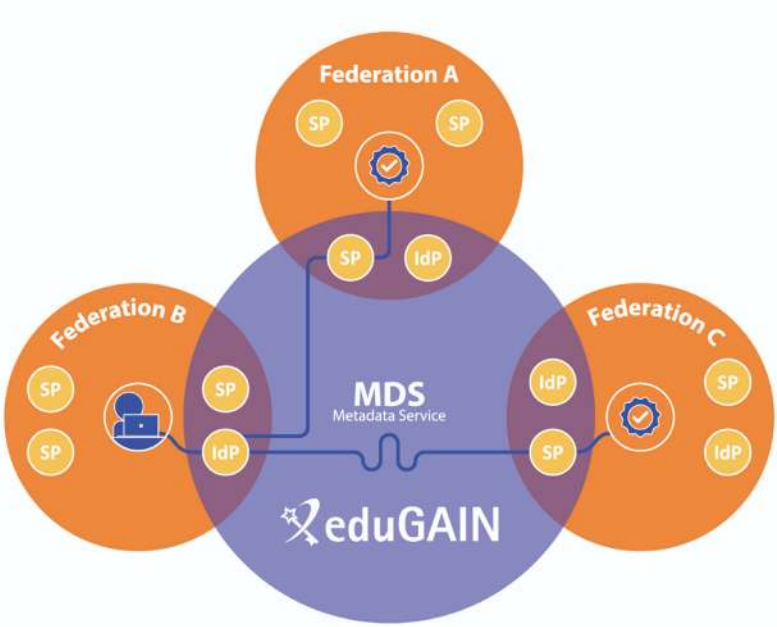


Figure 28 - Diagram eduGAIN system[26].
© 2021 eduGAIN

[26] eduGAIN federation system diagram from key-concepts: https://edugain.org/about-edugain/key-concepts/

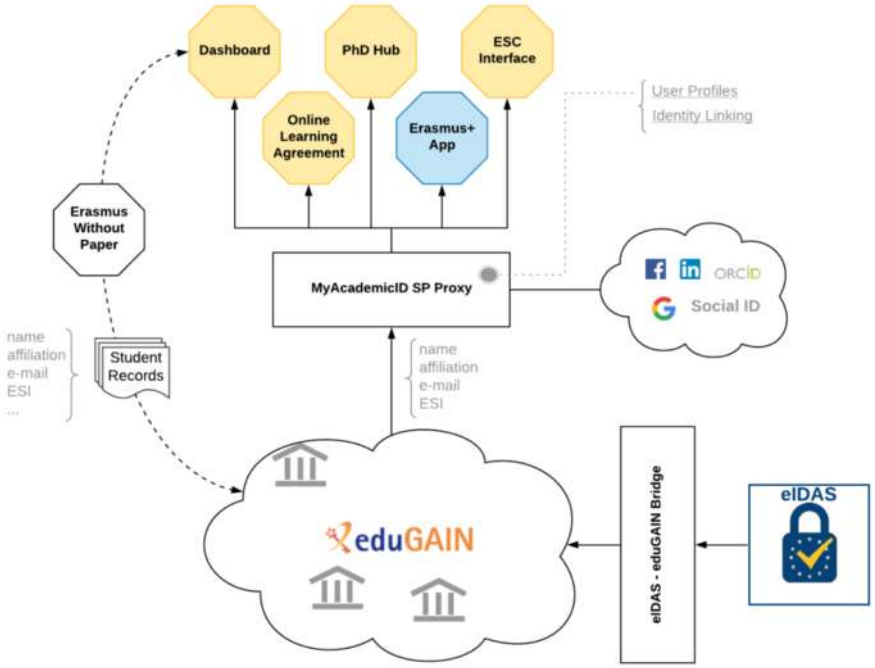


Figure 29 - ESCI MyAcademicID integration with eIDAS architecture[27].
© 2020 MyAcademicID

The image above shows how the tools developed by the aforementioned projects are integrated into the HE ecosystem, providing a secure and reliable user identity system. This is achieved by allowing HEIs to use eIDAS-enabled eIDs during the enrolment process. As part of the federated eduGAIN network, these HEIs would grant access to their services using this identifier. Currently, national level eID authentication does not replace the federated identities provided by HEIs to learners, which remain in place for accessing services like eduroam or institutional email.

These projects initially took a centralised approach to identity management. However, in Squad 7, the idea of distributed identity management was introduced, such as through the use of wallets.

The distributed or decentralised identity model has emerged as a solution giving users control over their credentials and identity, creating a more secure and transparent environment. In the European context, there are already projects strongly supporting these new technological paradigms.

[27] ESCI MyAcademicID architecture components diagram from the MyAcademicID blueprint: https://projects.uni-foundation.eu/myacademic-id/wp-content/uploads/sites/9/2021/03/MyAID_Blueprint_Architecture_FinalV2.pdf

One project often mentioned by the community is the **European Blockchain Services Infrastructure (EBSI)**. This is the EU's official blockchain-based infrastructure. It ensures the authenticity and integrity of digital records, like diplomas and certificates. A key feature is its decentralised data storage, which mitigates the risks of centralisation and gives learners control over their credentials. Additionally, EBSI can be used to manage decentralised identities through the Decentralised Identifiers (DIDs) standard. **The European Self-Sovereign Identity Framework (ESSIF)**, as part of EBSI, enables the management of digital identities in a sovereign and decentralised manner. This is achieved by building an identity layer on top of EBSI itself. Individuals, such as learners, retain full control of their credentials and decide when and how to share their personal data. This data exchange uses advanced cryptographic keys and technologies. They remove the reliance on central authorities. This ensures secure, intermediary-free identity management. ESSIF enables this approach to identity management while complying with regulatory requirements such as GDPR and eIDAS. During community engagements, when discussing decentralised identities, the concept of wallets has been highlighted as a key challenge. In line with this wallet paradigm, the **EU Digital Identity Wallet (EUDI Wallet)** is a prominent example. The EUDI Wallet is a tool developed under the eIDAS 2.0 Regulation, providing European citizens with a secure space to manage their digital identities, credentials, and official documents. Through the EUDI Wallet, learners can store their academic credentials and use them to access educational services seamlessly and securely in any member state. The Wallet's interoperability ensures that electronic transactions meet the highest security standards, thereby enhancing learner mobility and access to services across Europe. Also, the EUDI Wallet can be integrated with the ESC. This allows learners to use their wallet for both general identity services and for the ESC's educational services, like accessing certain resources.

	The National Approach	The Federated Approach	The Self-sovereign Approach
Concept	A Central authority, e.g. a Member State manages a centralised service responsible for authentication and identification of Citizens accessing its Digital Services.	The eIDAS regulation has put in place a mutual recognition of notified national electronic identification schemes (eID) across borders. Enabling citizens to use their national eIDs when accessing online services from other European countries.	W3C's Verifiable Credentials can be used to create Verifiable eIDs which can be easily combined with other Credentials to expand the number of attributes used for authentication and identification purposes but also for record matching.
Example	e.g. CSAM	e.g. eIDAS eID network	e.g. ESSIF part of EBSI
			Note: No personal data is stored on-chain.
Technology	Electronic identity card (eID) and others.	Security Assertion Markup Language and the eIDAS common dataset.	Verifiable Credentials and the eIDAS common dataset.
Wallet compatible?	Yes e.g. itsme	Yes e.g. itsme is an eIDAS notified eID means.	Yes e.g. Verifiable Credentials are designed for Digital Wallets.
Governance	A Central authority manages the service and acts as the custodian of the Citizens' identity.	National nodes, usually centrally managed, interconnect identity service providers that are eIDAS-compliant.	National nodes, usually centrally managed, interconnect identity service providers that are eIDAS-compliant.
Strength	Control of service by identity service provider.	Interoperability among different identity service providers.	Flexibility: selective disclosure of information and ease to combine it with other Verifiable Credentials.

Figure 30 - Identified identity management approaches – comparison by EBSI[28].
© European Union

[28] Image from EBSI documentation – chapter 1: https://ec.europa.eu/digital-building-blocks/sites/display/EBSI/Explained+Series

The figure above outlines three approaches to identity management. The federated identity method, using MyAcademicID and eduGAIN, supports mobility programmes like EWP. However, the community suggests a shift towards distributed identities in the future. With this wallet system, users would control their own identities and decide what information to share. This change promises greater scalability and better interoperability.

4.2 Credential issuing and recognition

Use case 6 (earn a credential) marks a significant milestone at the end of a learner's educational journey. Although credential issuance comes with complex challenges, it holds promising potential. To issue recognisable credentials, HEIs must meet essential standards, ensuring they are trustworthy, practical, and easily verifiable. These standards require credentials to be recognisable in academic and professional settings. They must be verifiable to confirm authenticity, and they must link clearly to a specific user identity to support their validity. Furthermore, credentials must be digitally signed, adding an extra layer of security and reliability that minimises the risk of fraud and forgery. Robust systems are necessary to guarantee credential integrity and facilitate the secure and standardised exchange of information between institutions at both national and cross-border levels.

These needs are closely linked to other use cases, such as use case 7 (user identity), which was discussed earlier along with its challenges and relevant projects. Moreover, there is an inter-dependency with use case 8 (institutional identity), focusing on building trust relationships between institutions. It's crucial to ensure a credential links to the user's identity. It must also link to a credible, trustworthy issuing institution within a mutual trust ecosystem among participating institutions.

Credential management has two primary phases: issuance and subsequent recognition. This recognition comes under use case 2 (apply and get recognition), which deals with the necessary standards that allow a credential issued by one institution to be recognised and accepted by another. To gain recognition, credentials must meet certain standards. They must verify their authenticity and allow objective evaluation across institutions. Also, each credential's structure and details, such as completed programmes or learning outcomes achieved, need to be clearly presented to aid evaluation and recognition.

Credential recognition involves verifying identities, ensuring digital trust relationships, and establishing equivalencies between courses and study programmes. The community sees this as a major challenge. Standardised course descriptions and their learning outcomes are often lacking. This lack of standardisation

makes it hard for institutions to assess courses or programmes, and leads to inconsistencies in credential recognition.

Relevant projects

Europe faces big challenges in issuing and recognising academic credentials. Initiatives like **Digital Credentials for Europe (DC4EU)**, **European Digital Credentials Infrastructure (EDCI)**, **Europass**, and EUDI Wallet aim to address this. These projects create a European ecosystem that streamlines and standardises processes. It aims to improve student mobility, transparency, and the recognition of academic achievements.

DC4EU promotes the use of verifiable digital credentials in standardised formats, ensuring easy recognition and transferability across countries. This project uses technologies like blockchain to safeguard credential integrity, supported by EBSI to enable cross-border verification.

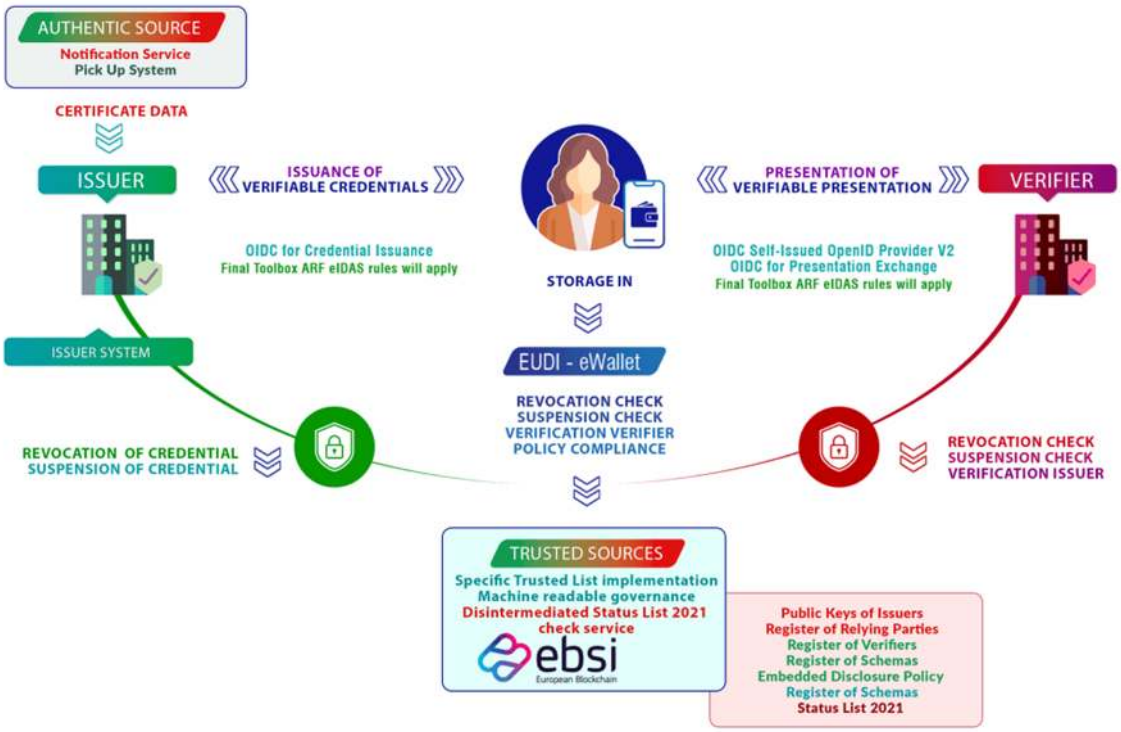


Figure 31 - DC4EU output[29].
© 2024 DC4EU Consortium

As shown in the previous diagram, based on the DC4EU project's outputs, this initiative promotes integrating credentials in digital wallets. Digital wallets, such as the EUDI Wallet, provide a solution for storing, managing,

[29] Image from DC4EU webpage with its outputs: https://www.dc4eu.eu/outputs/

and verifying digital credentials, as discussed in the previous section. This approach supports the European digital credential ecosystem. It lets students store their credentials in one place—the wallet - streamlining access to educational and administrative services across Europe. In the wallet context, the EBSI plays a crucial role in verifying credentials and ensuring security, integrating verification mechanisms under the eIDAS 2.0 framework.

Additionally, **DEQAR** (Database of External Quality Assurance Results) ensures that credentials come from reputable institutions. DEQAR acts as a repository, enabling institutions and employers to check if the bodies issuing credentials meet European educational quality standards. It is based on Europe-wide quality assurance standards (ESG) agreed upon in the Bologna Process. EQAR manages them. It is the official register of quality assurance agencies that comply substantially with the ESG.

Standardising learning outcomes is crucial for recognising credentials across borders. Tools like **European Skills, Competences, Qualifications and Occupations** (ESCO) and the **European Qualifications Framework** (EQF) aim to standardise these outcomes. They enable institutions and employers to assess students' competencies, regardless of where they studied. Implementing these standards requires institutions to adjust their curricula and credential formats, thereby promoting professional mobility within the European labour market.

4.3 Regulations

One of the primary regulations HEIs must adapt to is eIDAS (Electronic Identification, Authentication and Trust Services). This EU regulation sets standards for electronic ID and trust services. It aims to enable an infrastructure that allows EU states to recognise each other's electronic identities. Its main objective is to create a secure, verified framework for electronic transactions between citizens, businesses, and public administrations. For HEIs, eIDAS has major operational and technical impacts. It requires institutions to adapt their user authentication and identification systems to meet the EU's interoperability and security requirements. This concern was raised in community sessions.

eIDAS Impact on HEIs and Required Changes

Under eIDAS, HEIs must integrate authentication systems that meet the defined Levels of Assurance (LoA) in the regulation, which are low, substantial, and high. This ensures that the identification and authentication processes for learners, academic staff, and administrative staff are secure and recognised across the EU. In practice, the regulation requires HEIs to align with both national and European electronic identity systems. Many institutions are now integrating federated authentication services like eduGAIN and ESI.

The interoperability promoted by eIDAS benefits international mobility programmes like Erasmus Plus. With an eIDAS-verified electronic identity, learners can access services at other institutions and validate their identity without extra steps. This interoperability greatly simplifies the administrative aspects of cross-border mobility for both students and institutions.

eIDAS also sets directives for the use of electronic signatures, seals, and certificates. HEIs must use EU-wide recognised, qualified electronic signature systems for official academic documents, such as grade certificates, diplomas, and transcripts. This ensures not only the authenticity and security of these documents, but also their acceptance across Member States. To use these qualified electronic signatures, HEIs must partner with Qualified Trust Service Providers (QTSPs). This may require changes to their document issuance and management processes.

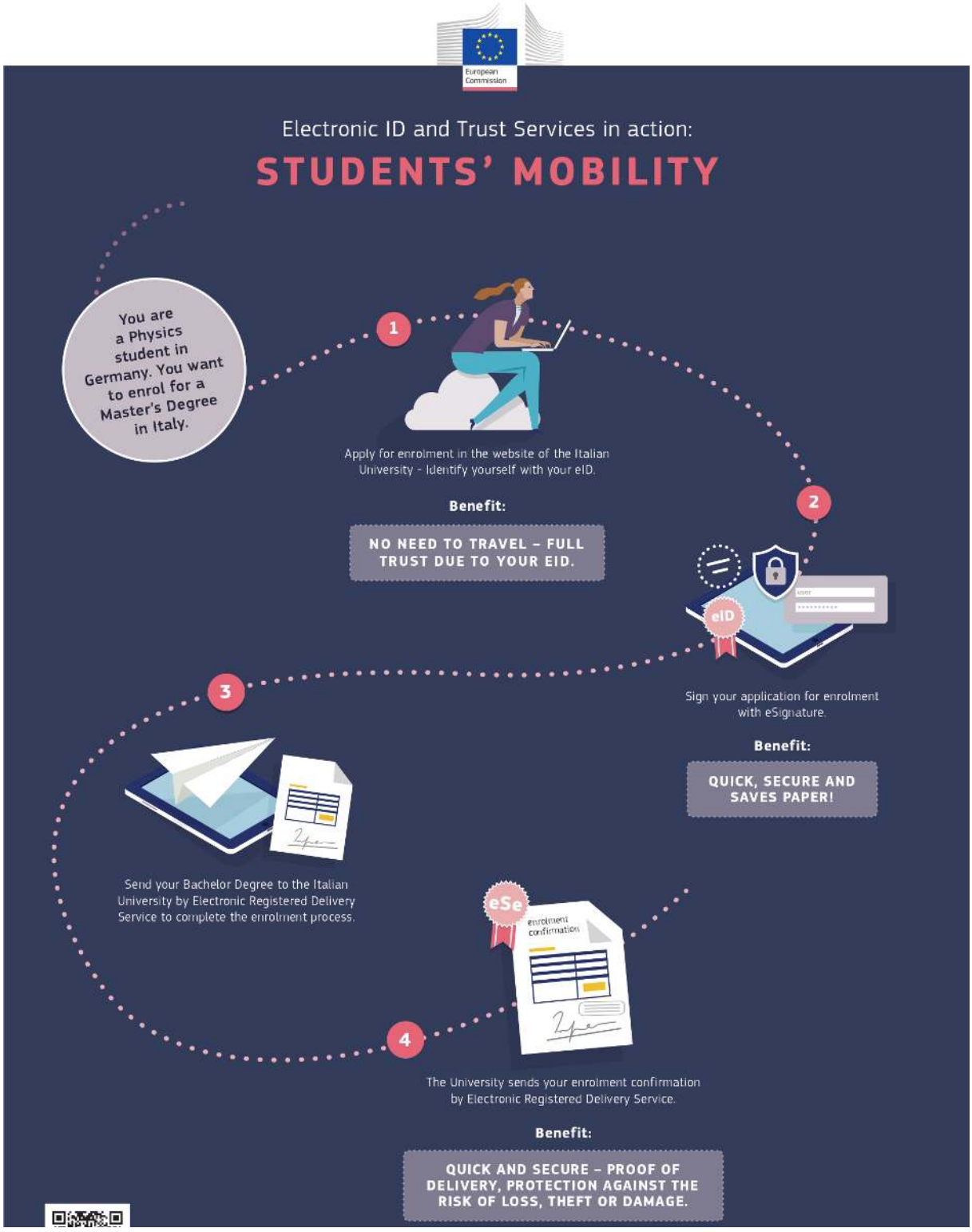


Figure 32 - eIDAS HEI scenario[30].
© 2025 European Union

[30] https://digital-strategy.ec.europa.eu/en/policies/eidas-regulation

The figure above illustrates the impact of eIDAS on a European education scenario, highlighting its role throughout the mobility programme lifecycle.

eIDAS 2.0 will expand the regulation. It will include the European Digital Identity Wallet (EUDI Wallet). This is a customisable digital identity system. It lets students store and manage their academic credentials and other forms of identity in one digital place. For Higher Education Institutions (HEIs), this means adjusting their authentication systems to work seamlessly with these digital wallets. Additionally, eIDAS 2.0 strengthens security to ensure strong authentication and user control over personal data. It requires institutions to adapt their platforms for secure, decentralised identity management.

GDPR Impact

GDPR is another European regulation that directly affects how HEIs manage personal data of learners, faculty, and administrative staff. GDPR requires institutions to implement strict privacy policies and protect personal data across all systems.

This affects information storage, processing, and transfer processes, obliging HEIs to adopt measures such as data encryption, restricted access controls, and anonymisation practices.

4.4 EIF Relation

The projects presented fall within the scope of the European Interoperability Framework (EIF), and many of them cover several layers of this framework. For instance, eduGAIN has an impact on both the organisational and technical layers. Below is an overview of the layers primarily associated with these projects.

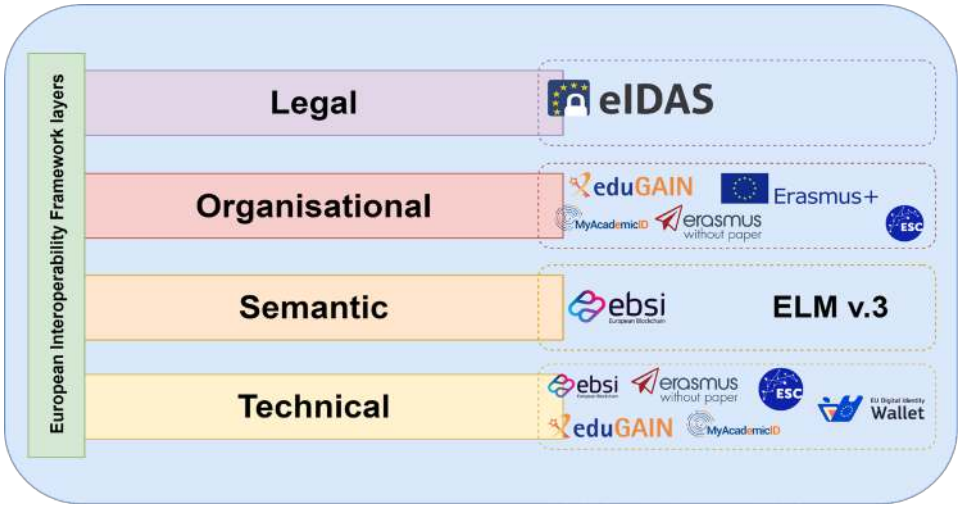


Figure 33 - Relevant identified projects related to each EIF layer.
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5 Beyond the alliance level

5.1 Caveats on the proposed solutions

As the previous elaborations and insights have shown, interoperability between institutions within the same alliance is a significant challenge. Shifting from this mixed state of alliance interoperability to a broader one – interoperability beyond the alliance – raises the difficulties and challenges that need to be addressed. Therefore, this section will outline the key points to consider when scaling the proposed solutions to this extent. To this end, the strategies identified for achieving interoperability will be outlined.

Take-away #6: There are three main strategies for achieving interoperability: the decentralised approach, the centralisation approach, and the broadcast approach. The decentralised approach offers the most preferable scenario for scaling due to its distributed nature. The other two approaches can scale, but they have drawbacks beyond the alliance level. They require centralised systems that are costly to maintain and coordinate. However, these strategies are flexible, allowing their combination or the creation of hybrid solutions that can be adapted to meet particular needs and costs.

Strategies

Decentralised: The decentralised approach provides an interface that collects data from all involved systems on demand. This set-up might make it suited for scenarios with a horizon beyond the alliance level. Without central elements that monopolise all the information, as present in the centralisation approach, it is more scalable and dynamic, keeping data within each alliance's private systems. Although there is no central data hub, a central access point is still required to enable calls to the various services exposed by the alliances. This element must possess the required capabilities for scaling. Moreover, the load of data requests, previously borne by the central system in the centralisation scenario, now falls on individual systems (centralised or not) within each alliance. This shift may necessitate scaling these systems to handle the increased requests from the central access point between alliances.

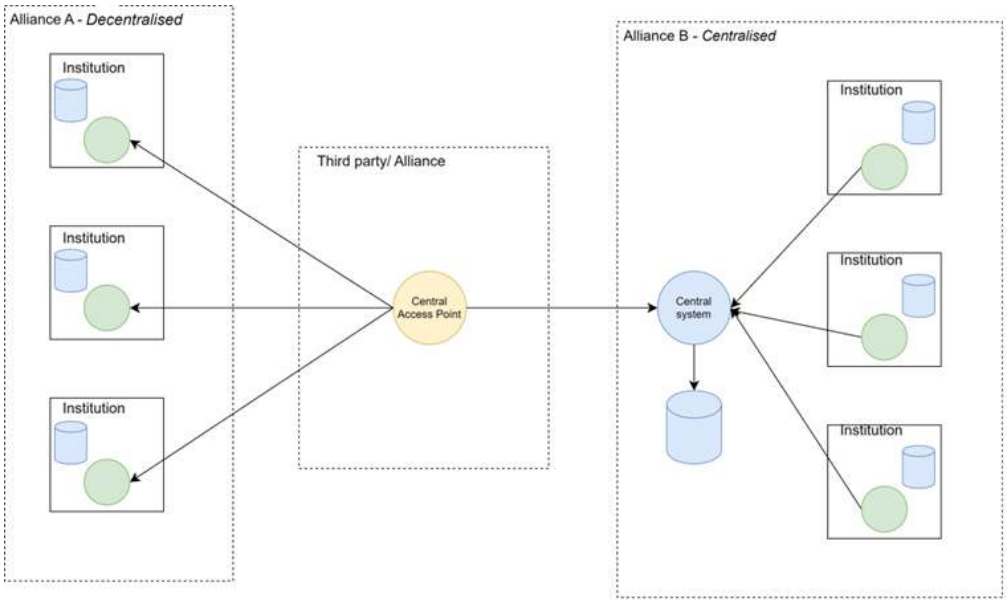


Figure 34 - Decentralised strategy on alliance-alliance scenario.
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Centralisation: Centralising at the alliance scale can be a viable option. With an average of nine HEIs per alliance, the volume of traffic that central components need to handle is substantial, but manageable with a medium-level infrastructure. However, centralising at a cross-alliance level may not be practical. The number of requests can increase to very high levels, making management challenging. Furthermore, alliances may not be interested in sharing their data to the extent of centralising it in a structure beyond their direct control. This would mean storing data in third-party systems or in the systems of one of the alliances, which would require the data to travel to systems outside the original alliances. This, in turn, would demand significant efforts in permissions administration and data management.

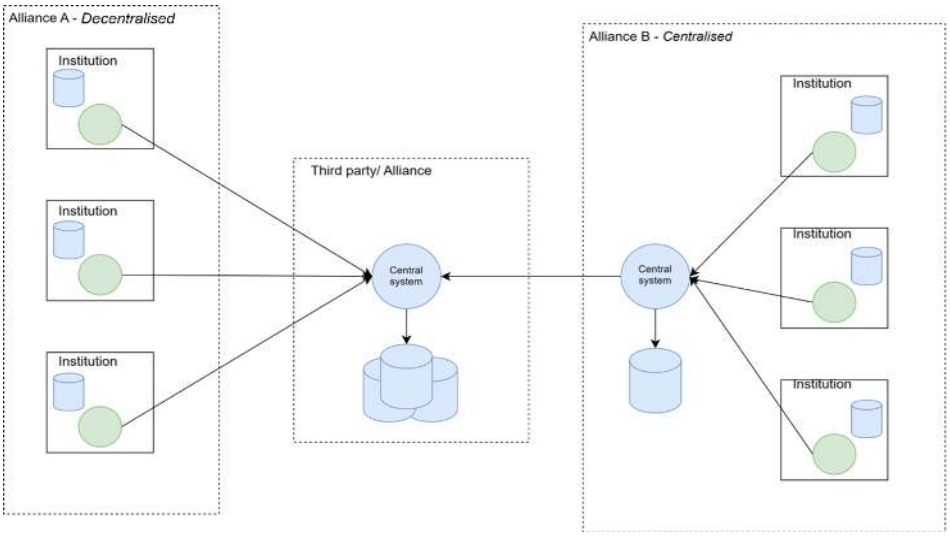


Figure 35 - Centralised strategy on alliance-alliance scenario.
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Broadcast: Broadcasting is a hybrid strategy where data from each system is shared with the rest and accessible from any point. This approach is not considered viable on a larger scale. This is due to three reasons. First, it's hard to sync data across many systems. Second, data protection laws limit having redundant data in multiple alliances. Finally, a high volume of communication is needed to keep the data updated.

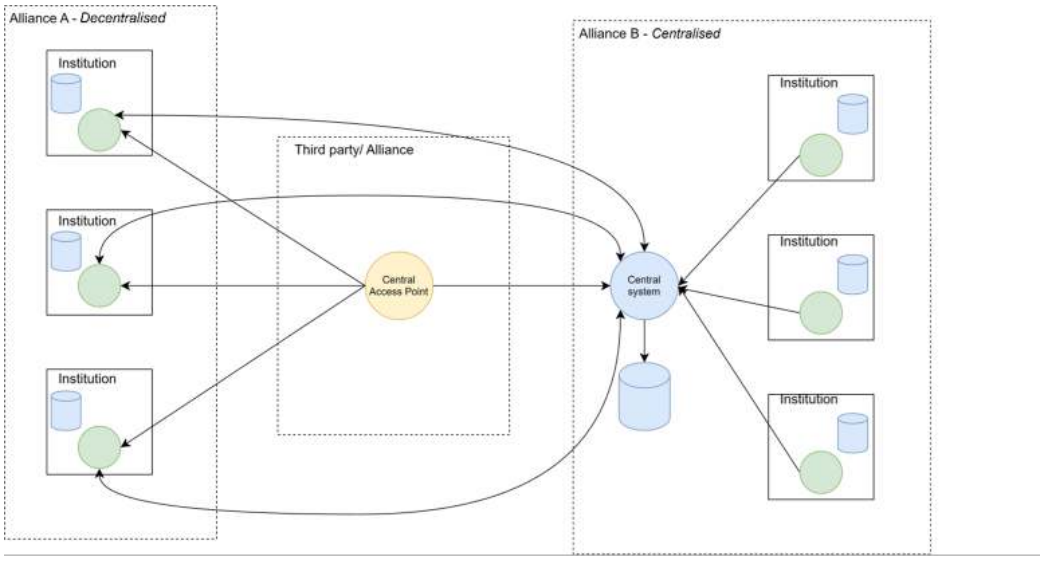


Figure 36 - Broadcast strategy on alliance-alliance scenario.
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Take-away #7: There are two approaches to implement mapping systems: a central access point with mapping capabilities, or local implementation by the involved institutions. For all use cases, data must be exchanged between institutions or alliances. In such cases, the local approach is recommended. It makes it easier to maintain the mappings in a distributed way. The ideal solution, however, would be to use data standards directly, eliminating the need for mapping processes.

Standards and protocols

Data diversity in the intra-alliance scenario poses a significant challenge to interoperability. The challenge becomes even more pronounced when considering standards and protocols, as this approach highlights interoperability issues between alliances.

Defining and adopting standards is necessary for all alliances seeking to collaborate in an interoperable manner. These standards must be multilaterally agreed upon by all parties, with the aim of choosing widely known standards for future collaborations with other alliances.

As noted previously, adopting standards implies either changing current data systems or implementing data mapping systems capable of transforming heterogeneous data into standardised formats. A mapping system was recommended for institutions within a single alliance, though it requires significant effort. But, in this larger inter-alliance scenario, it is a must.

Two approaches have been proposed for implementing mapping systems: either a central access point implements the required mapper, or each institution's local systems implement the mapping capability. In scenarios like collaboration between alliances, having a central mapping point or system is not advised, as the volume of mappings to be handled would be extremely high. Instead, it's recommended to implement a mapping system at the alliance level, allowing data to be exposed according to the standard agreed upon by all parties.

Beyond data standards, common rules should govern communication protocols at this level. For instance, using a REST API to expose data from certain systems, following agreed-upon communication standards. These standards control everything from the naming of exposed services to how they respond in case of any error, including the expected fields in each implemented call. This approach facilitates the registration, search, and use of exposed services among alliances.

Security and privacy

Take-away #8: Due to wider jurisdictions in alliance collaborations, 3 elements must consider: 1. Protocol compatibility. 2. Data protection laws. 3. The need for secure authentication and authorization systems in managing student data. These elements are critical to ensuring efficient and secure data exchange in educational institutions.

In the meetings with the alliances, one recurring concern has been how to handle data. Sharing data between institutions - whether it's learner data from an SIS or data generated by a learner using a tool in an LRS - is a delicate matter. When it comes to interoperability between alliances, the lack of a universal data exchange protocol can cause compatibility problems. Although standards like eduGAIN for identity federation or standard REST APIs can be helpful, their implementation differs across institutions. Moreover, strict data protection laws like Europe's GDPR require careful handling and transfer of student personal data, which can be complicated across different jurisdictions. Additionally, the security and reliability of authentication and authorisation systems, particularly in the context of identity federations and Single Sign-On (SSO), are crucial. Institutions must take steps to protect their systems from unauthorised access.

Administrative coordination

Take-away #9: Resource inequality can hinder smaller, less funded alliances in implementing interoperable solutions, risking a digital divide. Using open-source tools is recommended as one approach to overcoming some of these barriers. However, it is important to remember that open-source is not the only option. Institutions and alliances may also consider proprietary or hybrid solutions. These combine open-source and commercial software, based on their specific needs, resources, and goals.

Resource inequality is a significant issue among alliances, as they have different levels of resources and technical capabilities. This disparity directly affects their ability to implement interoperable solutions. Smaller alliances or those with less funding often struggle to adapt their systems, facing challenges such as a lack of technical expertise, financial constraints, or inadequate infrastructure. This inequality can create a digital divide, where some alliances cannot fully participate in the digital ecosystem due to limited resources. More experienced and resourced alliances should share their experiences, leading the way to foster collaboration between alliances and eliminate technical barriers that hinder collaboration.

One option to eliminate some of these barriers is using open-source tools. The widespread adoption of these tools, along with open data standards, will reduce budget differences between alliances, bringing them closer to achieving interoperability.

Alignment of policies

Participating alliances must align their administrative policies and procedures to enable effective interoperability. This requires harmonising academic calendars, evaluation criteria, credit transfer processes, and other administrative workflows. Alliances need to standardise student record management, grade calculation, and credit transfer between alliances to ensure seamless student transitions. Without alignment, administrative discrepancies can hinder the smooth exchange of student data and collaboration between alliances. Common agreed procedures can streamline admin tasks and improve students' education.

To facilitate cooperation between alliances, it is advisable to first define and standardise these processes within each alliance among its institutions. Building on this foundation, if adopting a set of common procedures is not possible, each alliance can agree upon or validate its own procedures, ensuring they are consistent within the alliances they comprise.

Credential signing on joint programmes between alliances

In the landscape of interoperability among alliances, the process of credential signing for joint programs becomes increasingly complex as more institutions participate. Options include delegating signing authority to a single alliance or institution or requiring signatures from each participating institution across alliances. Standardising signing protocols, complying with legal frameworks, and scalability are crucial factors to ensure the integrity and authenticity of credentials. Collaborative decision-making among alliance members is essential for establishing transparent and trusted processes that support seamless collaboration and recognition of joint programs across educational networks. The two principal options identified to sign credentials are:

- Centralised signing authority: Delegating credential signing authority to a single alliance or institution within the collaborative network is one approach. This centralisation streamlines the process, ensuring consistency and simplifying verification procedures. However, it requires trust and agreement among alliance members regarding the designated authority.
- Distributed signing across alliances: Each participating institution across different alliances must sign the credentials. While this approach ensures autonomy and distributed control, it may lead to variations in signing standards and verification processes, potentially complicating cross-alliance recognition.

Collaboration between independent institutions

A possible scenario that has not been explored until now is the collaboration between independent institutions. This level of cooperation simplifies all the proposed interoperability implementation strategies, as the relationship is 1:1. Institutions wishing to collaborate generally have fewer systems than an alliance, which means they have less data heterogeneity to standardise. The strategies to achieve interoperability are the same as those outlined at the alliance level, thus reducing scalability needs.

When alliances collaborate sporadically on specific programs, the decentralised strategy could best meet these needs. This approach avoids the need to create common systems. Each institution should map its own data to standards that allow for exchange or aggregation. Legally, this approach is also favourable in terms of data protection, as data sharing can be more straightforward without a central storage system and with fewer jurisdictions involved.

5.2 Way forward

The reference architecture outlines the components needed for interoperability in the use cases. It, along with the inventory mapping the landscape of standards and tools used across alliances, forms the technical core of the interoperability framework. It responds to the need for seamless digital teaching and learning across European borders, as envisaged by the

European Commission's Digital Education Action Plan[31].

To aid the use of this central reference point across alliances, it is accompanied by two key resources from the EDEH's interoperability project: the implementation resources and the governance model.

Implementation Resources

Implementation resources for priority use cases were co-developed with experts through interactive formats such as Design Thinking and feedback webinars. This collection of practical resources provides guidance for HEIs and alliances, helping to smooth the implementation of interoperability components in their daily operations. The resources comprise a modular and flexible kit that can be adapted to the specific needs and circumstances of each alliance. At the time of writing this report, the resource package is under development. To ensure its usability, the draft resources will be tested with several alliances prior to finalisation and publication.

[31] European Commission: Directorate-General for Education, Youth, Sport and Culture, Digital education action plan 2021-2027 – Improving the provision of digital skills in education and training, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2766/149764.

The resource package contains:

- An overall *Alliance Journey of Collaboration* provides a comprehensive overview. It can guide newly established alliances through their initial setup and help them understand what collaboration within an alliance entails. For more established alliances, this journey outline can serve as a reflection tool to better understand their current situation, define next steps, and set priorities.
- Resources are available to help alliances assess their current interoperability status and identify necessary components that are missing.
- Resources offer insights into the technical landscape of HE systems across Europe, applied standards, and tools to find solutions for their own interoperability pathway moving forward.
- More detailed resources are available for selected priority use cases, specifically: Use cases 1 (discover); 2 (apply and get recognition); 6 (earn a credential); and 7 (user identity).

Governance model

A governance model, that still needs to be development at the time of writing this report, addresses policy- and decision-makers in the European Education Area (EEA). To achieve this, a dedicated governance squad has been established, set to run from November to early December 2024. Under the co-facilitation of representatives from the consortium and the European Commission, in particular the Directorate General for Education, Youth, Sport and Culture (DG EAC), squad participants will jointly develop a white paper. It will outline potential governance models for managing interoperability in European higher education. The results will be presented at an in-person event attended by 90 stakeholders from leading organizations in the field of HE interoperability, EU agencies, various European ministries, and the European Commission in mid-January 2025.

The proposed governance models will integrate the interoperability framework. They will connect national and international stakeholders, standards, initiatives, and interests within the complex, historically grown European education ecosystem.

NC-02-24-713-EN-N

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PDF

ISBN 978-92-68-18732-6
doi: 10.2766/556601
NC-02-24-713-EN-N