Structural Challenges in the Educational System Meet a Federated IT-Infrastructure for Education: Insights into a Real Lab

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Abstract: This position paper describes the need and the proposed solution for a federated educational infrastructure currently developed in a national flagship project in Germany. Existing technologies and standards, tools, and services are brought together in a heterogeneous yet consistent infrastructure by a distributed middleware. These technical developments are accompanied by consulting and organizational activities. The article describes the expected outcomes of this pilot project that will be available as an interoperable prototype throughout the year 2022. This also includes the international perspective of such a solution.

1 INTRODUCTION

We are facing a structural change in the education system: Digitalization is changing IT infrastructures and thus access to and participation in education just as fundamentally as it is changing the structures of the education system itself (Komljenovic, 2018; Williamson 2018). This affects all sectors of the education system, with the digital transformation proceeding at different paces. In terms of teaching/learning artefacts and other educational information, digitalization rather contributes to individualizing and personalizing content, which at the same time has the potential to expose the tension between digital and traditional educational offers and to rethink the latter (Komljenovic, 2019; Reckwitz 2017).

Worldwide communication and networking through the Internet and the steadily growing, digital description and penetration of almost all areas of life should enable borderless information, personalized communication, and global mobility. At the same time, the landscape of digital services, IT infrastructures and data formats is paradoxically becoming increasingly fragmented (Glass, 2001). International standards have thus far been unable to establish themselves, as both software systems and education providers insist on their processes and structures; interoperable IT systems are still in short supply in the global education system. This circumstance indicates that singular or locally limited approaches have little chance of success in digitally paving the way for learners and preparing them for the labor market.

Digital infrastructures enable both new interactions between learners as well as interconnections between existing IT-systems that are reminiscent of railroads and highways (Peters, 2017), but at entirely new speeds. These emerging, networked infrastructures have a primarily private-sector character, leading to a so-called "extrastatecraft" (Easterling, 2014) that makes it increasingly difficult to distinguish between the private and the public sector (Hartmann & Kjaer, 2018). It is hence becoming more and more important to strengthen public information and educational offers while at the same time considering and – if possible - integrating the potentials of private-sector production and supply logic into digital educational ecosystems.

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The use of digital media in educational systems and processes has been researched for decades – from computer- or web-based training to networked and mobile applications or learning games to virtual reality or AI-supported methods for preparing new fields of knowledge. However, the findings have not yet found widespread adaptation in educational practice. During the COVID-19 pandemic, the need for change has become even more apparent for all sectors of society. Universities were rather quick to switch from analogue to digital (remote) teaching (in particular due to their expertise in digital education); this shift was much more difficult for schools and vocational training institutions.

The underlying reasons are manifold: By their very nature, evidence-based policy changes in the education system take a long time. It often takes years until the effects of successful interventions and experimentations have been politically recognized. In addition, the federal education system makes it difficult for the different tiers to agree on core issues; these include, for instance, the definition of quality standards, the use of digital media and e-learning tools in education, as well as increasing digital literacy among learners. On the user side, there is on the one hand the necessity to act maturely and sovereignly in a digitalized world; but on the other hand, there is still a lack of knowledge when it comes to basic operations of digital media and their usage in digital education.

Nevertheless, a transformative process is needed to change existing structures, processes, and systems. At the same time, IT-developers and users must be involved in an iterative approach alternating between small-scale networking and disruptive innovation. This urgent demand can be exemplified by previously dysfunctional transition points.

- vertical transitions:
  Users are often confronted with different educational platforms and learning scenarios when moving across sectors, e.g. between school and higher education. Personal data and collected materials must be repeatedly composed along with one's educational biography. This applies particularly to(prospective) teachers, who are at the same time teachers and learners in different contexts.
- horizontal transitions:
  Media disruptions also create user barriers for instance when students move from one institution to another within the same education sector, e.g., when they change universities or spend some time abroad. This change directly interferes with the compilation of personal learning portfolios and also impedes formal recognition processes of study achievements.

Every switch between the services used by individual education providers still requires a new registration and a manual transfer of materials and personal data. The horizontally and vertically fragmented responsibility structures that become visible here are a factor that must also be addressed in the design of digital education infrastructures. This requires a suitable architectural approach that respects the formal boundaries of subject areas and areas of responsibility while making certain components interoperable. A federated IT system in which the need for a central, potentially superordinating structure is reduced to a minimum through mutual trust between different components could achieve this goal by considering the principle that the IT structure must follow the organizational structure. In this paper, we want to elaborate on how to interlink existing and new digital education platforms into a nationwide (and European-connectable) federated infrastructure. An ecosystem of mutually independent education services will be created that will offer users support on their path through the educational sectors.

2 STATUS QUO

The contextualization of the proposed transformation process builds on preliminary work from both education policy and research perspectives:

The European “Digital Student Service Infrastructure” (EDSSI) is developing a system that will enable higher education institutions to exchange and authenticate student data seamlessly and securely. This project is aiming at providing a single point of access to services across Europe. The system tries to interlink the EU Student eCard core service platform and extends the Erasmus without Paper data exchange network and the MyAcademicID and European Student Card authentication solutions based on a common IT architecture to establish a harmonized authentication system.

On this basis, the exchange of teaching and learning opportunities and digital student mobility (e.g., to foster "internationalization at home") can be supported throughout Europe. Following this approach, the barriers between universities and their local infrastructures can be removed.

European University Alliances represent an important point of reference for the socio-technical networking of education in Europe. From a technical point of view, the development of inter-university campuses, in particular, poses several challenges and

requires interoperability, openness and scalability so that isolated solutions do not emerge as detached “islands”, but rather as interlinked networks that can be expanded effortlessly with seamless transitions becoming natural.

The Digital Education 2021-2027 Action Plan pursues the goal of the already launched "European Student Card Initiative" to facilitate the secure electronic exchange and verification of student data and academic records, thus becoming a substantial added value for universities by simplifying the management of their students' mobility.

From a German perspective and following the student journey, the project "Digital Campus" should be mentioned. The project aims at linking existing digital services for information, recruitment as well as linguistic, subject-related, and cultural preparation of international prospective students (Pineda & Knoth, 2020).

The "Platform for International Student Mobility" develops the conceptual and technical framework for a system that has the potential of simplifying the recognition of academic achievements. This information, which is not standardized and not always machine-readable, is the fuel for many workflows, such as the creation of individual learning paths based on recognized teaching and learning opportunities.

The idea of portal solutions has been pursued several times. The driving forces in Germany behind these developments were mainly federal programs supporting digitalization in education financially, especially the "Quality Pact for Teaching" (Kiy et al., 2017) and the previous programs "New Media in Education". Since 2001, for example, the CampusSource network is representing the interests of the use of open-source systems at universities; online platforms and portal solutions play an important role here. Among other things, there is a lively exchange of plug-ins for the *Liferay* software to simplify local developments and operating processes (Bußler et al., 2021), as well as to support connectivity across institutions (Kiy et al., 2014). One example of a university portal based on *Liferay* is “Campus.UP” which has been developed at the University of Potsdam (Lucke & Strickroth, 2020). Initial prototypes could already demonstrate that such a networked teaching and learning environment can be created: innovation spaces can easily be created by simply connecting what is already operational in place.

3 A FEDERATED NATIONAL INFRASTRUCTURE FOR EDUCATION

The main objective of the proposed infrastructure is the prototypical implementation of a technical backbone for a so-called “Digital Education Space”. That space forms the basis for the integration of existing portal solutions as well as teaching and learning service providers into a federated education infrastructure. The following measures are being implemented for this purpose: (1) The technical context is made up of technical developments. (2) The usage context is addressed by consulting measures. (3) The transfer context is expressed by organizational measures. To successfully carry out the project, expertise is involved not only from the field of technical development, but also from the areas of system administration, media didactics, media design, public relations, and project management.

3.1 Technical Measures

The focus of the project lies in technical development. These include in particular:

- Implementation of a prototype for federated education infrastructure, incl. comprehensive functionalities for all educational sectors
- Provision of interfaces for the connection of further components and services
- Consideration of the “Digital Campus” as the international client of the portal prototype

Two areas are of particular importance for the technical developments: the portal and the network layer distributed middleware. The resulting architecture is depicted in Figure 1. Details are given below.

As a communication and collaboration environment, the portal (upper layer) represents the access point to the national digital education platform that is visible to all users. The tools for interaction between users and the system (shared teaching/learning and workspaces, e-learning tools for documentation, collaboration, and reflection) are interlinked here. The open-source framework *Liferay* is used as the technical foundation for the networked approach. The portal is considered the visible counterpart of the middleware, which serves as a reference implementation for other educational software to be connected to the middleware in future scenarios of a Federated Educational Infrastructure.

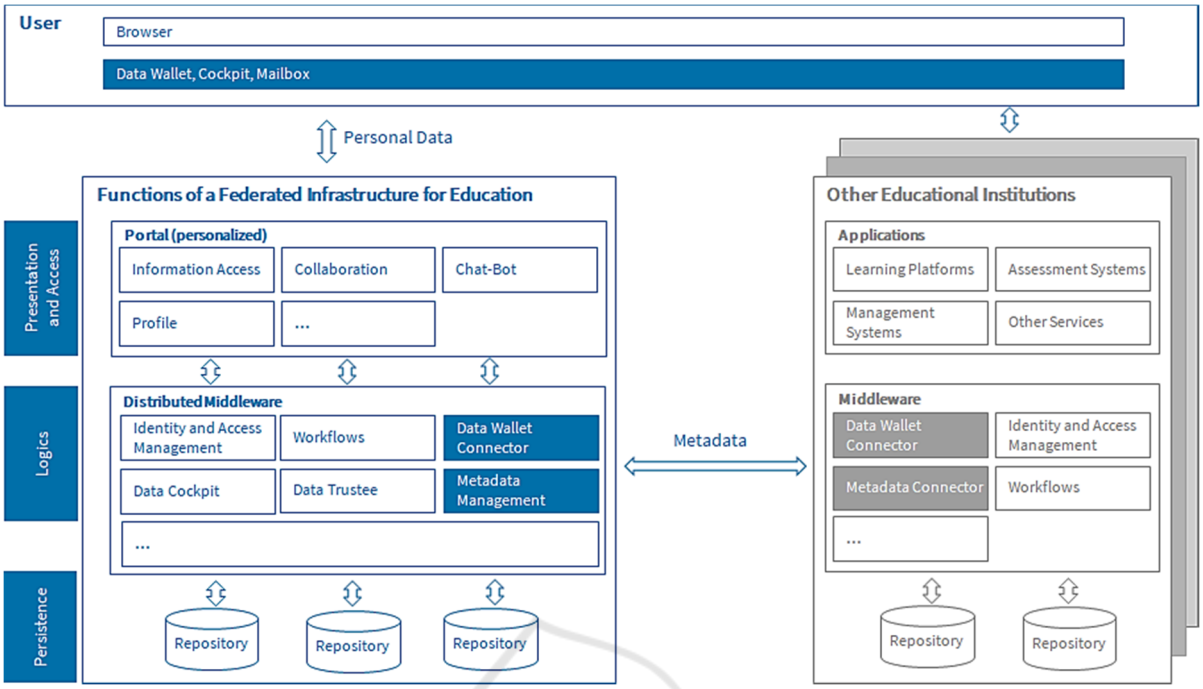

Figure 1: The heart of the architecture of the German National Infrastructure for Education is a distributed middleware.

Among others, the following components are part of the portal:

- Information access by searching the connected repositories or browsing curated catalogues.
- Personal profile containing preferences, achievements, and certificates of the user.
- Collaboration tools complementing the possibilities offered by connected service providers.
- Chatbot providing targeted and tailored information for certain pathways along the student journey.

The underlying distributed middleware (networking layer) serves as an intermediary layer between the portal and the other service providers connected in the Digital Education Space. The connection is made via clearly defined interfaces without deeper intervention in the systems of the education providers themselves, thereby minimizing efforts and obstacles. Among others, the following components are part of the distributed middleware:

- Identity and access management providing information on the identity of the users, their roles, and their authorization for access to the connected services as well as single sign-on.
- Workflows facilitating the planning and implementation of the individual user journey.
- Personal data wallet to manage acquired achievements and certificates, and to exchange them between the connected service providers and the portal upon user request.
- A mailbox for handling special (protective and safety-relevant) messages (acknowledge receipt, the timestamp when sending and receiving, and others).
- Metadata management for educational content in connection to various curated catalogs (e.g., OERsi).
- Data cockpit to enable the user to decide which service provider receives which data and when.
- Data trustee to manage anonymized data (beyond personal data in the users' wallets) for monitoring and optimization purposes.
- Digital certificate infrastructure to generate, exchange, verify and, if necessary, withdraw certificates.

For the components to function, the data storage layer also needs to specify data standards for harmonized storage and machine-readable data exchange without media discontinuity (e.g., of formal or informal certificates). For this purpose, European and national standards are used.

An overview of possible tools available in the current state of the prototype is presented in Figure 2. The navigation menu is shown on the left. On the right is the inclusion of a curated catalogue for learning/ teaching materials. Below is a collaborative text editor. In the center are three functionalities: a news board, a task managing application, and the single-sign-on to continue with a connected service.

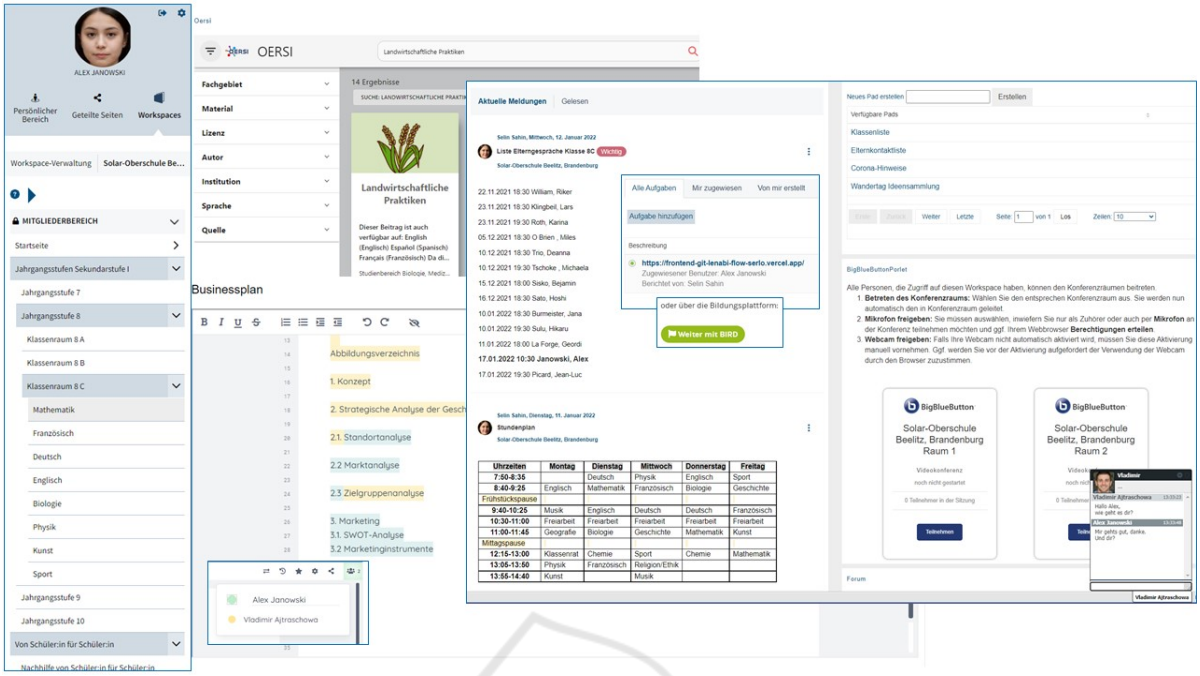

Figure 2: The prototype of the Educational Infrastructure combines tools from different providers in flexible workspaces.

On the right, the management of different collaborative text editors and an incorporated video conferencing tool, as well as a chat.

Further platforms of education providers are to be connected via the middleware, as shown on the right-hand side, including existing services as well as new educational developments or platform components by "sister projects" funded by the same governmental program. Within the framework of the Online Access Act (OZG) and the Single Digital Gateway Regulation (SDG), additional building blocks are to be considered in the ongoing work process. These include the integration of additional components such as a federal public key infrastructure.

3.2 Consulting Measures

The second area of core activities is consulting. This includes a bidirectional exchange with users of the Digital Education Space and various target groups:

- Learners who want to take advantage of digital educational opportunities.
- Teachers who want to design and supervise digital educational offers.
- Education providers who would like to join the Digital Education Space.
- Service providers who implement this connection on a technical level.

The goal of the exchange is to support these stakeholder groups in connecting to and using the distributed education infrastructure and, in turn, to systematically capture their needs in the context of a Digital Education Space. Both precise requirements for the design of individual use cases and general recommendations (guidance) for the development process can be derived from this exchange. Therefore, the specific use cases can be generalized into broader scenarios or associated templates that promote the further design process and thus sustainable development.

Finally, the Digital Education Space addresses two complementary content areas:

- Teaching and learning scenarios of different disciplines.
- Teach-the-Teacher training on digital literacy.

This comprises the provision of learning units via educational certificates that can be acquired or reused by other teachers. And in particular, the promotion of exchange between teachers, since this type of peer-to-peer exchange (within individual institutions and beyond) has proven to be a key success factor for digital educational offers.

Quality assurance measures are closely linked to these issues, including the establishment of quality criteria for the linked educational offers (which are also applied in the curation of content for the portal) and the systematization of the consulting services, e.g., through guidelines and checklists, to ensure the quality of the consulting processes.

3.3 Organizational Measures

The third area of core activities consists of organizational measures. They address the environment of the outlined project, both during the project term and with regard to a later transfer of the project results. Four individual measures are planned for this purpose:

- Support for further development and application projects:
  The Digital Education Space perceives itself as the core of a digital education infrastructure that can and should accommodate further providers and offers. We expect great interest from the relevant stakeholders and hope for supportive funding from the federal and state governments. The connection to the infrastructure described above will require negotiation processes to select suitable components and partners within the framework of the federated overall system. Regular meetings are used to coordinate interfaces and technologies, to transfer know-how where necessary, and thus promote the merging of systems that have so far operated in isolation.
- Contact with further, relevant projects:
  A systematic coordination process is conducted with the existing initiatives for the emergence of individual aspects of a federated infrastructure to identify common objectives and thereby avoid both, contradictory and duplicate developments. The goal of this dialog is to maintain heterogeneity while preserving interoperability.
- Dissemination:
  Beyond these two coordination processes with direct cooperation partners, further measures are carried out to involve relevant stakeholders (e.g. from the field of education policy, the open education community). The precise proceedings and the planned communication of the project results are to be determined in close consultation with the Federal Ministry of Education and Research. In addition, targeted community building is also important in the education and science landscape to promote the transfer and thus sustainability of the project.
- Quality assurance and transfer:
  All measures carried out – especially in technical development, but also in consulting and organization – are documented systematically and thoroughly. Established IT service management process models are used for this purpose. The goal is to achieve a high level of maturity, which supports the transferability of the general approach, the developed measures, and the development results. This is where quality management comes in, linking internal evaluation mechanisms with external evaluations, enabling the preparation of a tender for a later productive system (with then broad implementation).

Agile project management forms the structuring backbone behind the detailed conception, implementation, and success monitoring of the three outlined bundles of measures across the project.

4 INTERNATIONAL OUTREACH

From the perspective of the prototypical development of the National Digital Education Platform as a federated IT infrastructure and the building block of a Digital Education Space, the DAAD initiative Digital Campus represents the “sister project” focusing on internationalization. The Digital Campus and its interlinked services, such as the DAAD information and advice service My GUIDE and other qualification services for prospective international students, provide know-how on processes of international mobility and exchange procedures on the one hand. On the other hand, testing a teaching/learning service tailored to the target group 'international students' is also of high importance. Tools, accessible via the portal, for digitally enhanced collaboration, documentation, and reflection are additional functionalities required by the target groups. A cooperation agreement is concluded with the Digital Campus and a jointly coordinated division of labor is developed within the framework of agile product management.

European (and worldwide) connectivity represents one of the most important goals of transversal infrastructure projects. When it comes to learner data exchange, the EU’s approaches for “European Digital Credentials for Learning” and the “Europass” data model (EDCI) need to be considered. Despite the standard agnostic approach of the described prototype, synergies should be identified, and the implementation of an educational standard should be supported. The European University Alliances also play a crucial role in this context. These higher education networks represent both, an experimental space for various forms of (political, social, and infrastructural) collaboration and a unique source of knowledge. The described prototype could be tested and validated by applying to exemplary

alliances. The gained experiences can help to improve technological concepts and to prove whether learner-driven, collaborative, and cross-campus teaching scenarios can be realized or not. Finally, direct user feedback will provide evidence on how such an infrastructure impacts education. The first steps have been made in this direction, a few more should follow during the funding period of the presented research and development project.

5 CONCLUSIONS

At the end of the project duration, the following results will be produced by the national flagship project described in this article:

- Prototype of a federated IT service infrastructure for education.
- Proof of concept for integration mechanisms for service offers (single sign-on, metadata management, user-centric data management, and communication).
- Platform for the interactive, cooperative design of subject-specific use cases (teaching and learning scenarios).
- Contribution to further tender documents for the design of a national education space.

The development and usage conditions are explored to such an extent that the achieved project results will be available in the form of technical developments (e.g. interfaces, components, etc.) and documented project knowledge to be either perpetuated or transferred to other development projects.

Thus, the initiative for a Federated Educational Infrastructure in general and the described project for developing the prototype of a Digital Education Space will bring education significantly forward across all sectors by elevating the use of digital technology to a new level of interoperability. Mainly access to and participation in education is increased through seamless digitalization processes which allow for new dimensions of individual and institutional cooperation and pave the way for individual student journeys. For educational services providers, the coverage of learning opportunities is increased while their provision is facilitated by clear interfaces at the same time.

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