Interoperable Education Infrastructures: A Middleware that Brings Together Adaptive, Social and Virtual Learning Technologies

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What should a course provider do if all course content, which is stored in Moodle, needs to be migrated to a new learning management system? How could a provider easily use advanced technologies like learning analytics, learning recommender systems or virtual learning to create a compelling learning experience? How can a provider incorporate the content of another provider into an existing course? To address such questions, we developed the Common Learning Middleware in a joint project with several Fraunhofer institutes trying to solve these typical challenges facing educational institutions.

A wide range of technological components support or facilitate many successful approaches in the field of education, such as blended learning or flipped classroom learning. Learning analytics and educational recommender systems are based on statistical models and artificial intelligence; gamification and social- and peer-learning require appropriate backend services; learning content and media of these systems are typically hosted on different servers; and virtual and augmented reality used in educational systems require specialised hardware or software. Many promising approaches are being developed as isolated solutions, which individually are quite successful, but would only reach their full potential when used jointly. Together with the Fraunhofer Academy, Fraunhofer FOKUS is coordinating a research project that seeks to integrate isolated solutions with each other through a middleware component.

The Common Learning Middleware [L1] is based on open standards and specifications for educational technologies, including standardised interface definitions [L2], metadata specifications for content structures [L3], learning objects [L4], and quizzes [L5], and standards for persisting activity data [L6]. Figure 1 shows the overall architecture of the Common Learning Middleware. In the underlying conceptual design, every element that can be integrated into the learning context, be it a text, image, video, dashboard or virtual reality, is abstracted as a tool. The different servers act as tool providers and can publish and subscribe their offers to the middleware. From there, the user interfaces, such as traditional learning management systems (e.g., Moodle or ILIAS) or advanced learning applications, can access the tools through standardised interfaces. The middleware verifies the roles and rights of the requesting users via its own user enrolment system for each access. In addition, existing user management systems can be connected to the middleware to enable cross-system logins. This enables the most diverse learning scenarios, which can be very well tailored to the respective learning context, without requiring programming skills of the content creator. To showcase our system, we give a few example scenarios, which were realised on the basis of individual solutions.

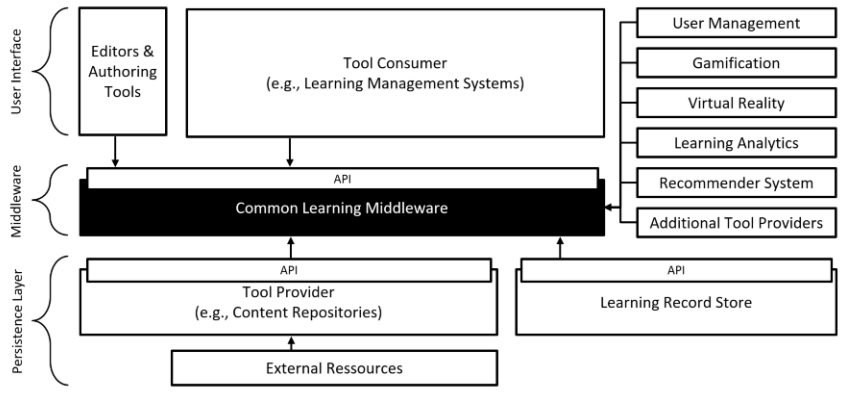

Figure 1: Simplified architecture of a learning infrastructure based on the Common Learning Middleware.

Together with the institutes Fraunhofer FIT and Fraunhofer IML, we have created a learning offer for the field of data science in which the learning content from the databases of several ILIAS platforms is presented in a self-developed learning portal from an external service provider. The portal also offers programming exercises (as individual Jupyter notebooks) after each major learning unit. Course participants can communicate via a tool provided by a start-up´s innovative social learning platform. In another case, together with Fraunhofer IOSB and Fraunhofer FIT, we combined various tools for the cyber security domain. It merges online learning content from ILIAS and Open edX learning platforms with interactive learning applications developed by an external service provider into a single offering. In addition, the learned theories can be practically applied in the serious virtual reality game Lost Earth 2307 [1], in which the learner has to solve various security-relevant missions in a future scenario. The game is seamlessly loaded into the platform. The middleware is also utilised for university courses in computer science [2]. And in a parallel project, we even used these interfaces to link six different educational institutes, which normally have little contact, from the fields of crafts, computer science and general school education. This created synergies between the institutes on the basis of content and technology. On the one hand, courses on bookkeeping and accounting only had to be developed once and could be utilised by all institutions in their respective learning platforms. On the other hand, more advanced components, such as learning

analytics, gamification, learning paths and a learning recommender system, were realised as tools and offered for the respective courses via the middleware.

Our recommender system [3] is a special tool provider that plays a central role, which focuses on determining "learning needs". These are numerical values that represent the relevance of the corresponding content to each individual course participant. The higher the individual's learning need for a topic, the more important it is that the learner should work on it. The learning platform loads the recommendation tool, which presents the content recommendations for the most relevant topics in order to make the learning process more efficient and effective. The recommender takes into account information that concerns the learning content itself. This includes, for example, data on whether certain content is relevant for exams or whether a lecture is about to take place. At the same time, information collected through direct user interaction is also included. For example, whether the participant has already edited all the underlying content, how the participant self-assesses in the subject area, how he or she has performed in exercises or how much of the content has already been viewed with the platform and for how long. A distinctive feature of the recommender system is the "forgetting effect", which provides information on whether the content was supposedly forgotten again based on the type of media, its scope and complexity as well as the time elapsed since the last learning. The users of the platform then see general and thematic recommendations in categories such as: "With these topics you can prepare for the next lecture.", "You haven't done so well in these exercises yet." or "You might have forgotten this already."

The Common Learning Middleware makes it possible to combine the most diverse educational technologies without having to forego content protection and rights management. Content from different learning management systems, such as Moodle, ILIAS or open edX, can easily be merged via a common interface definition and enriched with innovative technologies, such as learning analytics, gamification, social learning, virtual reality or learning recommender systems. Various institutions have already tested this middleware and Fraunhofer is successfully using it in several of its courses, such as those of the Fraunhofer FOKUS-Akademie [L7]. In response to high demand, the middleware is being opened up to external companies that value the independence of certain solutions.

Links:
[L1] https://kwz.me/hKr
[L2] https://kwz.me/hKY
[L3] https://www.imsglobal.org/cc/
[L4] https://www.imsglobal.org/metadata/
[L5] https://www.imsglobal.org/question/
[L6] https://www.adlnet.gov/projects/xapi/
[L7] https://akademie.fokus.fraunhofer.de/

References:
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[2] C. Krauss, et al.: "Teaching Advanced Web Technologies with a Mobile Learning Companion Application", in: Proc. of mLearn 2017, ACM, , Larnaca, Cyprus.
[3] C. Krauss, A. Merceron, S. Arbanowski: "Smart Learning Object Recommendations based on Time-Dependent Learning Need Models", in Proc. of EDM 2019, M. Desmarais, et al. (eds.), pp. 599 - 602, July 2-5, 2019, Montréal, Canada.

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Fraunhofer IAIS IoT Programming Language NEPO® in the Open Roberta® Lab

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Technology now pervades all areas of our lives, including our home life, education and work. As society becomes increasingly digitalised, digital skills such as "computational thinking" are becoming more important – this applies to children in school, adults in the workforce and senior citizens alike.

At Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, the business unit "Smart Coding and Learning" is dedicated to the topic of conveying digital skills, such as coding, in a sustainable way, regardless of gender, age or prior knowledge. As part of this, the educational program "Roberta® – Learning with robots" [L1] has been successfully accompanying teachers as well as inspiring students in STEM subjects since 2002. To date "Roberta" has reached over 450,000 children in Germany. This is one of Europe's largest STEM initiatives, its expansion being due in part to the EU project "Roberta goes EU" [L4]. In addition to the success of its hands-on didactic concept, one key component of the project is the development and implementation of new technology: the open-source programming environment "Open Roberta Lab" and the visual programming language NEPO® in particular, both initiated with the support of Google.org.

"Open Roberta Lab" is an integrated programming environment (IDE) that is available online, free of charge [L2]. As a state-of-the-art and open source cloud programming technology (CPT), it enables the web-based programming of hardware systems, such as robots and microboards, with the programming language NEPO on any computa-