A Conceptual Approach to an AI-Based Adaptive Study Support System for Individualized Higher Education

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Frank Otto(✉), Nico Kling, Christian-Andreas Schumann, Claudia Tittmann
West Saxon University Zwickau, Germany
frank.otto@fh-zwickau.de

Abstract—In the context of the digital transformation, the targeted implementation of AI-based or AI-supported technologies in "teaching & learning" as well as "administration & service" holds considerable potential for organizational change and quality enhancement for higher education institutions. The use of AI in higher education teaching and services lags behind the level in research. Therefore, holistic solutions must be planned and implemented in unity of teaching and research for the AI-based support of the stakeholders' inclusive administration, the further development or the establishment of new digital study programs and offers, and the prospective qualification of university staff in the field of AI. The solutions must be analyzed, systematized, and structured to generate a conceptual approach via an integrated architecture with adaptive services. This paper is an evolution of the concept presented at the Learning Ideas Conference 2022 and includes, in addition to explanations of the current state of the arts, the presentation of a systems-oriented approach for AI in higher education as well as the conception of the student lifecycle management at the author's university. The paper ends with the presentation of a concept regarding a decision support system for individualized studying.

Keywords—systematic approach for AI-based higher education, modular and adaptive services, individualization of studying in higher education, AI-based decision support

1 Introduction

The support of a wide variety of systems by AI will increase significantly and continuously. The many possible applications of AI are faced with immense challenges, which is why it is important to formulate and adhere to fundamental guidelines for the use of AI. The use of AI should serve to support people and not create a dominance of technology over people. AI, its possible applications, and its acceptance must be discussed in society in a broad, transparent, and comprehensive manner. In a 2018 survey by the Association of German Engineers, AI was ranked first as a leading trend in IT by 56% of respondents. Together with automation and digitization, AI is one of the three basic technologies for autonomous, smart, and adaptive systems that take on complex tasks in cooperation with humans and support them in all areas of life. AI will have a massive impact on life, education, and work processes, with AI systems serving

as assistance systems for humans and not making human performance completely obsolete. Ethics have a special place in the use of AI. The relatively high level of development of AI, especially in technology-related fields, helps to transfer application experiences regarding methodology and tools to other areas of life such as education, considering the specifics of these application fields, to push the further dissemination of AI on a professional basis [1].

With the coordination and elaboration of the global consensus on AI in education under the aegis of UNESCO, a framework with the claim of educational planning in the AI area has been created as a guide for the use of AI under the specific conditions of knowledge transfer in schools and universities in 2019 [2].

The underpinning regarding the use of information and communication technologies (ICTs) to calibrate the Sustainable Development Goal SDG4 by UNESCO's Quingdao Declaration in 2015 underscores the need to use emerging technologies to strengthen education systems, ensure access to education as well as quality and effective learning for all, and equitable and more efficient service delivery [3].

The 2019 UNESCO initiative on the application of AI in education thus serves to specify the overall UN and UNESCO sustainability and digitization goals of 2015. This finding is essential because it highlights the need to sustainably integrate AI into a general education framework, resulting in the challenge of complex solutions. The recommendations for action in the documents contain a clear message regarding a holistic and systematic approach to the use of AI in education, which among others includes [4]:

- Plan AI in education policies in response to the opportunities and challenges AI technologies bring, from a whole-government, multi-stakeholder, and inter-sectoral approach, that also allow for setting up local strategic priorities to achieve SDG 4 targets.
- Support the development of new models enabled by AI technologies for delivering education and training where the benefits clearly outweigh the risks, and use AI tools to offer lifelong learning systems which enable personalized learning anytime, anywhere, for anyone.
- Ensure AI technologies are used to empower teachers rather than replace them, and develop appropriate capacity-building programs for teachers to work alongside AI systems.
- Promote equitable and inclusive use of AI irrespective of disability, social or economic status, ethnic or cultural background, or geographical location, with a strong emphasis on gender equality, as well as to ensure ethical, transparent, and auditable uses of educational data.

To address the dynamics of transformation and the complexity of the task in using AI in education, UNESCO is pursuing further development of the approach through multiple international events that ultimately led to the launch of the AI and the Futures of Learning Project, September 30, 2021. Participants at the International Forum on AI and Education debated "Ensuring AI as a Common Good to Transform Education" in late 2021 [5].

There is also an understanding in the EU as well as in the countries of the community that AI as an emerging technology must be understood systemically and has to be integrated into all areas via complex planning, models, concepts, and implementations. Topics currently being pursued in this context include Fostering a European approach to Artificial Intelligence, Coordinating Plan on AI, up to a proposal for an Artificial Intelligence Act [6].

Experts commenting on the EU AI law proposal explicitly point out that education, just like, for example, critical infrastructure and security components, should be counted among the high-risk AI systems [7]. The high risk is derived from the complex effect of AI, which from a strategic point of view is one of the key policy areas, namely: High Performance Computing; Artificial Intelligence; Cybersecurity and Trust; Advanced Digital Skills; and Deployment and Best Use of Digital Capacities and Interoperability, listed in the context of establishing the Digital Europe Programme. Explicit reference is made to the fact that the five specific key topics are distinct but interdependent. The connection between digital transformation, which includes the application of AI, and education is made several times in the document in various relations [8]. Through the EU Commission, the integration of AI into education is linked to the updated Digital Education Action Plan [9].

2 AI penetration in higher education

Recent European University Association documents explicitly address the impact of AI in the context of technological developments. Universities are encouraged to study and assess the impact of emerging technologies and prepare graduates for labor markets that are changing due to digitization and emerging technologies, especially AI, which will also transform the mode and way of working practiced by universities and their partners [10].

The German Higher Education Forum on Digitization already took up this holistic approach in 2017 and placed AI as an emergent technology, especially in the form of machine learning, in the overall context of a digital turn for new ways of higher education in the digital age. Digital skills, digital teaching and learning, personalized learning, new understanding of roles and professions, academic program development, data security and privacy, and legal issues are mentioned as potentials and challenges for digital transformation. The focus should be on new business models; technologies; lifelong learning; internationalization; change management; organizational development; innovations in teaching, learning, and testing; curricular design; and quality development [11].

Understanding the complexity of the task means that any intervention to establish AI in existing higher education systems requires a holistic approach. Punctual or insular concepts and solutions carry the high risk that the AI deployment will not be compatible with all other processes and components and will thus be viewed as a foreign body and isolated.

The "Digital Higher Education" funding priority of the Federal Ministry of Education and Research in Germany is used to develop various topics and application

areas that are interrelated and encompass both practical knowledge for action and the development of framework conditions. The fields of application defined include experimental learning, digitized learning environments, and educational infrastructures and resources. Since 2021, the initiative "AI in Higher Education" has been funding projects ranging from the development of new study programs and modules in the AI field to the development of AI-supported systems at universities—e.g., using intelligent assistance systems or AI-based learning and examination environments. In order to do justice to the diversity and breadth of the higher education system and to achieve effective effects in studying and teaching, the following focal points are relevant [12]:

- Strengthening AI competencies in study and qualification programs.
- Improving higher education using AI.
- Sustainability, networking, and transfer between the former focal points.

Based on the described holistic approach of the use of AI in higher education, a project development for the establishment of an AI-based adaptive individualized study environment for students and university administration is currently underway, for which a conceptual design of an AI supported adaptive study system for the individualization of university services is required. Due to the complex impact of such a measure, the previous operating and process models of the university have to be analyzed, reengineered and optimized for AI support.

3 Process organization of AI-based system in higher education

Currently, many approaches to the use of AI in higher education are attempting to better address the complexity of the problem. In addition to the relatively narrow view of didactic, methodological, and/or technological nature, proposals are made that include, for example, an entire AI campus [13].

Unfortunately, they usually reflect only on the academic sphere without sufficiently including the other tangential higher education and administrative processes. Even if such a holistic approach were to be taken, massive problems of transition to upstream and downstream educational levels outside the universities would again be created in the end, which could significantly hinder the freedom to choose among educational paths for years to come. For this reason, process models have been developed that encompass complex educational pathways from school education to university training and continuing professional development. If service and administrative processes are integrated into the process models in addition to the educational pathways, the prerequisite for modeling and implementing processes and their AI support in a realistic manner is given [14].

Aspects of standardization as well as individualization of educational modules must be considered in the models. Processes can be controlled or regulated. When regulating educational processes, there are so-called feedback loops, whereby the processes can be better optimized. This approach is suitable for integrating AI support in a variety of ways. In particular, the adaptability of processes to the requirements of different

stakeholders in higher education can be significantly improved by applications of machine learning, for example. Starting from integrated educational systems, flexible systems with adaptive control and assistance for users are created.

The further digitization and automation of processes goes hand in hand in principle with data science or AI, which also applies to higher education. The use of AI has two fundamental goals: optimized and more efficient process management and user support for process operation. Assistance systems are also interesting in the field of higher education because they support users of different university groups (students, professors, and teachers as well as administrative staff) directly or indirectly in the execution of actions. They provide information and, if necessary, make suggestions for decisions and actions. With the use of AI, these processes can be upgraded. In process control, AI is currently being incorporated primarily for process data analysis, process modeling, model use (for example, for design, process analysis, and control), and process intervention, which is also transferable to AI use in higher education, including pre- and post-processes [15].

4 System-oriented approach for AI in higher education

The complexity of holistic, AI-based, and service-oriented higher education systems including the required regular adaptation and adaptivity of systems to support individualized educational pathways requires the application of complexity reduction methods. One common and proven way is system decomposition. Structurally, it means describing the higher education institution through the interaction of many components, resulting in a building block structure. The new Modular System involving AI will be the basis of individualization with simultaneous standardization and unification for the new higher education.

Higher education systems are separated from the outside world by a service layer (SL), which offers interested parties, students, lecturers, staff, and other stakeholders the opportunity to use the university's own products and services. Depending on the use case, this SL can be an interpersonal interaction facility (e.g., during advising sessions between prospective students and student administration staff) or a human-machine interface (e.g., when accessing digital learning content).

Within this layer follows the assistance layer (AL). This layer is responsible for providing the services offered by the university. In addition to administrative services, this primarily includes all services required for the proper execution of teaching and research. Basing on the AL there is an orientation layer (OL), whose purposes are:

1. the supportive provision of information for students and those interested in studying with regard to the courses of study and course content offered by the university (information layer, IL), and
2. the provisioning of a learning path layer (LPL), whose primary task is to show students the possibilities of how to connect various study modules on the way to an individual and successful degree.

The module layer (ML) following the LPL, as well as the learning unit layer (LUL) contained therein, are intended to enable students to access the individual modules and learning units and to support them in their daily tasks (see Figure 1).

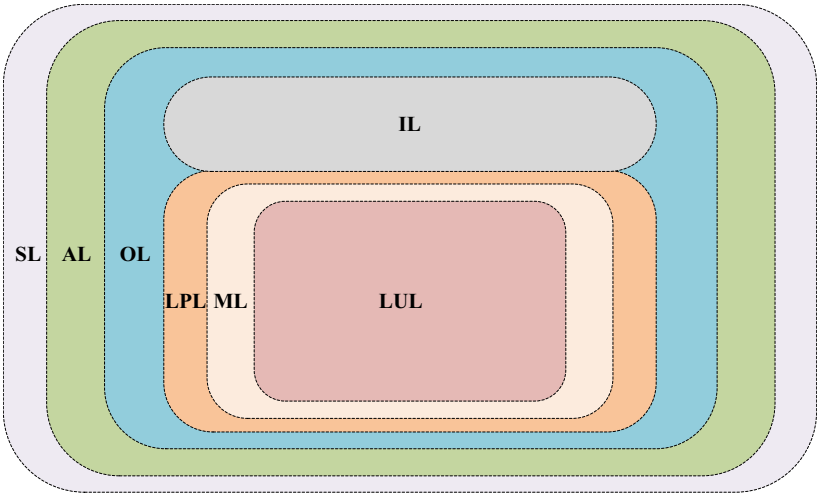

Fig. 1. Illustration of the different layers of a university

AI can be used in all of the named layers. However, a distinction must be made between the different ways in which AI can be used in institutions of higher education: as learning content within study modules, as a scientific method within research projects, and as a tool within administration. In the following, this section will focus on administrative processes, but the procedure described can be applied analogously to processes from the areas of teaching and research.

With regard to the use in administration, a further distinction must be made between the use of AI in:

1. general university administration processes, such as the administration of personnel matters or lecture rooms (SL, AL, OL, and IL),
2. student administration processes, such as AI-based decision support (SL, AL, OL, IL, and LPL), and
3. student recruitment processes (SL, AL, OL, and IL).

Users can interact with university members or the university's information systems by entering the AL via a desk. This desk can be either physical (e.g., when speaking to staff members in their physical office) or a virtual access point (when interacting with some information system). When interacting at a physical desk, the AI supports the corresponding employee working on this desk, while at a virtual desk, the AI directly supports the user.

Figure 2 shows the layers already described for service, assistance, orientation, information, and the learning paths. Within these layers exist different information

sources and their connections, represented by the circles and lines. The black circles represent the desk described. For a clearer presentation, the desk has been drawn twice, because it describes the beginning and the end of the users' interaction.

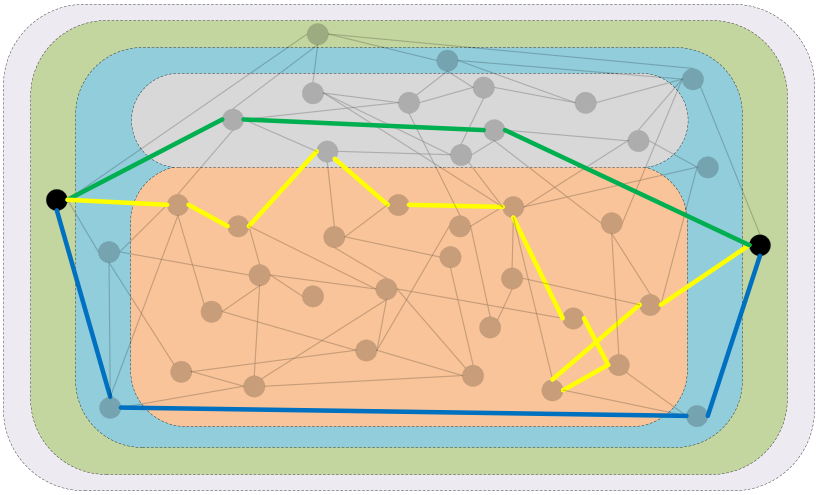

Fig. 2. Interaction possibilities of the users on administrative level

When entering a desk (either virtual or physical), the user's intention is to get some orientation, information or specific content. If the user needs some orientation (e.g., on what to study at the university), an AI-supported assistance system could be a suitable approach. In this case the following options for AI-support are possible:

1. The sematic linking of distributed information.
2. A rule-based or deep-learning-based decision support system.
3. A system, that provides speech recognition/language processing.

An example of a corresponding orientation path is shown as blue path in Figure 2. If a user is looking for information, the semantic linking of the existing, distributed information is also a possible way as well as a system with speech recognition or language processing provisioning. Figure 2 illustrates this option along the green path.

Another possibility is to support students on building their individual study path. In this regard, AI can also support by providing (semantic) linked information or by suggesting certain modules that suit the student's expectations (which have to be specified in advance) or that other students in analog situations have chosen and recommended. This process is represented by the yellow line in Figure 2. As the yellow line indicates, hybrids between the layers for orientation, information and learning paths are possible.

5 Student lifecycle management at the author's university

Student Lifecycle Management (SLcM) is the management of students throughout their lifecycle from the university's perspective. Thereby, it aims to support all (administrative) processes along the entire student journey from admission to graduation.

At the author's university the underlying basis for the student lifecycle is a circular process that aims to provide information and give orientation to the prospective and already enrolled students and thus enable them to make the best possible decisions for themselves (see Figure 3).

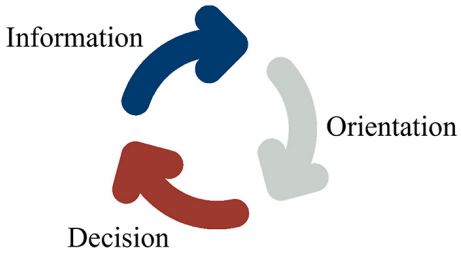

Fig. 3. The underlying basis

The actual student lifecycle at the university itself consists of three main parts: a pre-study phase, which includes all processes before the registration at the university; a study phase, which includes all processes from registration to graduation; and an alumni phase (see Figure 4).

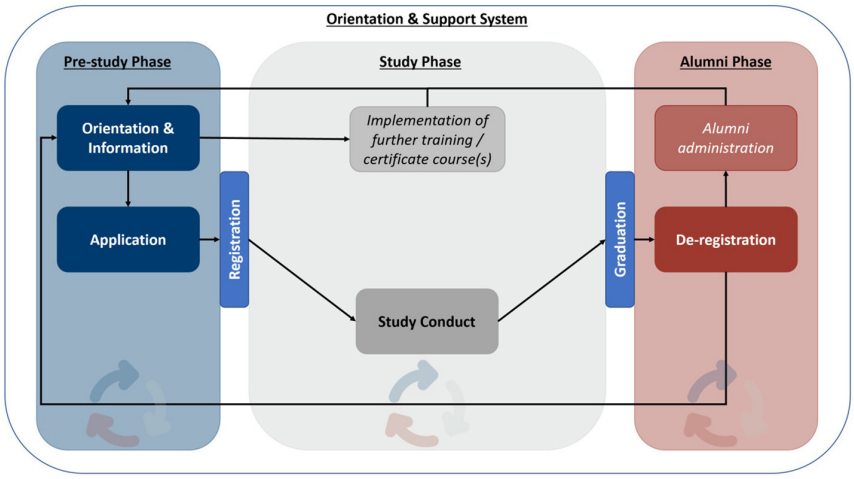

Fig. 4. Student lifecycle management at the university

For the university, the SLcM includes alumni administration and its mission of lifelong learning (by offering further training and certificate courses for non-students), because of the following goals:

- Improvement of the university's external presentation and thus potentially improvement of the image among prospective students.
- Involvement of alumni in teaching by inviting them to give lectures on corporate practice, which increases the attractiveness of teaching.
- Better corporate contacts for joint research projects with companies, whereby the results achieved in research can be directly incorporated into teaching, which in turn increases the quality of teaching.

From a student's perspective, the student lifecycle would look like the sequence of steps a student must complete on the way to graduation. This perspective has three layers: an overall administration level (blue line in Figure 5), a level for the enrolled study program (green line in Figure 5), and a sub-level for the study modules contained therein (yellow line in Figure 5). As shown in the figure, the underlying cycle of information, orientation, and decision-making forms the basis for choosing the most appropriate course of study and selecting the best possible elective modules.

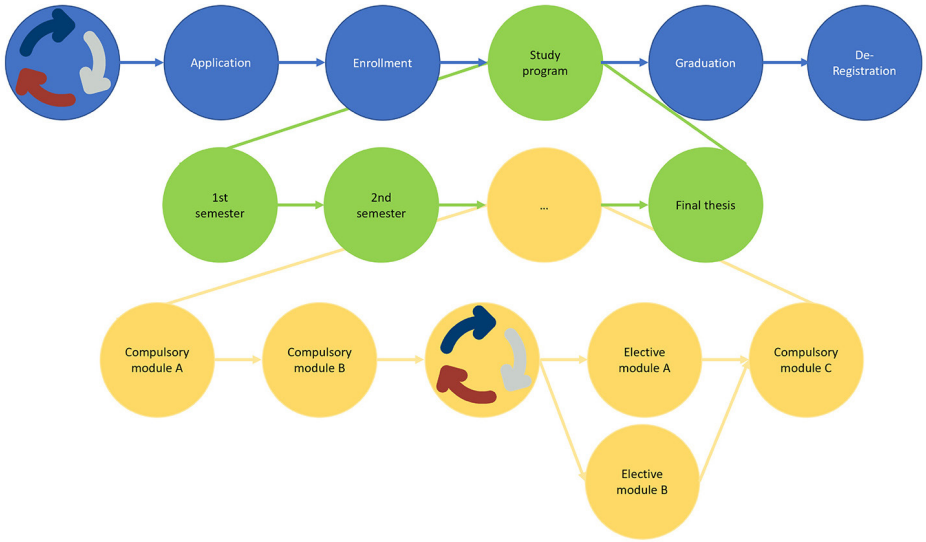

Fig. 5. Student lifecycle at the university from a student's perspective

All the parts of the university's student lifecycle and the underlying processes can additionally be supported by a holistic AI-based assistance system, which is to be implemented in the next years. This system should be usable for (prospective) students' needs as well as for the needs of the university's (teaching and administration) staff. In the following, this assistance system is described in more detail using an exemplary subtask.

6 Decision support for individualized studying

Today, young people have more opportunities than ever to choose an educational path that interests them. In Germany, more than half of all school leavers decide to study at one of the more than 420 universities [16, 17]. Prospective students can choose

from around 10,000 different undergraduate courses and almost as many graduate courses throughout Germany [18]. Accordingly, it is difficult for prospective students to find the best course of study for them from this large number of possible courses.

At the regarded university, this problem is to be addressed at least to the extent that prospective students are to be made aware of suitable courses of study simply and intuitively via the university's website by means of a decision support system. For this purpose, an AI-based dialog system for processing input on simple selection fields, but also natural language processing—a so called chat bot—is to be implemented, which is to map the following, conceptually recorded functionalities:

Students simply provide the system with some general information, such as their desired degree (Bachelor, Master, diploma) and preferred or non-preferred majors (e.g., business, languages, computer science, [mechanical or automotive] engineering, environment, health care). Based on this, the system creates a ranking, in which possible courses of study offered at the university are suggested in descending order of preference. The prospective students can then look at the corresponding course descriptions and module plans (optionally including the corresponding module contents) and compare them against each other. Once students have decided on a degree program, they click on a button "Apply for this degree program" and are automatically forwarded to the right place in the university application process. Of course, within the decision support system there is also the option of arranging a consultation at any time. In this case, the system differentiates according to the situation which advisor (central or subject-specific student advisor) can help the prospective student in a targeted manner. The according process of information, orientation and decision-making is represented in the first blue bubble in Figure 5.

In the same way, the decision support system is able to make suggestions to already enrolled students about suitable elective modules. All that is required is to specify the course of study taken, preferred or undesired specializations, and the competencies to be achieved. Based on these parameters, the system then searches through all the modules offered at the university and lists the appropriate results accordingly. Again, the according steps information, orientation and decision-making are represented in Figure 5 in the third yellow bubble.

In a second step, the system could then be expanded to the extent that it not only enables decision-making support with regard to individually optimized study paths, but that information or documents required in specific situations could also be found via the system. For example, students could ask the chat bot directly for a lecture script for one of their modules without having to manually click through the structures of a learning management system such as Moodle. Employees could use the chat bot as a central point of contact from which they can directly access the forms or documents they need (for example, to settle a business trip) without having to spend time searching for them in the university's knowledge and document base.

In the end those steps would lead to the holistic AI-based assistance system described, which would increase the user-friendliness of the university's information systems and thus lead to a better public perception of the university.

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8 Authors

Frank Otto is a research assistant at the West Saxon University Zwickau (Germany) in the field of business informatics. He deals with the topics of process modeling and optimization, knowledge management, and application of AI. Furthermore, he works as a lecturer for business information systems.

Nico Kling is a research associate at the West Saxon University Zwickau. His expertise lies in promoting data literacy and utilizing no-code applications for science. He is dedicated to advancing sustainable business and social practices through the application of AI technology.

Christian-Andreas Schumann is Professor of Business Information Systems at the West Saxon University Zwickau and the Rector's Representative for International Relations. He works intensively on the development of national and international educational networks and transferable study models through his work in a wide range of committees and networks. Since 2018, he has been Chair of the Continental Network of the British Academy of Management. Furthermore, he is a member of the advisory board of the accreditation agency ASIIN.

Claudia Tittmann is employed at West Saxon University Zwickau as a staff member at the Chair of Information Systems. In this context, she deals with the topics of knowledge management and innovative forms of learning.

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