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# Smart Decision-Making: The Role of Digital Twins, Retrieval-Augmented Generation-Enhanced AI, and Learning Analytics

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## Abstract:

Decision-making in higher education institutions faces complex challenges due to increasing data, regulatory demands, resource management, and changing educational needs. Effective decisions require accurate, timely insights into institutional processes. This study introduces an integrated decision-support approach consisting of Learning Analytics, Digital Twins, and Generative Artificial Intelligence (AI) with Retrieval-Augmented Generation (RAG). The objective is to enhance decision accuracy and operational efficiency in higher education. Learning Analytics provide insights into student performance, teaching effectiveness, and curriculum efficiency. Generative AI with RAG facilitates rapid retrieval and synthesis of institutional documentation and regulatory framework, enhancing decision accuracy. Digital Twins simulate institutional operations, enabling predictive resource planning and infrastructure modeling. Preliminary results indicate significant improvements in strategic planning and resource management by using an integrated decision support approach. Collectively, these technologies transform strategic decision-making and efficiency in higher education, enabling an agile and smart approach, offering a robust solution to contemporary challenges.

**Keywords:** Decision-making, Agile Approach, Learning Analytics, Generative AI, Retrieval-Augmented Generation, Digital Twins, Higher education

## Introduction

Decision-making in higher education institutions (HEIs) has become increasingly complex, driven by rapid growth in data volumes, shifting regulatory landscapes, and dynamic educational environments. Accurate, informed decisions significantly impact institutional effectiveness, student achievement, resource optimization, and sustainable development.

Currently, institutions rely on diverse technologies such as learning management systems (LMSs), student information systems, and business Intelligence tools. While these systems support data collection and routine administrative processes, they typically lack comprehensive predictive capabilities and integrated insights essential for strategic data-driven decision-making. Consequently, there is an urgent need for innovative solutions capable of offering deeper analytics, predictive modeling, and proactive support for institutional decisions.

Decision-making styles in higher education (HE) vary from intuitive to experience-based approaches. While intuition-based decisions draw from accumulated knowledge and experience, they often lack scalability and transparency. Conversely, data-driven decision-making approaches utilize quantitative analyses to support evidence-based strategies, enhancing accountability, precision, and strategic planning capabilities. However, traditional data-driven methods may still struggle with predictive accuracy, real-time adaptability, and integrated institutional planning.

To bridge these gaps, this paper proposes an advanced integrated approach utilizing Learning Analytics (LA), Generative Artificial Intelligence (AI) with Retrieval-Augmented Generation (RAG), and Digital Twins (DTs). Learning Analytics enable institutions to capture and analyze student behavior data comprehensively, thereby

supporting targeted interventions and refining educational strategies. Generative AI enhanced with RAG technology rapidly synthesizes relevant institutional and external information, facilitating efficient administrative processes and agile decision-making. Digital Twins create virtual simulations of institutional processes, facilities, and resources, thus offering predictive insights and enabling proactive resource allocation and infrastructure management. Together, these integrated technologies can substantially improve strategic planning and decision-making capabilities, agile responsiveness, and overall operational effectiveness, addressing the evolving complexities in the HE sector.

## Agile Decision-Making in Higher Education Institutions

In the contemporary landscape of HE, marked by rapid technological advancements, the imperative for agile decision-making has never been more important. Agile decision-making, characterized by responsiveness, adaptability, and data-driven insights, is thus crucial for HEIs to remain competitive and relevant.

The agile approach, initially developed in information technology (IT) for flexible software development (Beck et al., 2021), has gained relevance across various fields, including HEIs (Anifa et al., 2024; Philbin, 2015). HEIs, operating in a dynamic environment, face challenges like financial constraints, regulatory pressures, and evolving student preferences demanding agile adaptation (Ivetić & Ilić, 2020; Menon & Suresh, 2020). The emergence of technologies like AI further underscores the need for agility. Agile principles, emphasizing collaboration, adaptability, responsiveness, and iterative improvement, are crucial for HEIs to navigate these challenges (Prejean et al., 2019). However, bureaucratic structures and traditional leadership often obstruct agile adoption (Barrett-Maitland et al., 2024).

Agile decision-making in HEIs necessitates a shift from traditional, rigid approaches to more flexible and responsive strategies. Currently, **strategic planning** in HEIs is often tied to 4-5 year accreditation cycles, which limits adaptability. To enhance agility, annual revisions of strategies and action plans are recommended, allowing for timely adjustments to changing priorities and external pressures. **Collaboration**, while generally strong within HEIs, must be optimized to streamline processes and prevent delays caused by extensive stakeholder involvement. Promoting agile teamwork and fostering transparent communication are crucial. The **decision-making style** in HEIs, although collaborative, can be time-consuming due to its democratic nature. To align with agile principles, HEI management should encourage shared decision-making, situational leadership, data-driven approaches, and transformational leadership. **Change management** in HEIs is often reactive, caused by outside factors. HEIs should adopt a proactive, structured approach to change, raising awareness about its importance and moving beyond crisis-driven adaptations. The **lean approach** can be effectively applied at smaller unit levels. HEI leadership should encourage the identification and elimination of non-value-added activities, such as unnecessary paperwork and redundant meetings. Finally, **continuous improvement** initiatives, currently focused on quality assurance, should be expanded. HEIs should support agile teams to identify improvement opportunities, foster knowledge sharing and collect stakeholder feedback.

To effectively implement agile decision-making, HEIs can leverage the transformative potential of emerging technologies, including LA, Generative AI with RAG, and DTs. By integrating these technologies, HEIs can create a dynamic and responsive ecosystem for agile decision-making, ultimately enhancing the quality of education.

## Transformative approach for smart decision-making

The confluence of LA, AI enhanced with RAG, and DTs presents a transformative paradigm for enhancing agile decision-making within HEIs. This integrated approach fosters a data-driven culture, enabling HEIs to swiftly adapt to dynamic environments, optimize resource allocation, and ultimately enhance educational quality.

### *Learning Analytics*

A widely accepted definition of Learning Analytics (LA) is "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (Society for Learning Analytics Research (SoLAR), 2011). This professional and scientific discipline encompasses tracking student performance, monitoring teaching effectiveness, and assessing curriculum design. Institutions utilize learning analytics to proactively identify at-risk students, tailor instructional strategies, and refine educational programs, enhancing overall academic success and student retention. Numerous studies have demonstrated learning analytics' capacity to improve student engagement and institutional effectiveness, making it an indispensable tool for modern educational management (Foster & Francis, 2019; Qazdar et al., 2023; Ramaswami et al., 2023). Advanced analytical techniques, such as machine

learning and predictive modeling, are employed to forecast student outcomes and identify potential challenges before they arise. By integrating these insights into decision-making processes, institutions can implement targeted interventions, such as personalized learning plans and support services, to address individual student needs.

Furthermore, LA facilitate continuous improvement in teaching practices and curriculum design. Educators can use data-driven feedback to adapt their instructional methods, ensuring they meet diverse student needs and learning styles (Osakwe et al., 2022). This iterative process fosters a culture of evidence-based practice, where decisions are grounded in empirical dana.

The adoption of LA empowers educational institutions with data-driven decision-making, allowing for the identification of trends, evaluation of educational programs, and the optimization of learning outcomes based on empirical evidence (Qazdar et al., 2023). Stakeholders can access real-time data on institutional performance, fostering a collaborative environment focused on achieving shared goals. As a result, LA not only enhance academic success but also contribute to the overall operational efficiency and strategic planning of HEIs.

### *Generative AI using Retrieval-Augmented Generation*

Generative AI with Retrieval-Augmented Generation represents a sophisticated method combining generative AI models with advanced information retrieval systems (Khairi et al., 2024). RAG technology retrieves relevant documents from extensive databases based on a given query, then generates coherent and contextually accurate responses by synthesizing the retrieved content. Within HE, RAG significantly enhances administrative efficiency by rapidly providing precise answers to queries about institutional policies, regulations, accreditation requirements, and prior practices. Institutions leveraging RAG technology achieve greater responsiveness, improved compliance accuracy, and streamlined administrative decision-making processes (Arslan et al., 2024).

It integrates the strengths of generative AI and information retrieval to offer a powerful tool for HEIs. Generative AI models, such as GPT-4, are capable of producing human-like text based on input data, while retrieval systems ensure that the generated content is grounded in accurate and relevant information. This combination allows institutions to access a wealth of knowledge quickly and efficiently, supporting informed decision-making across various administrative functions.

In addition to enhancing administrative efficiency, RAG technology contributes to improved compliance and regulatory adherence. By providing precise and up-to-date information on accreditation standards, institutional policies, and legal requirements, RAG helps institutions maintain compliance with external regulations. This reduces the risk of non-compliance and associated penalties, ensuring that institutions operate within the legal framework.

The implementation of RAG technology also fosters a culture of transparency and accountability. It not only enhances administrative processes but also supports the overall strategic planning and decision making of HEIs.

### *Digital Twins*

Digital Twins are sophisticated virtual models that replicate physical entities, systems, or processes in a digital environment, facilitating real-time monitoring, simulation, and predictive analytics (Kartashova et al., 2020; Yan et al., 2021). Within HEIs, DTs offer transformative opportunities for enhancing management, strategic planning and decision making, and resource allocation. By creating detailed digital representations of campus infrastructure, academic programs, and administrative operations, institutions can explore scenarios and outcomes through simulation without disrupting actual processes.

DTs enable higher education administrators to perform comprehensive predictive analyses for enrollment patterns, facility usage, and service demands (Han et al., 2022). For example, through simulation of academic scheduling, institutions can proactively adjust faculty assignments and classroom allocations to optimize resource utilization and minimize operational costs. Additionally, infrastructure modeling via DTs supports strategic planning for future campus expansions, renovations, or emergency preparedness by virtually testing various scenarios and assessing potential impacts. By anticipating issues before they occur, institutions can significantly enhance their resilience and responsiveness, promoting sustainability and efficiency across institutional operations.

Furthermore, DTs facilitate continuous improvement in campus management and academic program development. By integrating real-time data from various sources, such as IoT sensors and administrative systems, DTs provide a comprehensive view of institutional operations. This enables administrators to make informed decisions based on accurate and up-to-date information, enhancing overall operational efficiency.

The implementation of Digital Twin technology also promotes collaboration and transparency within HEIs. Stakeholders can access detailed simulations and predictive analyses, fostering a collaborative environment focused on achieving shared goals. As a result, DTs not only enhance operational management but also support strategic planning, decision making and resource allocation, contributing to the overall effectiveness and sustainability of HEIs.

## Innovative Practices for Enhanced Smart Decision Making

The proposed integration of LA, RAG with AI, and DTs constitutes an innovative approach because it transcends the traditional isolated application of these technologies, emphasizing their synergistic potential in decision-making support for HEIs. Implementing such a comprehensive framework requires careful strategic planning, collaboration across departments, and systematic change management.

A successful integration strategy begins with establishing a centralized data infrastructure, ensuring interoperability between Learning Analytics platforms, Digital Twin systems, and Generative AI solutions. This infrastructure should enable real-time data sharing and analysis, enhancing the accuracy and responsiveness of institutional decision-making. Additionally, institutions must clearly define goals and performance indicators to measure the effectiveness of the integrated system, aligning them with strategic objectives like improving student outcomes, optimizing resource allocation, and increasing operational efficiency.

The initial steps toward implementation include comprehensive stakeholder engagement to communicate the value and benefits of adopting this integrated framework. Institutional leaders, faculty members, administrative staff, and IT professionals must collaborate to identify specific decision-making processes that will benefit most from these technologies. Pilot projects in select departments or programs can provide valuable insights into the practical application and fine-tuning of the integrated system, allowing iterative improvements and demonstrating early successes to foster broader institutional buy-in.

Given the complexity of integrating these advanced technologies, institutions may face several barriers, including resistance to change, technological compatibility challenges, data privacy concerns, and the need for significant investments in infrastructure and training. Effective mitigation tactics involve robust change management strategies, clear communication of the benefits and anticipated outcomes, targeted professional development and training programs, and careful attention to privacy and ethical considerations, ensuring adherence to regulatory requirements.

Overall, this integrated decision-support approach offers a groundbreaking pathway to enhance the strategic agility and resilience of HEIs, empowering them to proactively respond to emerging challenges and dynamically shape their future directions.

In the following sections, we demonstrate the application of innovative practices in HEIs for smart decision-making by showcasing an implemented example for each component of the transformative approach. These examples are further elaborated as case studies.

### *Case Study: Higher Education Learning Analytics Capability Maturity Model*

To illustrate a LA case study, this section presents the development and structure of the Higher Education Learning Analytics Capability Maturity Model (HELA-CMM), a framework designed to facilitate the strategic implementation of LA for agile decision-making within HEIs (Šimić et al., 2025). The HELA-CMM is specifically tailored to address the complexities of LA adoption, providing a roadmap for HEIs to enhance their capacity for data-driven, agile decision-making.

The development of the HELA-CMM adhered to a design science research paradigm. The proposed HELA-CMM comprises 28 capabilities organized into eight key categories, each critical for the effective implementation of LA and the promotion of agile decision-making:

- Teaching / Learning / Assessment: Focuses on the integration of LA into pedagogical practices to enhance student engagement and learning outcomes.

- Data Management & Analytics: Addresses the infrastructure and processes necessary for collecting, storing, and analyzing educational data.
- Ethics, Privacy, Legal Issues: Emphasizes the importance of responsible data handling and adherence to ethical and legal standards.
- People Competences: Highlights the need for developing the skills and knowledge required to effectively utilize LA tools and interpret data.
- Management / Leadership: Underscores the role of institutional leadership in championing LA initiatives and fostering a data-driven culture.
- Culture: Focuses on cultivating an organizational culture that values data-driven decision-making and continuous improvement.
- Infrastructure: Addresses the technological and organizational infrastructure required to support LA implementation.
- Quality Assurance: Emphasizes the use of LA to monitor and enhance the quality of educational programs and services.

Each of these categories encompasses specific capabilities that enable HEIs to assess their current maturity level and identify areas for improvement. Figure 1 illustrates the HELA-CMM categories positioned in the Generic Capability Reference Model (Šimić et al., 2025).

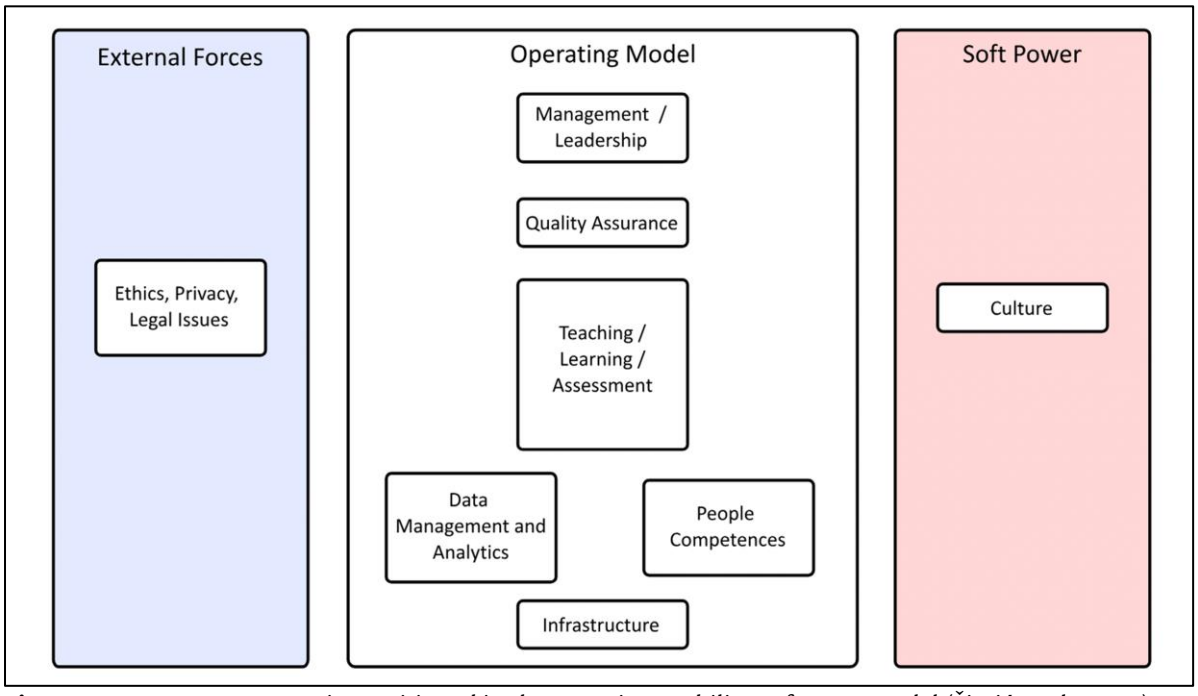


**Figure 1:** HELA-CMM categories positioned in the Generic Capability Reference Model (Šimić et al., 2025).

The HELA-CMM is designed to empower HEIs to leverage LA for agile decision-making. By providing a structured framework for assessing and improving LA capabilities, institutions can:

- Identify areas for strategic intervention: The model enables institutions to pinpoint specific areas where improvements in LA capabilities can lead to enhanced decision-making.
- Facilitate data-driven adaptation: By utilizing LA insights, institutions can respond rapidly to emerging trends and student needs, promoting agility and responsiveness.
- Enhance resource allocation: LA can provide valuable insights into the effectiveness of various programs and initiatives, enabling institutions to allocate resources more efficiently.

- Improve student success: By leveraging data to personalize learning experiences and provide timely interventions, institutions can enhance student engagement and success rates.
- Benchmarking and continuous improvement: The HELA-CMM provides a tool for benchmarking against other institutions and for tracking progress over time, facilitating continuous improvement.

### *Case Study: RAG-Enhanced AI for Smart Document Management in Higher Education*

The developed Document Management System (DMS) is designed to simplify and streamline document handling within organizations and was developed at the University of Zagreb Faculty of Organization and Informatics (Center for Software Development) with a particular focus on the needs of higher education institutions. Key functionalities include the upload of all relevant documents, automatic metadata generation (e.g., title, summary, type, and category), advanced document search using filters and metadata, as well as interactive retrieval through chatbot-based queries. The system is currently undergoing real-world testing with initial users to validate performance and usability.

Technically, the system is built upon the RAG paradigm, ensuring efficient document retrieval and intelligent response generation. The backend is implemented using PHP (Symfony) or Python, while data storage and vector search capabilities are supported by a PostgreSQL vector database. The system leverages OpenAI's Large Language Models (LLMs) for natural language processing. The frontend is developed using modern JavaScript and associated web frameworks. The entire solution is predominantly based on open-source technologies, promoting transparency, flexibility, and sustainability.

The developed DMS featuring automatic metadata generation and advanced search capabilities, directly supports data-driven decision-making in HEIs.

By enabling quick and precise retrieval of relevant documents through metadata filters and chatbot-based queries, management and researchers can efficiently access critical information for informed strategic planning and operational adjustments. Leveraging the RAG paradigm and OpenAI's LLMs, the DMS ensures intelligent and contextually relevant document retrieval, facilitating agile decision-making. This technology empowers HEIs to rapidly respond to evolving needs by providing instant access to needed data, thus enhancing their ability to adapt and innovate in a dynamic educational landscape. It supports data-driven decision-making by enabling comprehensive data analysis and trend identification, crucial for strategic resource allocation and policy development in HEIs. Figure 2 illustrates the end-user interface for query-based document retrieval and interpretation within the developed DMS system and Figure 3 illustrates administration interface – LLM prompt definitions of the DMS system.

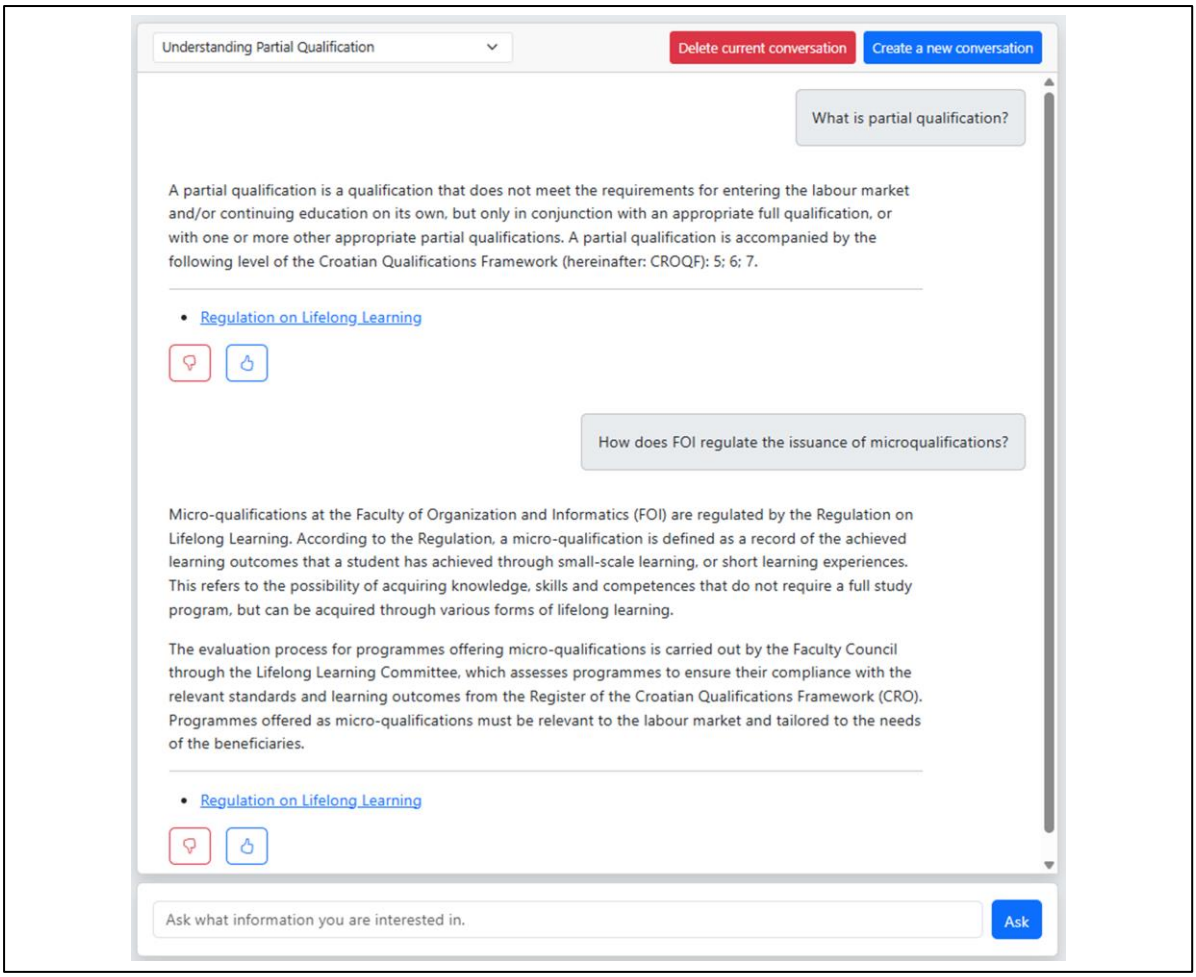


**Figure 2:** End user interface of the DMS – query base document retrieval and interpretation.

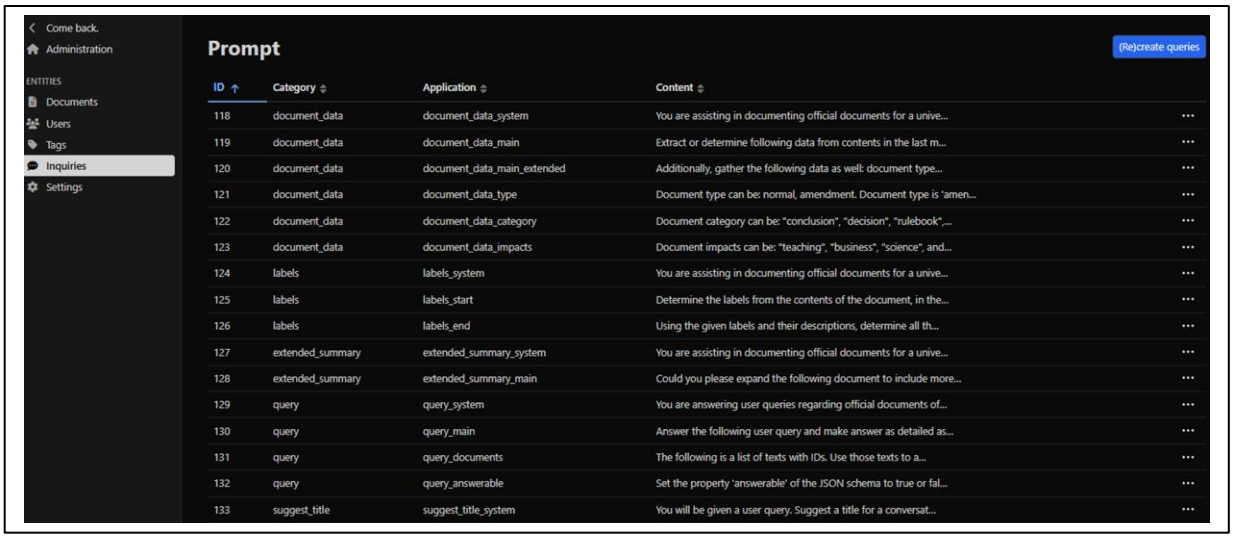


**Figure 3:** Administration interface – LLM prompt definitions.

### *Case Study: Digital Twin for Dynamic Class Scheduling*

In our illustrative case study, a medium-sized university implemented a DT system to enhance its decision-making processes regarding course scheduling and delivery formats. The DT integrated real-time data collection from multiple sources, including student attendance tracking systems (both physical classroom presence and online platform activity), along with strategic data from the university's student information system such as historical attendance patterns, student academic performance, and course completion rates.

The system monitored real-time attendance trends, providing instant visibility into how many students attended classes physically versus those joining online. Simultaneously, predictive analytics were applied to historical data to evaluate the impact of attendance mode (physical vs. online) on student academic success. This predictive component identified correlations between attendance patterns and academic outcomes, enabling administrators to anticipate potential performance issues and intervene proactively.

Additionally, the DT allowed administrators to simulate various class-scheduling scenarios, considering different ratios of physical and online attendance. These simulations provided insights into optimal resource allocation, helping the institution decide whether to scale classroom infrastructure or invest further in online teaching platforms. As a result, the university optimized its resource utilization, improved student academic performance, and demonstrated increased flexibility and responsiveness to shifting student attendance behaviors.

Figure 4 illustrates the end-user interface for Dynamic Class Scheduling developed at the University of Zagreb Faculty of Organization and Informatics (Center for Software Development). The system enables the collection of data on students attending classes in person as well as those attending online; it plans and records classes by subject and by teacher; exam dates, teacher office hours, generates various reports, and schedules the classes of faculty staff.

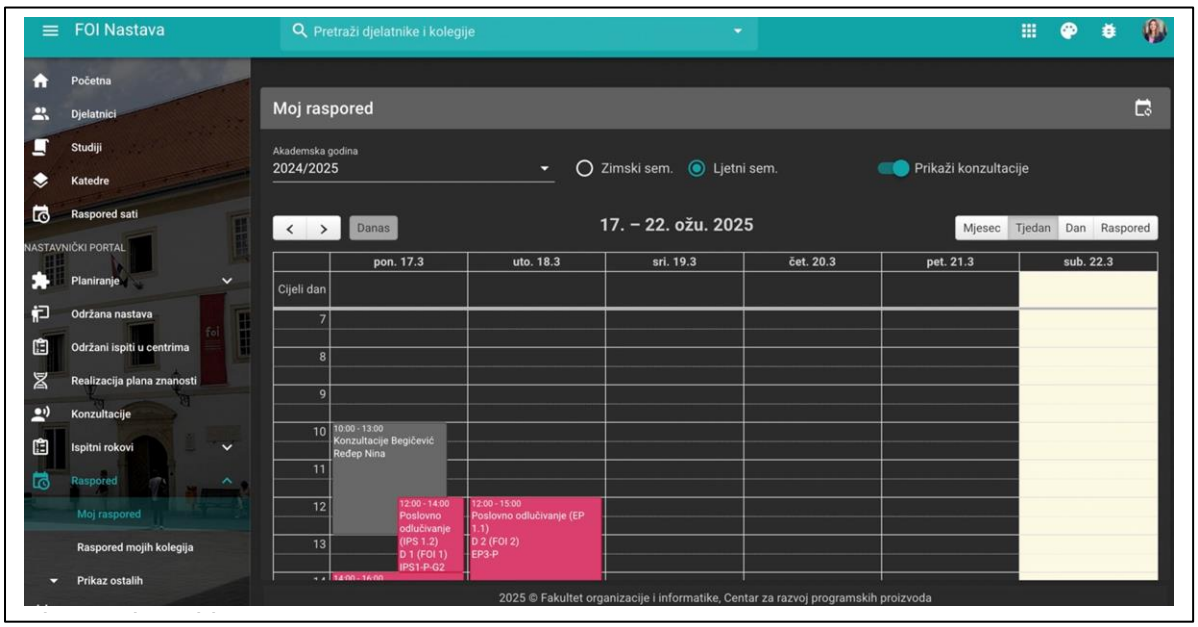

**Figure 4:** End user interface of the Digital Twin – Dynamic Class Scheduling.

## Conclusion

The integration of LA, AI enhanced with RAG, and DTs represents a transformative approach to decision-making in HEIs. This integrated framework addresses existing gaps in institutional effectiveness, offering advanced predictive capabilities, real-time decision support, and comprehensive insights across various operational dimensions. Learning Analytics enhances educational outcomes through precise analysis and targeted interventions, Digital Twins offer robust simulations for strategic resource planning, while Generative AI with RAG streamlines administrative decision-making by efficiently synthesizing essential institutional knowledge.

The collective implementation of these technologies significantly elevates institutions' capacity to proactively respond to dynamic educational landscapes, changing regulatory environments, and evolving student needs. As a result, institutions can achieve greater strategic agility, operational efficiency and improved educational quality.

Despite the notable advantages, successful implementation requires careful planning, strong organizational commitment, and continuous adaptation to technological advances and ethical considerations. Institutions

must address potential barriers such as technological complexity, initial resource investment, resistance to change, and ethical concerns related to data privacy and AI decision-making processes. Future research should explore further refinements to the integration of these technologies, addressing ongoing challenges and continually enhancing their practical application within HE settings.

### Competing interests

The authors have no competing interests to declare.


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