

CHAPTER 3. HUMAN CAPITAL IN THE IT AND CYBERSECURITY SECTOR: EDUCATION, WORKFORCE TRAINING, AND DIGITAL COMPETENCE DEVELOPMENT

3.1. Digital Technologies for Managing University Research Activities: European Experience and Prospects for Implementation in Ukraine

Tetiana DERKACH,

Andrii DMYTRENKO,

National University “Yuri Kondratyuk Poltava Polytechnic”,

Lina KLOCHKO,

Geological Bureau BEG SA, Switzerland

Contemporary developments in science, education and digital technologies call for better mechanisms to manage research and research and development activities in higher education institutions (OECD, 2023; UNESCO, 2023). Universities are increasingly adopting digital tools to support research, manage research outputs and monitor research performance (European University Association, 2021).

The quality of specialist training depends substantially on integrating education with research. The active involvement of academic staff in research projects, publishing, international collaboration and the implementation of research findings helps create a modern educational environment that develops students' professional competencies, creative thinking and research skills.

At the same time, the continuing growth of scientific information, the increasing number of publications and the need to prepare numerous reports place an additional burden on academic staff. A considerable amount of time is spent on administrative procedures associated with collecting, organising and analysing data on research achievements, reducing the time available for research itself.

One promising response is to introduce specialised information systems to support research activities. Such systems provide centralised information storage,

automate report preparation, monitor research indicators and integrate with external bibliometric resources. Modern information technologies can substantially accelerate data processing, reduce errors and make management processes more transparent.

In the context of digital transformation, automating the collection, analysis and use of research information is particularly important. Growing volumes of research data require modern research information management systems that integrate information resources and support management decisions (Bryant et al., 2021).

One priority in developing research infrastructure is to implement open science principles and ensure access to research findings (Schuetze et al., 2024; Wilkinson et al., 2016). In this context, international researcher identification and bibliometric platforms such as ORCID and Google Scholar are important for monitoring researchers' publication activity and citations.

The digitisation of research is especially significant in the context of European Union initiatives to develop the European Research Area (ERA). Current European research policy prioritises open science, digital research infrastructure and integrated research information management systems. Horizon Europe places considerable emphasis on effective management of research outputs, open access to research data and stronger international scientific collaboration. The European Open Science Cloud (EOSC) is an important means of achieving these goals, providing researchers with a shared digital environment for storing, processing and disseminating research data. These initiatives shape current trends in research management information systems and provide a conceptual basis for the digital transformation of higher education institutions.

Intelligent information systems can automate a substantial share of the administrative procedures associated with supporting research, thereby improving the efficiency of educational and research institutions (Bryant et al., 2021).

The aim of this study is to develop an intelligent information system for managing a department's research and research and development activities. The system is intended to automate the recording, analysis and presentation of research outputs and improve information support for academic staff.

The digital transformation of higher education institutions has encouraged the adoption of specialised platforms to support research, manage research outputs and monitor research performance. In today's research environment, these systems are important tools for collecting, analysing and disseminating scientific knowledge (European University Association, 2021; OECD, 2023; Smith, 2023; UNESCO, 2023).

ORCID is one of the most widely used international tools. It provides unique researcher identifiers and supports the integration of information on publications, projects and professional activities. Its use improves the reliability of authorship data and facilitates interaction among information platforms.

Google Scholar plays an important role in scholarly communication by automatically indexing publications and calculating key bibliometric indicators. Given its broad coverage of sources, it is one of the most accessible tools for assessing researchers' scholarly activity.

Academic social networks, particularly ResearchGate and Academia.edu, have also become widespread. They support scholarly communication, the exchange of research findings and the formation of professional research communities (Bryant et al., 2021; Wilkinson et al., 2016). However, these platforms primarily disseminate research materials and do not provide comprehensive support for management processes within higher education institutions.

Universities increasingly use current research information systems (CRIS) to manage research outputs centrally (Schuetze et al., 2024; Wilkinson et al., 2016). Prominent examples include Pure, Converis and Symplectic Elements. These systems bring information on researchers, publications, grants, projects, patents and other research outputs together in a single information environment (Leal Filho et al., 2023; Wilkinson et al., 2016).

A comparison of existing platforms indicates that most focus either on collecting bibliometric information or on supporting scholarly communication. Automation of internal research management processes at the level of university departments and other units often remains insufficiently addressed. This creates a need for specialised

information systems adapted to the way research is organised at individual institutions (Leal Filho et al., 2023).

The system developed in this study differs from existing solutions by focusing on the automation of a department's internal research management processes, report preparation, monitoring of research indicators and integration of research outputs within a single information environment. This approach combines the recording, analysis and management of research resources in one software system.

The development of modern research management systems is influenced by EU strategic initiatives aimed at creating a common digital research environment and implementing open science principles. Within the ERA, research management processes are being digitised, research outputs made more accessible and information resources integrated internationally.

Horizon Europe is one of the EU's key initiatives and its largest framework programme supporting research and innovation. The programme emphasises digital research infrastructure, open data, collaboration between institutions and modern research management information systems.

The development of the European Open Science Cloud (EOSC) is particularly significant. EOSC gives researchers access to an integrated environment for storing, processing, analysing and reusing research data. It brings together resources from universities, research centres and international organisations in a shared digital research environment.

Current research information systems (CRIS) aligned with the standards of euroCRIS are being adopted across EU countries. The CERIF standard (Common European Research Information Format) enables interoperability among university and research institution systems, facilitating automated exchange of information about researchers, projects, publications, grants and research outputs.

European open science policy plays a substantial role in the digital transformation of research. It calls for open access to scientific publications, research data and the outputs of publicly funded research. Applying open science principles

makes research more transparent, strengthens international collaboration and improves the use of research resources (European Commission, 2021, 2022, 2023).

These approaches and technologies can inform the development of research management information systems in Ukrainian higher education institutions. Integration with international digital platforms, support for open science standards and the adoption of European research information management models can improve research efficiency and expand international academic collaboration.

Information system design is a key stage of development: it establishes the conceptual structure of the future software product, defines how its components interact and sets principles for scalability, reliability and further development (Galliers and Leidner, 2020; Galliers and Stein, 2025; Ivanova et al., 2024; Tekli et al., 2025).

The intelligent information system for managing a department's research and research and development activities was developed using contemporary approaches to multilayer information systems. The main priorities were coherent information flows, efficient data processing and a convenient means of interaction between users and the software environment.

The first design stage analysed functional requirements based on how higher education institutions organise research. This identified the main business processes to be automated and defined the information objects and their relationships.

The system architecture is based on modularity and the distribution of functions among distinct layers. This gives components independence, simplifies software maintenance and supports future upgrades.

The overall structure of the information system is shown in Fig. 3.1.

The software system has three principal layers. The first enables user interaction and presents information. The second implements application logic, processes requests and performs data analysis. The third stores, retrieves and manages the system's information resources.

Reusing software components is especially important in the design process. Standard libraries, service modules and exception handling mechanisms shorten development time and improve software reliability.

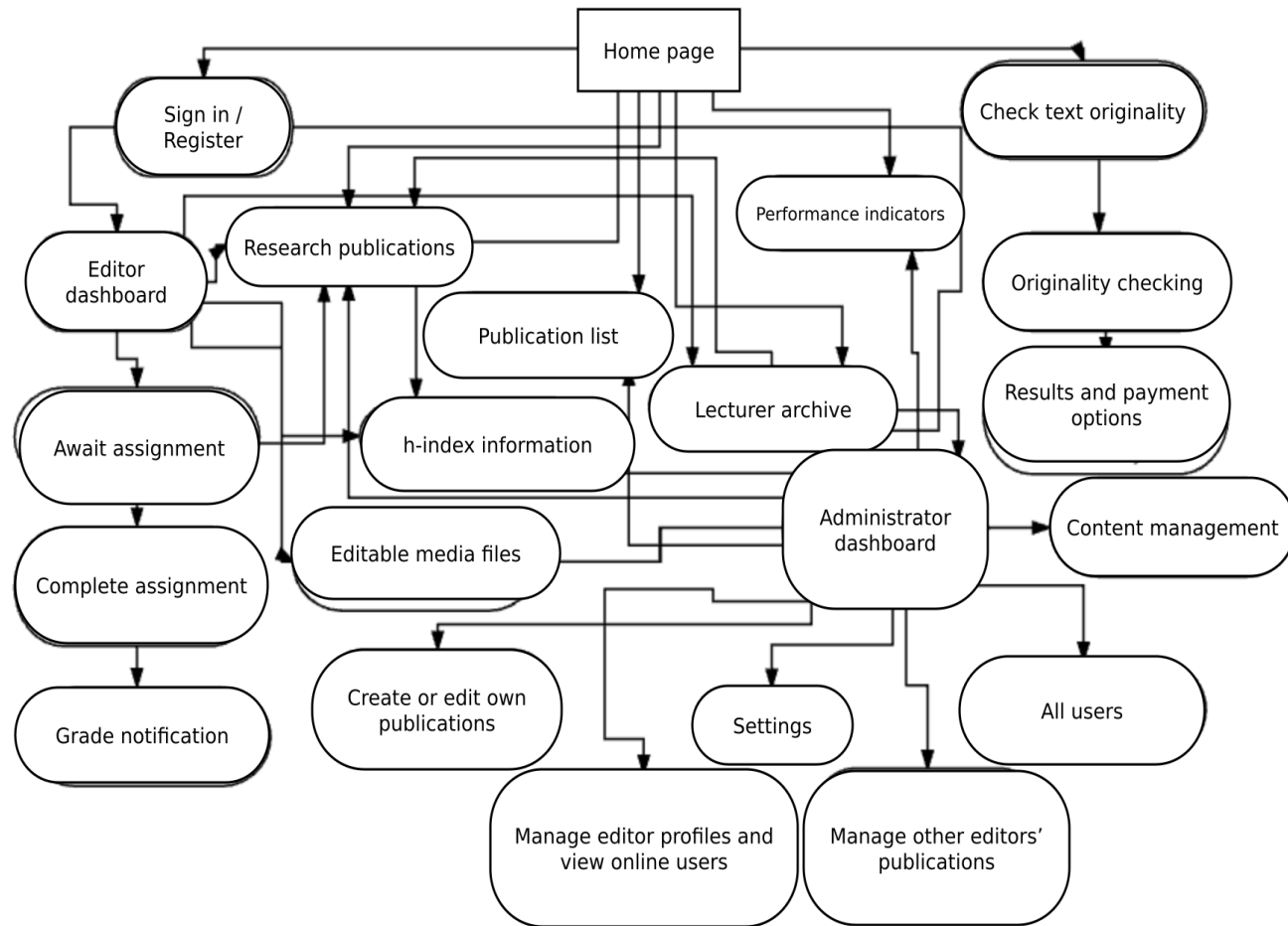


Fig. 3.1. Overall structure of the information system

Object oriented modelling tools were used to formalise the system structure and describe interactions among its components. This approach visualises the software architecture, describes system functions and defines scenarios for user interaction with the software environment.

Modelling the information system provided a coherent understanding of its structure before implementation began. This reduced risks associated with later functional expansion and helped align the functional requirements with technical solutions.

The architectural design stage produced a conceptual model of the research and research and development management system. It defines interactions among users, software modules and the database, and provides a basis for implementing the software.

An important stage in creating the information system is formalising functional requirements and describing user interaction with the software environment. Functional modelling was therefore performed to define the main services, user access rights and the logic of key business processes.

The system's functional model uses scenarios describing typical sequences of user actions involving information resources. At the design stage, this helps establish the system's functional boundaries, assess whether the requirements are fully addressed and identify potential conflicts among software components.

The study identified three main user categories, each with its own functions and level of access to information resources.

The first category comprises system administrators, who manage the software environment, oversee user registration, keep reference information up to date and maintain the information services. Administrators have access to all functional modules and are responsible for configuring them.

The second category comprises editors: lecturers, academic staff, postgraduate students and researchers authorised to create, edit and publish research materials. Their

functions include managing publications, checking texts, preparing information on research outputs and maintaining a personal profile.

The third category consists of external users, who cannot edit information but may view published materials, statistical reports and information on the department's research. This supports access to research outputs and dissemination of information to interested parties.

Formalising interactions between users and functional modules established the system's principal use cases: user authentication, creation and editing of research publications, profile management, report generation, viewing statistical indicators, monitoring bibliometric data and checking texts for originality.

Particular attention was given to the system's operating dynamics. Analysis of the sequence of operations defined the flow of information among users, application modules and the database. The resulting model shows the sequence from receipt of a request to delivery of the required result to the user. Figure 3.2 shows the administrator activity diagram.

Functional modelling provided the basis for subsequent database design, software module implementation and user interface development. It also aligned functional requirements with architectural decisions made during system development. The system use case diagram is shown in Fig. 3.3.

The effectiveness of any information system depends substantially on the quality of its database design. The database is the central element of the information environment, collecting, storing, processing and retrieving the information needed to support management and research processes.

A logical data model was developed for the department's research and research and development management system, representing the structure of research information and the relationships among its main elements. This domain includes many interrelated objects, including academic staff, students, research publications, conferences, research projects, performance indicators and reporting documents.

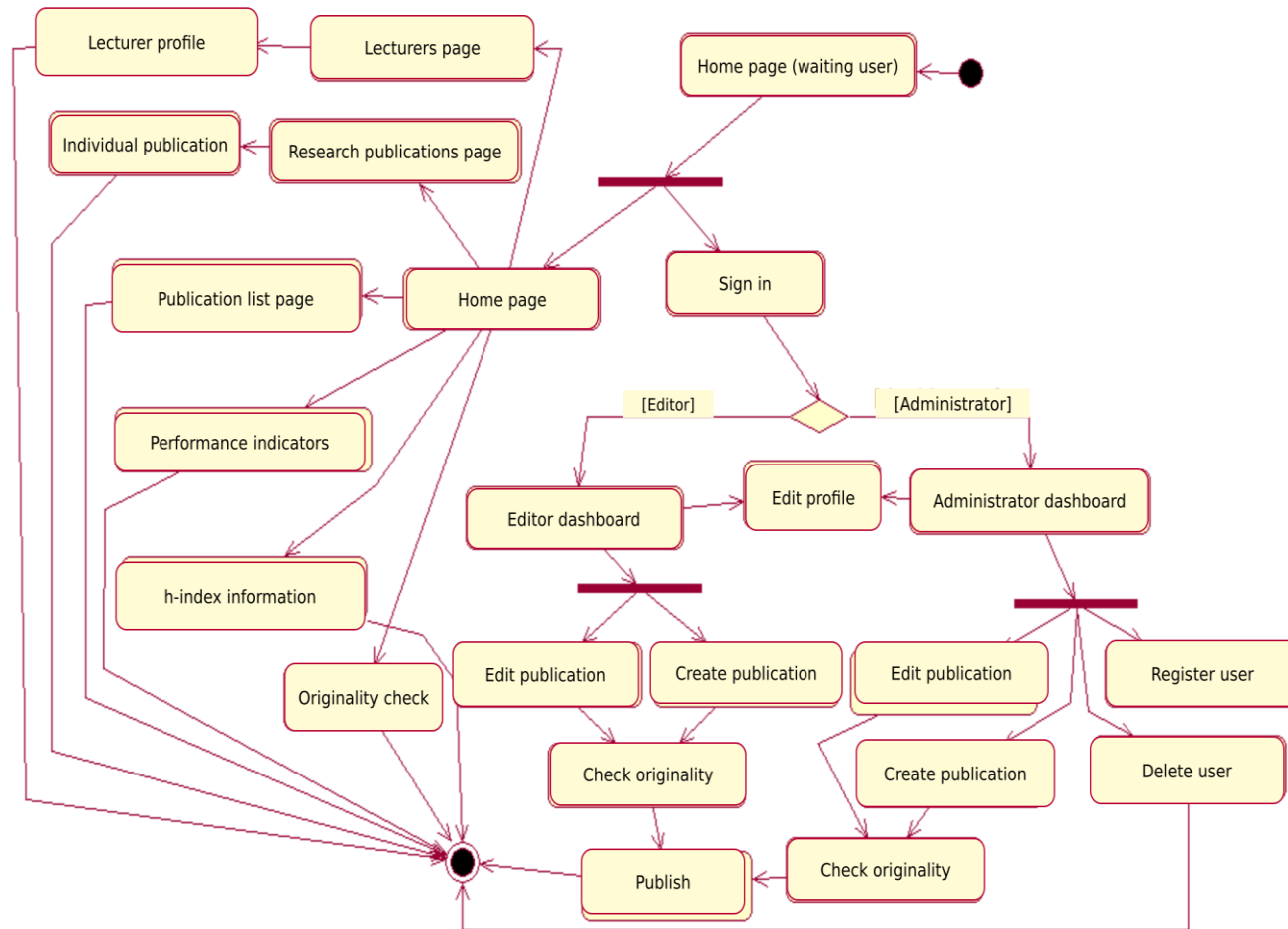


Fig. 3.2. Administrator activity diagram

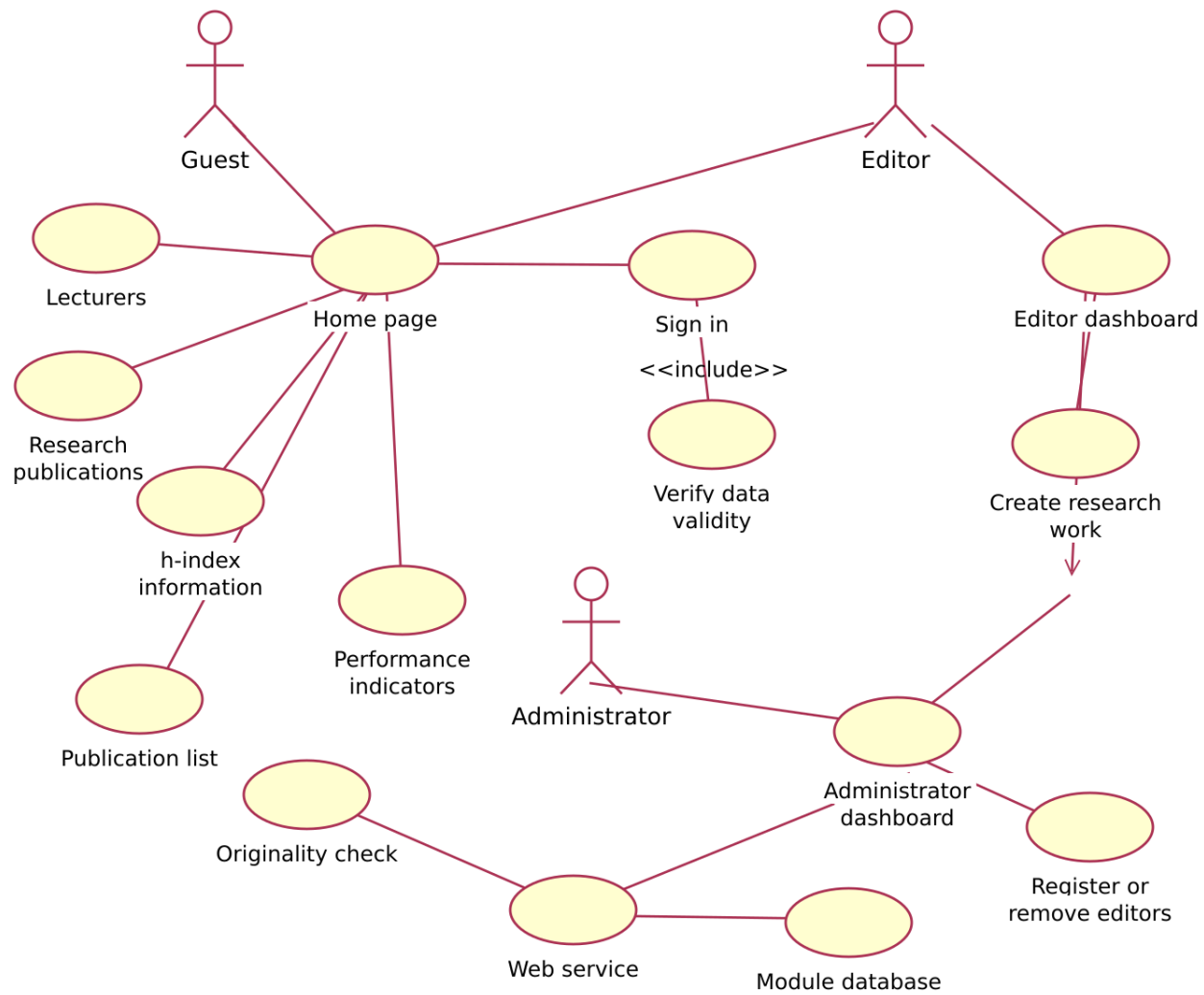


Fig. 3.3. Use case diagram

Database design focused on data integrity, minimising duplication and enabling efficient analytical queries. Relational modelling principles were used to represent complex information objects through interconnected tables (Akhtar, 2023; Amer-Yahia et al., 2023; Tekli et al., 2025).

The database distributes information among separate entities according to their functions. This provides flexibility in managing and updating data and allows the system's functions to be expanded without substantial changes to its architecture.

Maintaining consistency between research outputs and their authors is particularly important. Logical links between information objects keep data current and ensure correct report generation. These links increase information reliability and reduce the likelihood of processing errors (Bauer et al., 2023; Galliers and Leidner, 2020).

A key system requirement was the ability to accommodate changing information. Details of publications, academic degrees, citation indicators and other aspects of research activity are continually updated. The database was therefore structured to allow prompt changes without compromising the integrity of the information environment.

Search and reporting were also optimised during design. The database structure enables rapid retrieval of statistical indicators, preparation of analytical reports and selection of records by different criteria. This supports management decisions and comprehensive analysis of research outputs.

The resulting database model provides a reliable information foundation for the research and research and development management system, enabling effective storage, analytical processes and future software development.

The quality of user interaction with the software environment is another important determinant of system effectiveness. Regardless of the software's functional complexity, ease of access to information and intuitive core operations directly affect its usefulness.

The department's research management information system was designed with particular attention to a clear, logically organised interface. The principal goal was an environment that provides rapid access to system functions and minimises the time users spend on routine operations.

Interface design was based on the professional needs of the main user categories. The working practices of academic staff, administrators and external users informed a navigation structure aligned with the most common usage scenarios.

Functional consistency across all interface elements was an important design principle. Information blocks, menus, navigation and search were arranged so users could find what they needed and complete tasks without additional training (OpenStax, 2025).

The organisation of the system's information space is particularly important. A hierarchical presentation of data was implemented to make information easier to understand and allow users to access additional detail as needed. This reduces information overload and improves work with large volumes of research data.

The interface design also considered visual consistency. Common design principles create a coherent information environment, strengthen users' confidence in the system and contribute to a positive user experience.

User guidance is an important interface component. Notifications, hints and feedback on completed operations support effective interaction. They inform users promptly about data processing status, help prevent errors and make the software's functions easier to learn.

Search and filtering also received particular attention. Because the system handles substantial volumes of research materials and statistical data, rapid access to relevant information is essential. Search tools enable users to retrieve information promptly using defined criteria and work conveniently with information resources.

The resulting user interface supports effective interaction with the software environment, improves productivity and makes the information system easier to use in research management.

A key functional component of the system is its reporting and analytical data processing subsystem. It automates the collection, organisation and aggregation of information on the department's research and research and development outputs.

Higher education institutions continually monitor research activity indicators, which requires processing large volumes of information. Conventional report preparation often involves manually collecting data from multiple sources, taking considerable time and increasing the risk of errors. Automated reporting substantially improves the speed and reliability of the resulting information.

The system includes tools for producing statistical, reference and analytical indicators. It automatically generates reports on departmental staffing, academic staff publication activity, lecturer and student participation in research events, and research outcomes.

Analysis of early career researchers' activities is particularly important for assessing their involvement in research and identifying directions for developing research groups. The system also generates reports on student participation in research, an important indicator of integration between the educational and research functions of the university.

The analytical module aggregates indicators for individual departments and other organisational units. This enables comparisons of research performance, assessment of trends in research areas and an evidence base for management decisions.

An important feature is automatic calculation of indicators describing publication activity, research productivity and individual academic staff contributions to overall departmental results. These data can support internal reports, accreditation, assessment of organisational units and planning future research.

The reporting subsystem thus automates routine tasks and supports management processes aimed at improving research effectiveness in a higher education institution.

Implementing the department's research and research and development management system involved creating an integrated software environment that supports the collection, processing, analysis and presentation of research outputs.

The system's functional structure follows a modular architecture. This makes software components independent, simplifies maintenance and permits future functional expansion.

The user management module forms the core of the software system, handling authentication, authorisation and access control. Role based access enables different interaction scenarios according to user category and responsibilities.

A research publication management module is central to the architecture. It supports the complete lifecycle of research materials, from creation and editing through publication and archiving. This centralises research output storage and provides a shared information environment for academic staff.

The bibliometric indicator management module is another important component. It collects and analyses publication, citation and other research performance data. This functionality provides prompt access to current information on the research achievements of individual staff members and the department as a whole.

A text analysis module supports quality control of research materials. It assesses text originality and identifies potential matches with existing information resources. Integration into the information environment automates preliminary checks of research materials before publication.

The analytical reporting module is essential to system operation. It automatically generates statistical and analytical materials about departmental research outputs. This reduces the time needed to prepare reports and increases the reliability of the results.

Personalised workspaces make the system more convenient. Each user accesses a set of functions suited to their permissions and professional needs. This improves work efficiency and supports effective use of the software.

Particular attention was paid to system administration. The administration module manages users, configures software settings, maintains reference resources and oversees information security. Centralised administration supports stable and secure operation.

The software can adapt to changes in the organisation of research. Categories of research materials can be expanded, report structures changed and new information services integrated without major changes to the architecture.

The implementation results indicate the value of modern information technology for automating research management. The software environment centralises research information management, improves data processing and strengthens information support for the institution's educational and research activities.

The study addressed a practical research problem: improving the management of research and research and development activities in higher education through modern information technology. Analysis of existing approaches to research information support showed a need for specialised software that automates the collection, processing and analysis of research information.

The study developed a concept for an intelligent system to manage a department's research and research and development activities. It integrates information resources, automates report preparation and supports management decisions based on current research output data.

Analysis of the subject area informed a software architecture integrating modules for user management, research publications, bibliometric indicators, analytical reporting and quality control of research materials. The modular approach provides scalability, flexibility and capacity for further development in response to the needs of the educational and research environment.

Functional modelling formalised the main business processes, defined user interaction scenarios and aligned functional requirements with technical solutions.

The database structure reliably stores information on research outputs, supports complex analytical queries and enables effective management of departmental information resources. The data processing mechanisms automate statistical and analytical reports used to assess research performance.

Particular attention was devoted to a user interface that supports effective interaction with the system. The proposed solutions improve usability and reduce the time needed for typical operations.

The practical value of the findings is that the system can automate research management in individual departments and other units of higher education institutions. The approach can be adapted to different organisational settings and integrated with external information resources, bibliometric databases and electronic document management systems.

Future research may develop intelligent methods for analysing research data, apply artificial intelligence to management decision support, automate forecasts of research performance indicators and expand integration with international research information platforms.

The findings support the use of intelligent information systems as effective tools for the digital transformation of research in higher education institutions and provide a basis for further development of research knowledge management technologies.

Current trends in digital research across the EU underscore the relevance of these findings. EU initiatives within the ERA, Horizon Europe and EOSC demonstrate the need for integrated systems that manage research data effectively, support open science and enable digital interaction among research institutions. The proposed system aligns with the main directions of digital transformation set out in European research and innovation policy and provides a basis for further integration of Ukrainian higher education institutions into the international research information environment.

Future research may develop intelligent analysis of research data, apply artificial intelligence to management decision support, automate forecasts of research performance indicators, expand integration with international research information platforms and implement European research information management standards, including FAIR and open science principles and the CERIF standard used by modern CRIS platforms.

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3.2. Digitalization of higher education: integration of information quality systems and information security standards

Alla KAPITON

National University "Yuri Kondratyuk Poltava Polytechnic"

In the context of the European course toward the digital decade and the automation of production, purely technical and algorithmized skills are losing their status as a market advantage, since they can easily be delegated to artificial intelligence. In accordance with the concepts of the European Education Area, the key value is shifting toward uniquely human competencies, such as critical and creative thinking, reflection, and ethical maturity. It is precisely this human-centered approach, enshrined in the strategies of the European Union (EU), that enables the transformative power of technology to serve the goals of sustainable development and social inclusion.

Extrapolating current trends in pedagogical innovation and computer science makes it possible to state that artificial intelligence (AI), Big Data, Educational Data Mining, and machine learning (ML) technologies will form the fundamental basis of the architecture of higher education for the coming decade. However, the large-scale diffusion of emergent AI tools (in particular, generative models and adaptive learning systems) into educational practice not only optimizes processes but also fundamentally transforms the threat model. Designing future educational trajectories requires the implementation of the concept of Secure AI by Design, since the use of large volumes of personal and academic data creates new vectors for cyberattacks, including the leakage of confidential information, manipulation of learning analytics, and data poisoning in machine learning algorithms [1-7].

Within the framework of the implementation of the EU Digital Education Action Plan, generative and predictive artificial intelligence has become a systemic driver of