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# The Concept of Digital Transformation of Monitoring Scientific Activity of Participants in Educational Process of the Ukrainian HEI

The article proposes the criteria of the information and reference system for digitalisation of collection, storage, accounting and analysis of scientific publications (conference abstracts) of teachers of the Ukrainian higher education institution (HEI), providing reporting according to certain criteria and interactive data visualisation. The paper presents the results of modelling the structure of data storage that meets the standards of bibliographic description; digitalisation of reporting, which allows generating bibliographic references in APA, IEEE, DSTU 8302:2015 formats and exporting them to PDF, CSV, JSON, XML; implementation of dashboards for visualising statistical data in real time; forecasting scientific activity in accordance with licensing requirements, which allows analysing the dynamics of publications of teachers and students; substantiating the use of project architecture to provide remote access. The proposed approaches can be scaled up to take into account other types of scientific activity, such as scientific articles, methodological publications, patents, etc.

Prospects for further research are integration with external scientific platforms (Scopus, Google Scholar, ORCID), the use of artificial intelligence to forecast activity, introduction of a rating system and personalised settings for users. The developed system can be used as a SaaS solution for Ukrainian higher education institutions, which will contribute to the digital transformation of research management

**digital transformation, licensing conditions, teacher's scientific activity, information system, database, monitoring, bibliographic reference, forecasting, digitalisation**

**Problem statement.** Information technologies play an important role in the development of modern educational environment. Control over activities of subjects and objects of the educational sphere is carried out on the basis of communication management.

Communication management includes purposeful management of the flow of documented information that takes place in basic spheres of society, as well as in the economic, financial, legal, business and educational spheres. ‘Documented information is information recorded on a material carrier with certain features that allow its identification’ [1].

Documented information is conveniently managed through information systems implemented on modern information technologies. Accounting for the work of academic staff is an important component in management of an educational institution. One of the most pressing issues is monitoring the implementation of licensing conditions for the conduct of educational activities, in particular clause 38.12 of Resolution of the Cabinet of Ministers of Ukraine No. 1187 ‘On Approval of Licensing Conditions for the Conduct of Educational Activities’ [2].

**Analysis of recent research and publications.** The issue of informatisation of higher education institutions is aimed at automating and improving various aspects of their activities, including increasing productivity, improving quality of services, accelerating management,

and increasing the availability of information [3]. Administrative and legal regulation of informatisation in the field of education is considered in work [4]. The issue of educational management is a dynamic process and has a multifaceted nature: from the organisation of education to the presentation of educational materials by means of information systems. The problems of virtualisation of the educational environment [5, 6, 7, 8] for the organisation of a distance learning format have become relevant during martial law and are related to the security component. Learning is moving to an asynchronous mode. The services of organising accounting and control of the curriculum to ensure quality of educational process are covered in work [9].

'Information technologies significantly improve access to information, increase communication opportunities during distance learning, increase efficiency and motivation of learning, provide new ways of presenting information that facilitate its understanding, and provide an opportunity to test your own ideas and projects' [10, p.100]. The paper analyses modern learning platforms and their advantages in use.

Aspects of the use of information technology in management of a higher education institution are described in the work of I. Shorobura. In particular, it is noted that 'the development of information management is associated with the organisation of data and knowledge processing system, their consistent development to the level of integrated automated management systems of higher education institution' [11, p.189].

The use of information system for presentation of work programmes of educational components determines a number of advantages in communication management of higher education institutions and promotion of student centred policy in educational process [12, p.24]. Some works are focused on the development of management of an educational institution by means of information technology [13, 14].

The issue of virtualisation of monitoring the implementation of licensing conditions for the conduct of educational activities, in particular clause 38.12 of Resolution of the Cabinet of Ministers of Ukraine No. 1187 'On Approval of the Licensing Conditions for the Conduct of Educational Activities' [2], needs to be covered more thoroughly.

Studies [14-15] focus on digitalisation of municipal healthcare services in Ukraine. The developed information system for the provision of medical services by municipal healthcare facilities provided citizens with convenient access to information about medical services through a mobile application. This became possible due to 'the creation and implementation of an improved model of the municipal information system of healthcare services with offline access, improvement of the model to provide access to data without an Internet connection, implementation of algorithms for the functioning of the client of the municipal IS of healthcare services for mobile platforms' [14]. That is, studies [14-15] show that digitalisation can improve a business process or service, increase efficiency, facilitate the work of employees, ensure digitalisation of society, and enable scaling and integration of proposed business solutions.

Papers [16-17] present the results of digitalisation of educational processes at Zhytomyr Polytechnic State University. The results of these studies allow increasing efficiency to manage a class schedule, the process of preparing, reviewing and defending theses. The authors 'for the first time implemented a complete digital transformation of the process of preparing theses, including electronic signatures, plagiarism check and integration with the university portal', 'reduced the workload of teachers and students, reduced the use of paper, and eliminated bureaucratic delays' [17]. This positive effect was achieved precisely because of the digital transformation of academic processes.

**Tasks statement.** To digitise the process of monitoring scientific activity of research, teaching staff and students, where approbation publications on scientific or professional topics

are one of the types of such activity, it is necessary to develop the information and reference system that records these publications, generates reports according to certain criteria and provides prompt information on the state of scientific activity.

To achieve the goal, the following tasks need to be solved:

1. Based on the analysis of the structure of bibliographic reference to the abstract of a scientific conference report, identify entities and attributes for storing this information in the organisational structure.

2. To model a data output template in order to automate reporting in the form of a bibliographic reference in formats (APA, IEEE, etc.), with the ability to select information export formats (PDF, CSV, JSON, XML).

3. Develop a dashboard structure for visualising key monitoring indicators as web pages with interactive controls (in JavaScript using Chart.js, D3.js, etc.).

**Results.** Automation of monitoring of scientific activity of research and teaching staff (in particular, clause 38.12 of the Law of Ukraine 'On Higher Education') and higher education students should be carried out through the information and reference system 'Theses'. The information and reference system of conference abstracts is a web-based platform for organising processes of collecting, storing, processing and analysing information on conference abstracts.

The system is responsible for implementing such precedents: Collection and storage of information on published abstracts of scientific conferences; Automation of reporting – generation of reports in the form of a bibliographic list based on templates according to certain criteria: research and teaching staff, student, department, faculty, calendar year, calendar period, field of knowledge; Dashboards with statistics – data visualisation using specialised libraries based on real data; Forecasting – formation of analytical data and a list of publications will be relevant in accordance with clause 38.12 of the Licence Terms in future.

To ensure remote access and collaboration with system resources, it is necessary to design a web-based platform based on a client-server architecture.

**Modelling the structure of storing information about abstracts of scientific conferences**. Analysing the requirements for the list of references in accordance with the Order of the Ministry of Education and Science of Ukraine of 12 January 2017, No. 40 (registered with the Ministry of Justice on 3 February 2017, No. 155/30023) and the National Standard of Ukraine 'Information and Documentation. Bibliographic reference. General provisions and rules of compilation. DSTU 8302:2015', it is possible to formalise information on abstracts of scientific conferences for storage in the Theses information and reference system.

By formalising data on scientific publications, information can be represented as a tuple, where each element corresponds to a certain attribute:

$$P=(Team;\ TP;\ TC;\ T;\ L;\ D;\ LI;\ C;\ Y;\ PD;\ Ps;\ Pf;\ URL;DOI;L), \quad (1)$$

where *Team (team of author)* is team of authors, *TP (title publication)* is thesis title, *TC (title conference)* is conference name, *TC (type of collection )* is collection type, *L* (location) is conference venue, *D (date event)* is the date of the conference, *LI* is responsible institution, *C (city)* is the city of the conference, *Y* is calendar year of the conference, *PD (publication date)* is the date of publication, *Ps (page start*) is home page of the publication, *Pf* (*page finish*) is final page of the publication, *URL (url)* is the link to electronic version, *DOI (doi)* is the link to electronic version, *L* (*language*) is the language of publication.

The set of tuples *P* is the set of theses (1) and is defined by the following formula:

$$Database=\sum_{i} P_i .$$

The author of the abstract in the bibliographic reference is represented by the surname and abbreviation of the first name, patronymic, or surname and abbreviation of the first name

in the language of publication (hereinafter referred to as the representation). In view of this, the representation of the author of a thesis can be given by one value from the list of representation options - surname, first name, and patronymic. The set of representations is determined by the formula:

$$N=\{n_i,\ \ i=\overline{1,k}\}, \tag{2}$$

where $k$ –is the number of presentation options.

The universal set of all possible representations $U$ consists of the union of the sets of representations (2) of all authors of theses that will be stored in the system.

$$U=N_1 \cup N_2 \cup \ldots \cup N_j,\ \ j=\overline{1,d} \tag{3}$$

where $d$ is the number of authors.

The team of authors *Team* is represented as a list of one specific representation (2) for all authors of theses and is a list of elements of the universal set $U$ of author representations:

$$Team=(a_i,\ \ i=\overline{1,c}) \subseteq U, \tag{4}$$

where $c$ is the number of authors of one thesis.

The set $U$ is a dynamic structure and is supplemented based on the analysis of the authors' representation when adding new bibliographic references.

Types of conferences constitute a set of possible types; conference name is an element of the set of conference names; responsibility is an element of the set of responsible institutions/organisers. These sets form database entities. Each entity has certain attributes. The following relationships are established between the entities:

– One conference abstract has a team of authors (1:$n$);

– One conference can be an attribute of several abstracts (1:$n$);

– One publisher can publish collections of scientific papers from different conferences (1:$n$);

– One type of conference can be inherent in several conferences (1:$n$);

– An arbitrary number of conferences can be held in one city (1:$n$);

– Several representations of the surname, name and patronymic record correspond to one author (1:$n$).

– Several authors can be responsible for one representation (1:$n$).

Taking into account the relationship between entities, a relational database structure was chosen to organise the storage of information, and a DBMS using non-procedural data management languages (SQL) was chosen for implementation.

Information is collected into the database based on the GUI user interface with consideration of UX. GUI provides the attributes defined by formulas (1), (2), (4). When designing GUI, it is necessary to ensure the addition of fields for entering the authors of the publication, since the number of authors is an uncertain condition and fuzzy criteria when designing the interface. In addition, to eliminate errors when entering information, it is necessary to ensure initial (technical) validation of the data according to the main criteria: compliance with one input language; absence of special characters; elimination of unnecessary spaces, etc. The final validation is carried out by the relevant department.

The collection of information can be automated on the basis of a JSON file that has the structure in accordance with (1), (2), (4). To work together with the information system, it is necessary to define user roles and delegate to them the rights to work with the database and system precedents. The role-based access model implements access rights to the information system resources of users by linking roles to accounts.

**Automation of reporting.** An important functionality of the system is the automation of reporting based on database queries according to certain criteria. The main criteria are: calendar period of time (calendar year, academic year, semester of the academic year, last five years); name of the academic staff member or student; department or faculty. These criteria can be used separately or in combination.

A reporting document is generated on the basis of a template of a specific form. Reporting automation is performed programmatically using the object-oriented programming paradigm. The base class *Publication* has been developed, which has some of the properties (1), (4) and abstract methods. The base class can be used to store data about other scientific publications. The child class *Thesis* complements the properties of the base class in accordance with (1), (2), (4) and overrides abstract methods that construct a bibliographic reference of the thesis using a template in the format of DSTU 8302:2015, APA, IEEE or others. The class diagram is shown in Figure 1.

When an object of the *Thesis* class is initialised, the *team* array (the result of an SQL query for the team of authors by the abstract's Primary key identifier) and the *attr* array (the result of an SQL query for the publication's attributes by the abstract's Primary key identifier) are passed to the constructor. To obtain data on the team of authors (*team*) and publication attributes (*attr*), a query is executed where the publication identifier is specified in the selection criterion.

To obtain the list of publications of one academic staff member (ASM), it is necessary to follow the algorithm:

1. Select all primary keys of publications where the academic staff member is in the team of authors.

2. Search the obtained publication keys: 2.1) For the current key, run a query to get the publication attributes; 2.2) For the current key, run a query to get the data of the team of authors and their views.

3. The received data initialises an object of the *Thesis* class. The constructor parses the received arrays, assigns their values to the corresponding class properties.

4. Objects are elements of the *List_thesis* data organisational structure, which is used for further display on the web platform, generating a test file or PDF report, exporting data in JSON, XML format.

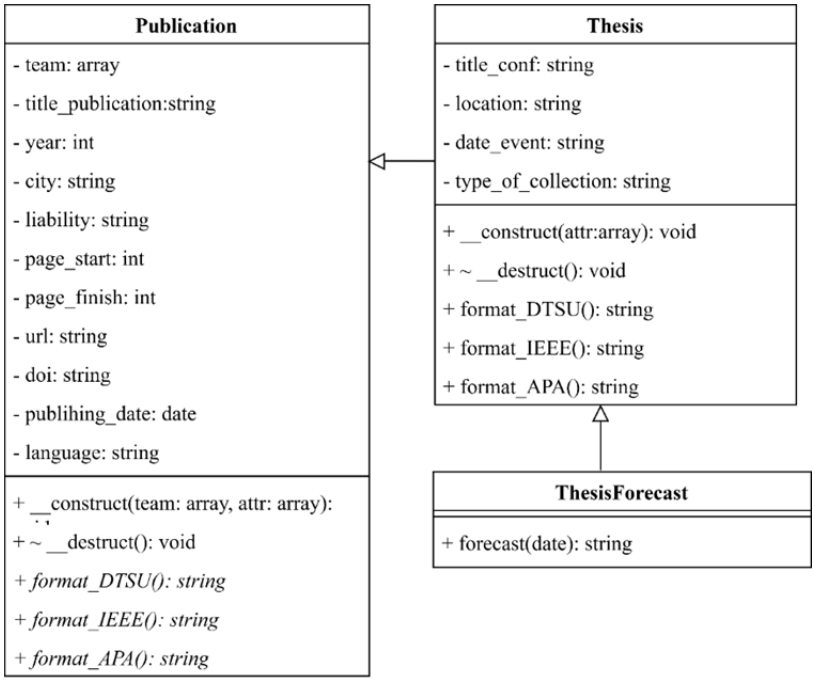


Figure 1 – Class diagram of the Thesis project

*Source: developed by the authors.*

The *format_DSTU()* method of the *Thesis* class generates text value as a bibliographic reference of a publication in accordance with the requirements of DSTU 8302:2015 using the following basic formatting template: Author(s). Title of the paper. Name of the conference: type of proceedings, city of the conference, date of the conference / Information about responsibility. City of publication, year of publication. Pages.

The code snippet for implementing the *format_DSTU()* method of the described object in the PHP server logic language is as follows:

```
public function format_DSTU() {
    $team = implode(", ", $this->team);
    $reference = "$team $this->title_publication. 
    <em>$this->title_conf:</em> $this->type_of_collection,
    $this->location, $this->date_event / 
    $this->liability. $this->city, 
    $this->year. C. $this->pages_start  
    $this->pages_finish.";
    if (!empty($this->url)){
    $reference .= " URL: $this->url";}
    if (!empty($this->doi)) {
         $reference .= " DOI: $this->doi";}
    return "<p>$reference</p>";}
```

Mandatory spaces for separating template elements are marked with the   code. The *format_APA()* and *format_IEEE()* methods generate a ribbon according to the basic APA and IEEE format templates, respectively. The methods of generating templates can be improved with the following functionality: handling empty class properties; removing duplicate spaces or periods, etc.; transliterating bibliographic references into English; converting text values to the 'As in sentences' format; adding design styles in accordance with the web platform design. Such additional validation is necessary to bring the bibliographic reference to a single format.

By supplementing the query with the criterion 'range of calendar dates', the reporting of an individual research and teaching staff member on scientific activities for the calendar period is generated.

**Monitoring and forecasting research activities.** The monitoring provides up-to-date information on the number of abstracts of publications based on the selection criterion 'last five years'. If the number of sample items is at least five, the professional activity is confirmed in accordance with clause 38.12 of the Licence Terms [2]. If the number is less than five, proposals are provided to keep this professional activity up to date. The forecast is presented in the form of a dashboard with publication statistics for the years and a general list of publications *list_thesis*.

The management of the higher education institution is responsible for compliance with and implementation of the Licence Terms, so it is interested in forecasting the state of implementation of clause 38.12 in future.

The methodology of forecasting software implementation is as follows:

1. Create a collection of objects of the *ThesisForecast* class based on the selection of publications according to the additional query criterion 'publication date' in the range from the current date *current_date* to the current date minus five years (*current_date* - 5 years).

2. Organise the passage of the collection and apply the *forecast(date_forecast)* method to each object, to which the calendar date of the forecast is passed - *date_forecast*. This method compares the value of the *publishing_date* attribute in the range from *date_forestcast* to *date_forecast - 5 years (item_active).*

3. The method returns two values *active_item* and *message: active = False* or *True*, depending on whether the publication date belongs to the *item_active* range. The message is the value of the *format_DSTU()* method, which is additionally provided with a CSS styling class (*active_item = False*) that visually distinguishes the text of a bibliographic reference when displayed on a web platform. In report documents, this is the corresponding marker.

4. Sum the values of *active_item* using the formula $active=\sum active\_item$ and create a list of publications. Provide a conclusion: if *active>=5*, then clause 38.12 is 'fulfilled', otherwise 'not fulfilled'. In case of non-fulfilment, the number of publications required to grant the status of 'fulfilled' is indicated.

A partial case of forecasting is the submission of proposals to the individual plan of the academic and pedagogical staff (APS) for the next academic year. For this purpose, we add a calendar year to the selected forecast date (start of the academic year: 09/01/2026) and follow the forecast precedent.

All the precedents identified can also be used to analyse and report on the research activities of higher education students.

**Development of dashboards for data visualisation**. A dashboard is a software solution that allows processing data in real time (i.e. create, receive, analyse digital information) and visualise statistical information. Dashboards are best used for information where queries group data using aggregate functions. Such queries include: the number of publications of a department, faculties, familiarisation with the geography of publications, etc.

The dashboard template consists of two blocks:

Block 1: The container that displays statistical data of the factor in the form of a table 'indicator → value'.

Block 2: A container for visualising statistical data.

Since we have a web-oriented information system, it is advisable to visualise it using the Chart.js, D3.js, Google Chart, etc. libraries.

All libraries have patterns of various data visualisation. To create a real-time visualisation, it is necessary to sample operational data. Using Chart.js library as an example, to build a chart, it is essential to have the values of the *labels* and *data* parameters. To obtain real-time data, it is advisable to use AJAX technology, which allows processing server response without blocking main thread of execution. The *fetch()* method, which is used in JavaScript to send HTTP requests (GET, POST, etc.) and process responses, corresponds to the declared technology. Response processing implements the formation of *labels* and *data* parameters for data visualisation.

**Discussion.** This paper presents the concept and aspects of practical implementation of information and reference system for monitoring scientific activity of teachers and students. This system for a university provides digital recording and storage of bibliographic references to conference abstracts, digitalises reporting by various criteria, visualises data through interactive dashboards, and forecasts research activity in accordance with licensing requirements. Based on the conclusions drawn from the analysis of recent research and publications, this work is valuable and provides a positive effect in the implementation of business processes of higher education institutions in Ukraine.

At the same time, the following prospects for further work on the project are already visible.

1. Integration with external platforms. It is promising to implement communication with scientific databases, synchronisation with Scopus, Google Scholar, ORCID. This will ensure automatic import of information about conference abstracts. Import and export of data can also be effective by implementing support for XML, JSON, CSV, BibTeX export formats, as well as integration with LMS.

2. Authors do not exclude the possibility of using the system to automatically generate a researcher's profile, i.e. to create a portfolio for each teacher or employee of a higher education institution.

3. The need to improve analytics and forecasting is expected to arise in the future. Therefore, the prospect of further work is the creation of additional analytical tools: dashboards for analysing the number of publications, co-authorship, and popularity of conferences.

4. The introduction of AI for the forecasting is already relevant. The use of machine learning algorithms will allow for more accurate forecasting of scientific activity.

5. A valuable development and improvement is the implementation of the possibility to assess the effectiveness of departments or faculties, as well as the rating of researchers and teachers.

6. Prospects for practical implementation are obviously expanding the functionality of the system. The addition of reminder and notification functions will be very useful, as automatic reminders of the need for publications to meet licensing requirements.

Attention should also be paid to personalisation mechanisms, i.e. the ability to customise the interface and choose convenient visualisation formats, digitalisation of data entry through text recognition, automatic data entry from PDFs and scanned documents.

7. Already at this stage of project implementation, it is worth starting to create opportunities for commercialisation, taking as an example positive experience of creating 'Zhytomyr Polytechnic Science Park' LLC and 'Innovation Hub' [18]. After all, e-service for monitoring research activity of teachers and students is a good offer for Ukrainian universities; this system can be used as a SaaS for universities.

Thus, this work has real prospects for further development: integration with external scientific platforms, improvement of analytics, automation of data entry, personalisation of user experience, and further commercialisation of the project.

**Conclusions.** The information and reference system 'Thesis' is an element of communication management of a higher education institution. It has the functions of promptly informing about aspects of scientific activity of research and teaching staff, and students, automated generation of reporting documentation, in particular in text and PDF formats, monitoring the relevance of clause 38.12 of the Licence Terms and forecasting future professional activity of participants in educational activities.

To organise remote access and collaborative work of users, the information and reference system is based on a client-server architecture and implemented as a web-based platform by means of information technologies.

The analysis of the structure of forming a bibliographic reference to an information source has allowed identifying entities and necessary attributes for organising the storage of documented information. The entities have been identified and the necessary and sufficient attributes for information preservation have been determined. The relationships between data entities are established, which are the basis for creating the structure of a relational database.

The developed conceptual models of the database, class structures, data processing methods, templates for generating bibliographic references to published abstracts of scientific conferences in various formats, and the methodology to forecast professional activities for the publication of testing materials on scientific or professional topics can be implemented by a diverse stack of software tools from the server to the client parts of the web platform.

The proposed approaches to database design and object-oriented classroom modelling can be scaled up when developing information systems for accounting scientific papers, scientific and methodological publications, inventive activity, etc. Further development of the information system may include integration with other educational platforms, integration of the list of published abstracts into the portfolio of academic staff and individual student cards, expansion of analytical tools, improvement of the notification system, and user personalisation mechanisms. Automation of data entry from ORCID and Google Scholar information systems is promising.

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## Концепція цифрової трансформації моніторингу наукової активності учасників освітнього процесу в українському ЗВО

Ця наукова праця присвячена вирішенню науково-технічного завдання синтезу інформаційно-довідкової системи для цифровізації збору, збереження, обліку й аналізу наукових публікацій (тез конференцій) викладачів закладу вищої освіти в Україні, забезпечуючи цифрове формування звітності за визначеними критеріями та інтерактивну візуалізацію даних. У статті представлені: результати моделювання структури збереження даних, що відповідає стандартам бібліографічного опису; цифрову трансформацію процесу створення звітності, яка дозволяє формувати бібліографічні посилання у форматах APA, IEEE, ДСТУ 8302:2015 та експортувати їх у PDF, CSV, JSON, XML; реалізацію дашбордів для візуалізації статистичних даних у реальному часі; прогнозування наукової активності відповідно до ліцензійних вимог, що дозволяє аналізувати динаміку публікацій викладачів та студентів; обґрунтовано застосування архітектури проєкту для забезпечення віддаленого доступу та можливості спільної роботи з системою. Запропоновані в статті підходи й рішення можуть бути масштабовані для обліку наукової діяльності, серед яких наукові статті, навчально-методичні видання, патенти і інші академічні активності й досягення, які передбачені чинними в Україні Ліцензійними умовами провадження освітньої діяльності.

Перспективами подальших розвідок є інтеграція створеної інформаційно-довідкової системи із зовнішніми науковими платформами (Scopus, Google Scholar, ORCID), використання ШІ для прогнозування активності, впровадження рейтингової системи та персоналізованих налаштувань для користувачів.

Розроблена інформаційно-довідкова система може бути використана як SaaS-рішення для закладів вищої освіти в Україні, що сприятиме цифровій трансформації управління науковою діяльністю.

**цифрова трансформація, ліцензійні умови, наукова активність викладача, інформаційна система, база даних, моніторинг, бібліографічне посилання, прогнозування, цифровізація**

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