BULGARIAN ACADEMY OF SCIENCES

CYBERNETICS AND INFORMATION TECHNOLOGIES • Volume **24**, No 2
Sofia • 2024 Print ISSN: 1311-9702; Online ISSN: 1314-4081
DOI: 10.2478/cait-2024-0017

# Quality of Blended Learning Implementation in HEIs: Tool for Monitoring the Use of e-Learning Management Systems

*Silvia Gaftandzhieva, Rositsa Doneva, Milen Bliznakov*

*University of Plovdiv Paisii Hilendarksi, 4000 Plovdiv, Bulgaria*
*E-mails: sissiy88@uni-plovdiv.bg rosi@uni-plovdiv.bg milen@uni-plovdiv.bg*

***Abstract*: *Despite the wide acceptance of blended learning in Higher Education Institutions (HEIs) worldwide, the issue of monitoring its implementation has been little addressed in the literature. The paper presents the results of the first stage of the study for the development and implementation of tools for monitoring the degree of use of blended learning courses within the learning process in HEIs. The tool introduced here extracts data from the database of the e-learning environment and visualizes the results of the data analysis in dashboards that provide valuable insights to decision-making for improving the quality of blended learning implementation. The tool allows governing bodies to track trends in the user registration, development, and updating of blended learning courses, the number of learners, and the usability of the courses by users for a selected period. Based on the results of tool experimental testing, goals for its further development are set.*

***Keywords*: *Blended learning courses, Implementation, Higher education institution, Monitoring.*

## 1. Introduction

Technological innovations in recent decades faced Higher Education Institutions (HEIs) with the need to adapt to the new realities of the knowledge society and digitize the services offered to meet the students' expectations. To ensure a higher quality of education and to be more attractive to their students, many researchers and HEIs worldwide are looking for ways to provide an innovative educational environment [1-2] and various forms of online learning for their students [3-6]. Since blended learning entails a combination of traditional face-to-face and online learning forms [7-11], it has become an increasingly popular form of online learning [12]. It allows HEIs to meet the challenges of customizing learning and development to student needs by incorporating the innovative and technological advances offered by online learning with the interaction and participation offered in traditional learning [13-14], internet, and physical presence in classrooms [5], face-to-face and video-conference learning complemented with the use of a Learning Management System (LMS) [15]. It provides a flexible platform that offers new opportunities for students to interact with learning content, peers, and faculty inside and outside the classroom [13, 16-17]. Thus, blended learning is a solution that has the potential to enhance the student learning experience and engagement [18-19], improve access to information [20-21], and offer a flexible learning solution while meeting the institutional requirements of higher education.

The process of introducing different forms of online learning was catalyzed within the COVID-19 pandemic when HEIs were forced to transform their traditional ecosystem in a short time to move from face-to-face to online learning to provide their students with access to learning [12, 20-24].

The results of experimental blended learning conducted in many HEIs show that the right combination of online and traditional learning can be more effective and efficient when compared to the face-to-face learning model [5, 27-28]. Results from surveys for student satisfaction conducted worldwide show that the majority of students highly value the blended learning offered and believe that it increases their motivation to learn and engage in training and has the potential to lead to better results [1, 5, 14, 18, 23, 29-34]. As a significant benefit, many students value the ability to easily access learning content anytime, anywhere [1, 23, 35-36]. This flexibility allows students to be more autonomous, regulate their studies, and balance their studies and personal lives [37]. Blended learning enhances critical thinking and problem-solving abilities by increasing student engagement and promoting independent learning [18, 23, 36, 38-39]. As another advantage, students point out the increased opportunities to communicate with the instructor and believe they receive better quality and faster feedback in blended learning courses [5, 34, 36, 40-41]. Blended learning creates a sense of community among students, where they feel free to express their opinions, discuss the covered ideas, and enable collaborative activities [12, 14]. Because of all these advantages of being an experimental concept in distance education, blended learning has become a worldwide trend, and many universities all over the globe have adopted it in addition to traditional face-to-face learning [12, 27, 41]. The benefits of blended learning courses encourage HEI leaders to boost their investment in infrastructure and teacher training for using blended learning courses in their teaching practices [14, 42-43].

Despite the wide acceptance of blended learning in HEIs worldwide, the issue of monitoring its implementation has been little addressed in the literature. To guarantee the effectiveness of the developed blended learning courses, HEI leaders should build tools for central and longitudinal data collection (from surveys among students and teachers and data from user activity in the LMS) for monitoring and evaluation purposes [44-45]. The tools should provide HEI management with aggregated reporting information on the implemented blended learning courses, which allows tracking the achievement of the set goals and guiding strategic decision-making in HEIs. T a’ a et al. [46] use the Business Intelligence and Data Warehouse to capture, process, and analyze data on blended learning implementation to monitor the total number of learning resources for blended learning courses (assignment, chat, feedback, forum, quiz, files, resources) created by teachers. M e r s h a d and S a i d [47] propose a framework to monitor the degree of students’ involvement, the percentage of students participating, and the amount of engagement of each student during online lectures. These tools are intended for use primarily by teachers and do not give management a complete understanding of the use of blended learning courses within HEIs. Habrusiev et al. [45] use Google Analytics and Moodle tools to analyze the use of e-learning based on defined metrics (most active courses for a period, courses with the highest number of students, courses with the highest number of views, event register, page views, exact request time, average page view time, bounce rate, daily activity, website presence time) to plan and implement further development and improvement of e-learning. None of the considered solutions allows the governing bodies to track the process of implementing blended courses in HEIs to a full degree. The overall monitoring of the use of blended learning courses in HEI requires tracking both the activities of students and teachers in a specific course and general metrics for the LMS use in which the courses are located, as well as the provision of the offered study programs with blended learning courses, the usage of the created courses in the learning process, the relevance of the developed courses, the number of students trained, the competences of teachers for creating blended learning courses. Such tools can help HEI leaders identify study programs with few developed blended courses and platforms with few users and make informed decisions to stimulate teachers to create blended learning courses and invest in new software.

The paper presents the results of the first stage of the study for the development and implementation of tools for monitoring the degree of use of blended learning courses within the learning process in HEIs. At the same time, the paper demonstrates the use of different mathematical methods in software tools and data analysis to support quality assurance and decision-making in modern higher education institutions. Specifically, a tool is introduced here that extracts and analyzes data from the database of the e-learning environment and visualizes it in dashboards that provide valuable insights through data analysis to decision-making for improving the quality of blended learning implementation. Elementary set theory in combination with logic, mathematical expressions, and aggregating functions was applied for data extraction and analysis. The tool allows governing bodies to track trends in the user registration, development, and updating of blended learning courses, the number of learners in courses, and the usability of the courses by students for a selected period.

## 2. Materials and methods

The design and development of a tool for monitoring the degree of use of blended learning courses proceeds in three stages (see Fig. 1). *Stage* 1 *is the preparatory stage.* It requires the identification of stakeholder groups and a thorough analysis of their needs. After getting to know the needs of the stakeholder groups, one can proceed to stage 2. *Stage* 2 *is a design a model with indicators*, which involves forming a set of indicators and ways to measure them. Determining how to assess indicator values requires a thorough understanding of the data sources from which the information will be drawn (e.g., the LMS in which the courses are located). This analysis aims to determine which stored data can form the values of the defined set of indicators and how these values can be calculated. *Stage* 3 *is design and development of monitoring dashboards* include a selection of the technology for implementation, development of dashboards with appropriate elements to allow tracking of the set of indicators formed in Stage 2, development of a module that visualizes the developed dashboards and can generate documents on them and, if necessary, integration of the developed module with existing software solutions.

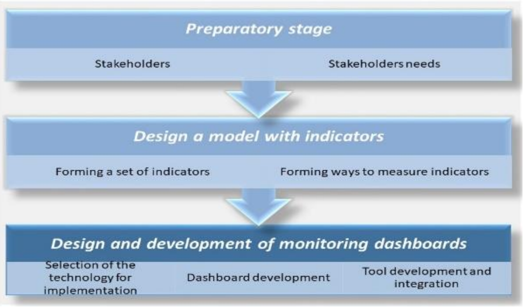


Fig. 1. Stages

The following subsections describe the process of developing a monitoring tool for the needs of a typical Bulgarian university.

### 2.1. Stage 1. Preparatory stage

During that stage, the stakeholders in a typical Bulgarian university and their needs were identified.

University governing bodies are directly interested in introducing blended learning courses. These bodies can make decisions to promote this process and encourage teachers to develop, update, and use blended learning approaches in their practice at both the faculty and university levels. The Faculty management (Group 1), i.e., middle management, has an interest in tracking what part of the courses included in the curricula of the study programs offered in the faculty there are blended learning courses developed, whether teachers update these courses, and what extent the trainees enrolled in these courses are active and taking advantage of the learning resources offered in addition to formal training, as well as tracking the extent to which faculty staff is engaging in the training to enhance their competencies to use different forms of e-Learning in their practice. Due to the many proven benefits of blended learning, the University management (Group 2), i.e., top management, is interested in tracking the process of introducing blended learning courses in addition to formal learning at the university and encouraging individual faculty managers to encourage teachers in the faculty to use such learning approaches to increase student satisfaction with the education and attract more prospective students.

Another stakeholder group is the e-Course quality assurance and assessment units (Group 3). They need to track the number of courses in the LMS and the number of registered and active students. Based on the analyzed and aggregated data, they can make decisions about offering support to teachers who do not regularly update their courses (e.g., organizing training sessions and round tables to exchange expertise and ideas), releasing resources (e.g., archiving courses that are not being taught and deleting them from the LMS, deleting profiles of inactive users, etc.), and to generate reports on the use of the LMS to be attached to unit activity reports and self-evaluation reports on the LMS and learning courses.

## 2.2. Stage 2. Designing a model with indicators

During that stage, based on the analyzed needs of the three stakeholder groups (Faculty management, University management, e-Course quality assurance, and evaluation unit), a model with a set of measurable numerical indicators was proposed, the values of which will be calculated using extracted data from the LMS. The indicators from the proposed model allow for tracking the registrations in the system, the developed courses, and the training of the registered users (students, PhD students, and teachers). Table 1 presents the developed model with measurable indicators. The set of indicators is the same for the three stakeholder groups. There are differences in the way the indicator values are formed. When calculating the indicator values for the needs of stakeholders from Group 2 and Group 3, the data for all registered users and courses are analyzed, while when calculating the indicator values for the needs of stakeholders from Group 1, only the data for registered users from the faculty led by the manager and courses developed by faculty staff members of this faculty are analyzed.

Calculating the values of the proposed set of indicators requires familiarity with the capabilities of the LMS in which the courses are deployed, and a detailed analysis of its database and the tables that store information about registered users, the courses developed, the resources and activities added to the courses, the users enrolled in learning courses, users activities on the course level. This analysis aims to determine what data the LMS database stores and how it can be used to form numerical indicator values.

Calculating the values of some of the indicators from the model requires aggregating data on registered users and courses at different levels. Some LMSs (e.g., Moodle) do not support the whole information needed to identify users, e.g., faculty. This fact makes it necessary for these LMSs to look for solutions to store additional information about registered users that facilitates their identification and allows the calculation of indicator values from the model. For this purpose, an analysis of the LMS should be made to add additional user fields for different groups of registered users, in which the data required for monitoring and calculating indicator values should be stored as follows:

- Students – faculty, study program, degree, professional field, status;
- PhD students – faculty, teaching unit (department), doctoral program, professional field, status;
- Teacher – faculty, department, status.

At first glance, this solution poses risks as the LMS may allow editing of the data entered. A solution should be sought to disallow users from editing the values in these fields and enable only the system administrator to edit them to overcome this drawback. Extracting such data from student information systems during registration eliminates the possibility of incorrect data entry. At the same time, this guarantees the reliability of the stored additional user data for analysis and monitoring procedures. In addition, some LMSs may not store information about the unit responsible for developing and updating courses, organization, and learning delivery. Since such information is needed to form values of some indicator of the proposed model, a solution to the problem of where to store this information should be sought for these LMSs.

Table 1. Model with measurable indicators

| Criteria | Indicators |
|---|---|
| 1. Registered users | 1.1. Number of registered users<br>1.2. Number of registered students<br>1.3. Number of registered PhD students<br>1.4. Number of registered teachers<br>1.5. Number of registered users for the period<br>1.6. Number of registered students for the period<br>1.7. Number of registered PhD students for the period<br>1.8. Number of registered teachers for the period<br>1.9. Number of registered students by the study program<br>1.10. Number of registered students by study program (per period)<br>1.11. Number of active students by study program (per period)<br>1.12. Number of registered students by year<br>1.13. Number of active students by year<br>1.14. Number of registered PhD students per PhD program<br>1.15. Number of registered PhD students (per period)<br>1.16. Number of active PhD students (per period)<br>1.17. Number of registered PhD students by year<br>1.18. Number of active PhD students by year<br>1.19. Number of registered teachers by faculties<br>1.20. Number of registered teachers per faculty (per period)<br>1.21. Number of active teachers per faculty (per period)<br>1.22. Number of registered teachers by year<br>1.23. Number of active teachers by year |
| 2. Training courses developed | 2.1. Number of courses developed<br>2.2. Number of courses for students<br>2.3. Number of courses for PhD students<br>2.4. Number of courses for teachers<br>2.5. Number of courses developed during the period<br>2.6. Number of courses for students developed during the period<br>2.7. Number of courses for PhD students developed during the period<br>2.8. Number of courses for teachers developed during the period<br>2.9. Number of courses updated during the period<br>2.10. Number of courses for students updated during the period<br>2.11. Number of courses for PhD students updated during the period<br>2.12. Number of courses for teachers updated during the period<br>2.13. Number of courses for students (by study program)<br>2.14. Number of courses for students developed during the period (by study program)<br>2.15. Number of courses for students updated during the period (by study program)<br>2.16. Number of courses for students (by year and faculty)<br>2.17. Number of updated courses for students (by year and faculty)<br>2.18. Number of courses for PhD students (by unit)<br>2.19. Number of courses for PhD students developed during the period (by unit)<br>2.20. Number of courses for PhD students updated during the period (by unit)<br>2.21. Number of courses for PhD students (by year and unit)<br>2.22. Number of updated courses for PhD students (by year and unit)<br>2.23. Number of courses for teachers (by unit)<br>2.24. Number of courses for teachers developed during the period (by unit)<br>2.25. Number of courses for teachers updated during the period (by unit)<br>2.26. Number of courses for teachers (by year and unit)<br>2.27. Number of updated courses for teachers (by year and unit) |
| 3. Trained users | 3.1. Number of trained users<br>3.2. Number of students trained<br>3.3. Number of PhD students trained<br>3.4. Number of trained teachers<br>3.5. Number of trained users during the period<br>3.6. Number of students trained during the period<br>3.7. Number of PhD students trained during the period<br>3.8. Number of teachers trained during the period<br>3.9. Number of trained students by the study program<br>3.10. Number of trained students by study program (during the period)<br>3.11. Number of trained students (by year)<br>3.12. Number of PhD students trained (by PhD program)<br>3.13. Number of trained PhD students (during the period)<br>3.14. Number of trained PhD students (by year)<br>3.15. Number of trained teachers per faculty<br>3.16. Number of trained teachers per faculty (during the period)<br>3.17. Number of trained teachers (by year) |

The values thus entered for the additional fields created for each group of users (students, PhD students, and teachers) allow the values of the quantitative indicators in *Criteria 1. Registered users* to be formed (23 in total). For example, the value for *Indicator 1.2. Number of registered students* is calculated by finding the number of users for whom values are entered for the additional user fields specific to registered students. More similarly, the values for the indicators that measure the number of active users (Indicators 1.5-1.8) are formed by calculating only the number of students/doctoral students/teachers whose registrations in the system were made during the time interval under study. To find the number of active users in each group (Indicators 1.11, 1.13, 1.16, 1.18, 1.21, 1.23), we must decide when a student/PhD student/teacher will be counted as active in the learning system. Solving this problem requires analysis of the data stored in the LMS database. In this case, there are two possible approaches to solving this problem. The first approach is to count as an active student/PhD student/teacher for whom the date of last access to the system in the table storing data on registered users is within the time interval under consideration. The disadvantage of this approach is that any user who logs into the system without accessing a specific resource will be counted as an active user. The second approach to determining whether or not a user is active is to consider the user activities in the courses in which the user is enrolled. These activities are specific to different user groups. For example, a student and PhD student is active when s/he performs activities such as reviewing a course, viewing learning resources (folders, files, pages, web resources, etc.), completing assignments, participating in synchronous and asynchronous communication activities, etc. Because the main activity of the teacher is related to the development of training courses and not a participation in organized training, the reporting of teacher activity also examines whether the teacher has developed courses during the period, added or edited modules, resources, and activities in the course, participated in communication activities with students, provided feedback on the completion of assignments to students, etc. The advantage of the second approach is that it allows reporting on the actual use of the system from the user and only on the activities performed within the training courses. Therefore, it is preferable to apply the second approach when calculating the values of indicators for active users.

The formation of the values of some indicators in *Criteria 2. Training courses developed* requires calculating the number of training courses developed (2.2-2.4, 2.6-2.8, 2.13-2.14, 2.16, 2.18-1.19, 2.21, 2.23-2.24, 2.26) and updated (2.10-2.12, 2.15, 2.17, 2.20, 2.22, 2.25, 2.27) courses for each user group (student, PhD student and teachers), as well as the total number of developed and updated courses (2.1, 2.5., 2.9). Determining the course type in LMSs that do not store detailed user information is again possible due to the additional data stored on registered users. Thus, courses in which students are enrolled as learners will be counted as student courses, and those in which PhD students and teachers are learners as PhD student/teacher courses. An approach to define an active course must be selected to calculate the quantitative indicator values for active courses. The LMS databases usually store the last modification date of each developed course, based on which it can be determined whether the course has been updated in a given time interval or not. A disadvantage of adopting this approach is that all courses with edits to the underlying course metadata (e.g., start date, course name, etc.) will be reported as updated. Another possible approach is to examine whether new learning resources or activities are added or updated in the course in the given time interval. This approach requires a very detailed examination of the LMS database and familiarity with the structure of all the tables that store information about resources and activities added to courses. Despite the implementation difficulties, Approach 2 is preferable as it considers the actual updates in the course. Stored data for courses and users can be used to form the values of indicators 2.13-2.27, requiring the number of courses developed/updated/created during the period for students/PhD students/teachers at different levels (study program, faculty, unit responsible for developing, organizing and delivering training).

The indicators in *Criterion 3. Trained users* provide insight into the use of available courses in training students, PhD students, and teachers. Calculating the values of indicators representing the role of trained users from each group (students, PhD students, teachers), including at different levels (faculty, study program, degree, PhD program), is possible thanks to the data stored for each registered user.

Determining how to form the values of the indicators from the model allows proceeding to the next stage of development, namely the design and development of control panels.

### 2.3. Stage 3. Design and development of monitoring dashboards

Based on a survey of software solutions available in the market for extracting, analyzing, and visualizing data from different sources, software solutions for developing dashboards for monitoring the implementation of blended learning courses were selected.

The community versions of two TIBCO Software tools (JasperReport Server and JasperSoft Studio) were chosen for the software implementation of the dashboards. The JasperSoft Studio tool offers rich capabilities for designing dashboards with multiple elements to be populated with data extracted from various data sources (relational databases, big data sources, unstructured data, etc.). JasperReport Server allows organizing a repository for storing the dashboard designs developed with JasperSoft Studio, generating documents based on the designed dashboards, exporting the generated documents in the user's preferred format, and can be integrated easily with external applications, including via shared web services.

In the second step of this phase, eight dashboards (four for Group 1 stakeholders and four for Group 2 and Group 3 stakeholders) were designed and developed using JasperSoft Studio to visualize aggregated and detailed information about registered users, developed courses, and conducted user training. The dashboards contain a variety of elements (labels, text fields, tables, charts) to visualize indicator values from the indicator model presented in Section 2.2, the values of which are generated based on queries to extract data from the selected data source (Moodle database) and subsequent processing of the results obtained. In determining the type of elements to be placed in the dashboards, the number of rows in the resulting dataset is the determining factor. Therefore, for the values of indicators that imply obtaining a result dataset with more than one row (1.9-1.23, 2.13-2.27, 3.9-3.17), tables and(or) charts are selected as visualization elements, for those indicators for which the result of query execution contains a single value, text fields are selected. In the versions developed to meet the needs of different stakeholder groups, a mechanism has been provided to determine how indicator values are calculated according to the user role. The versions differ from each other in the number of parameters based on which the resulting dataset is formed – the dashboards for Group 2 and Group 3 stakeholders have two parameters that set the start and end date of the time interval under study, those for Group 1 stakeholders have one additional parameter that sets the name of the faculty being managed. This parameter allows the dashboard to display only summary data about the students and PhD students trained in the selected faculty and the faculty members who work in the faculty. Fig. 4 shows the dashboard developed to present detailed information about trained users for the needs of Group 2 and Group 3 stakeholders (to add a screenshot of the trained users template). All developed dashboards are stored in the JasperReports Server.

In the last step of this stage, a module was developed in the PHP programming language to allow registered users to visualize dashboards and generate documents based on them by interacting only with the developed module without the need to know the LMS database structure and to be able to work with the JasperReport Server and JasperSoft Studio tools. The last is possible thanks to the integration of the module with JasperReport Server, made possible by using the JasperReports Server PHP Client (**https://community.jaspersoft.com/wiki/php-client-sample-code**), which allows the integration of a client application with the JasperReports Server REST API. When the user is identified in the developed module, it starts a JasperReport Server REST service, which retrieves from JasperReports Server and returns a list of all the dashboards with their corresponding parameters accessible to the stakeholder group to which the user belongs. The module allows the user to select which of the developed dashboards to display and selects parameter values for the start and end date of the period, based on which the indicator values will be calculated and the dashboard items populated. The module populates the value of the additional parameter for Group 1 users without user intervention, thus eliminating the possibility of generating a dashboard displaying data for registered users and courses from another faculty. The data filled in by the user is validated, after which the module creates a client instance with the specified parameter values, format (HTML, PDF, DOC, etc.), and dashboard address (Fig. 2). The module starts a REST service on the JasperServer to populate the dashboard according to the submitted parameter values. The web service interface responds to the HTTP request from the module, the JasperReport Server contacts the data source, retrieves the data needed to populate the items in the dashboard, populates the items in the dashboard with actual data (obtained from the database or by computation), and returns a populated dashboard as a response to the request made by the module. The module visualizes the dashboard, and if the user wishes (if another format is selected), the module starts a REST service to generate a document with the completed dashboard in PDF or XLS format.

```
public function getReports($parameters, $formats, $report_url) {

    $report = new Report( array(
            'format' => $format,
            'report_url' => $report_url,
            'parameters' => $parameters
        )
    );

    $request = $report->makeRequest();
```

Fig. 2. Fragment of code for parameter submission and selected report download format

The developed module can be integrated easily into software tools written in PHP. For this purpose, the tool in which it will be integrated must support the specified user roles (Group 1, Group 2, Group 3).

The module can be implemented in any HEI. For this purpose, the following steps need to be fulfilled:

- Step 1. The queries in the designed dashboards are to be modified to retrieve data from the used LMS.
- Step 2. Deploy the designed dashboards in the repository of the installed JasperReport Server.
- Step 3. To update the connection address of the developed module with JasperReport Server.
- Step 4. To be set from where the faculty parameter value will be passed.

## 3. Results and discussion

The developed module has been tested in Plovdiv University "Paisii Hilendarski". The module has been integrated successfully into the University's electronic portal (PU e-portal), which offers administrative services to students, teachers, and administrative staff. The portal allows students to check grades and up-to-date information on health insurance status, pay semester fees, and apply for scholarships and dormitories. Teachers can complete individual plans and material books, generate exam reports and student lists, etc., and administrative staff can access a module for student administration and the learning process. Each user can access the functionalities of the university e-portal according to their role (student, teacher, and administrative staff) and position (rector, dean, department director, head of department, etc.). Users' rights to use certain portal functionalities are set by an administrator and recorded in the portal database. Upon successful login to the portal, data about the allowed functionalities are stored for the user according to its rights, which allows appropriate access within the session (Fig. 3).

The integrated module will allow the University Management, Faculty Management, and Quality Assurance staff to track the values of the model indicators for a selected time interval in visualized dashboards and export the visualized dashboards in PDF and XLS format. Only users who hold the relevant positions have access to this functionality.

```
// Check for rights
$keyPerm = $_SESSION['user'][$contoller][$pages];

switch ($method) {
    case 'view':
        if (!empty($pages)) {
            $hasPermissions = 1;
        }
        break;
    default:
        $hasPermissions = 0;
        break;
}
```

Fig. 3. Checking user rights to access a page

The developed dashboards were modified (Fig. 4) to retrieve data from the database of one of the LMSs used at the university, Moodle, located at **http://e-learning.uni-plovdiv.bg** (Step 1). This LMS hosts e-Learning courses for students and PhD students (such as compulsory curriculum courses and additional courses offered by the Centre for Young Scientists and PhD students), developed to support traditional face-to-face learning and courses to enhance faculty competencies in organizing and delivering e-Learning. Additional fields have been added in the LMS to store detailed information about students, PhD students, and teachers needed for calculating indicator values.

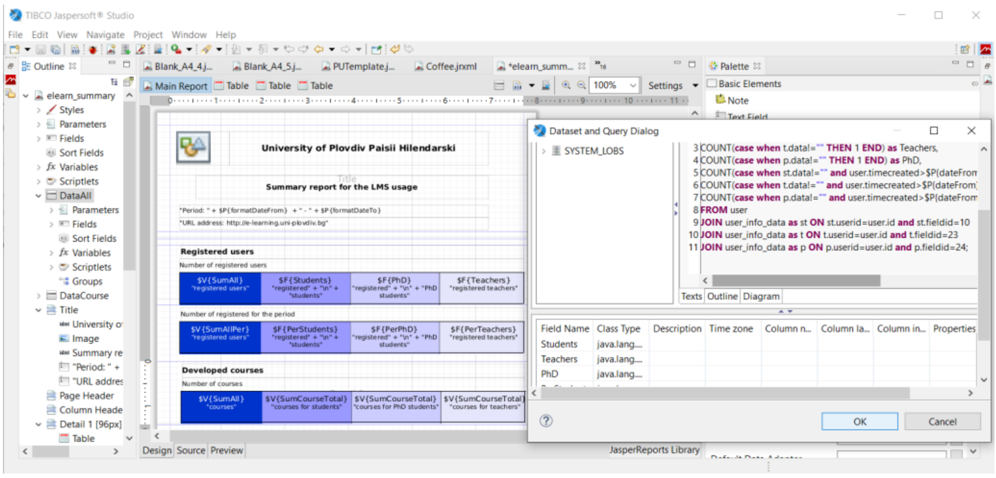


Fig. 4. Dashboard design

Dashboard elements are populated with data extracted from the relational database of the e-Learning environment. Each table in the database can be viewed as a set, and the entire database as a collection of sets. Retrieving data to populate the tableau elements requires performing operations on these sets, such as joins, unions, and intersections, derived from set theory. So, for example, the user table is a set that stores data about registered users, denoted with U, the user_info_field table is a set storing data about additional user profile fields, denoted with UF, and the table user_info_data is a set with the stored field values, denoted with UD.

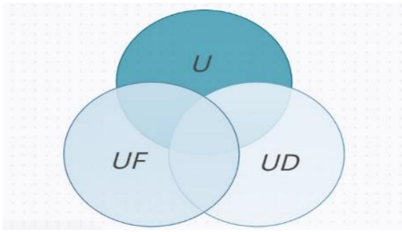

Fig. 5. Venn ddiagram

By applying the relational algebra of set theory, especially the JOIN operation that combines rows from the three tables based on related columns between them, we retrieved the data for the registered users (students, teachers, PhD students). For example, to retrieve the number of registered students, we look for intersections of the U, UD, and UF sets, containing all registered users with entered values for the additional field for the study program. This intersection forms the set of Students *S*. Similarly, the sets of Teachers (T) and PhD students (D) are obtained. The total number of users is calculated via an expression that counts the number of elements in the union of the three sets – $|S| \cap |T| \cap |D|$. When constructing part of the requests, predicate logic was also used, including expressions that are evaluated as true/false and filter the arrays of data according to given criteria, and new predicates were built by combining existing predicates using logical connections known as conjunctions (logical AND), disjunction (logical OR), negation (logical NOT). Calculating the values of part of the elements requires performing calculations and manipulating data through expressions that combine various SQL operators, functions, and values. Aggregate functions to evaluate and group values to generate a summary, such as sum or sum of values in a given column, are used in all requests. Fig. 6 presents an example of a query using set unions, predicate logic, and aggregation functions that retrieves the total number of trained students by study program and the number of trained students for the period.

```
SELECT uid1.data, uid2.data, uid3.data, course.fullname, COUNT(us.id) as totalstudents,
COUNT(CASE WHEN s.timemodified>1276193702 AND s.timemodified<1686420902 THEN 1
END) as periodstudents
FROM course
JOIN context ON context.instanceid = course.id AND contextlevel=50
LEFT JOIN role_assignments as s ON s.contextid = context.id AND s.roleid=5
JOIN user as us ON us.id=s.userid
JOIN user_info_data as uid1 ON uid1.userid=us.id AND uid1.fieldid=9
JOIN user_info_data as uid2 ON uid2.userid=us.id AND uid2.fieldid=11
JOIN user_info_data as uid3 ON uid3.userid=us.id AND uid3.fieldid=10
WHERE course.category NOT IN (69, 70, 72, 73, 74, 75) and uid1.data!= ""
GROUP BY uid1.data, uid2.data, uid3.data
```

Fig. 6. SQL query for trained students

The dashboards are located in the JasperReport Server installed for the university's needs (Step 2), and the address of the JasperReport Server with which the module will be integrated has been updated in the module (Step 3). In the last step of the integration, the module code was modified to allow the value of the faculty parameter to be retrieved from the e-portal database (the value of the field that stores the faculty in which the logged-in dean works). Fig. 7 presents the architecture of the developed module.

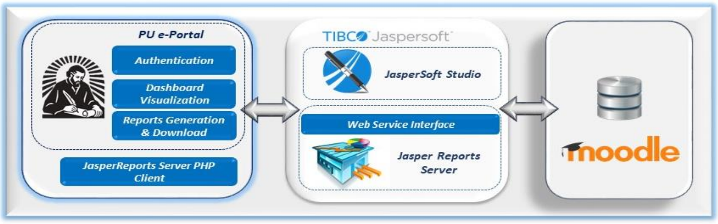


Fig. 7. Integration of the module into a university information portal

The unit responsible for the assessment and quality assurance of e-Courses has tested the developed module. During the experiment, members of the unit visualized dashboards for different time intervals, generated documents based on the visualized dashboards, and assessed the effectiveness of the proposed solution for gaining high-level insights into the use of the LMS.

Fig. 8 presents a generated dashboard view summarizing registered users, developed and updated training courses, and trained users for the period 1.1.2019-1.1.2024. The summary data shows that of the total 11045 students registered, 4146 (37-54%) were registered during the selected period. The number of teachers registered during the period is 14 (12.84%). It should be noted that most PhD students (94.29%) were registered in the last five years. This fact is mainly because, during this period, courses for the needs of the University Centre for Work with Young Scientists and PhD Students and training of PhD students at the Faculty of Physics and Technology were developed. At the time of report generation, 466 e-Courses have been developed in the LMS, of which 57 (12.23%) have been developed and 161 (34.55%) have been updated in the last five years. Using the LMS, 21202 students, 28 PhD students, and 397 teachers have been trained, with a large majority of students and PhD students trained in the last five years – 8900 students (41.98%) and 25 (89.29%). These data show that the teachers are interested in using blended learning courses and regularly update the developed courses.

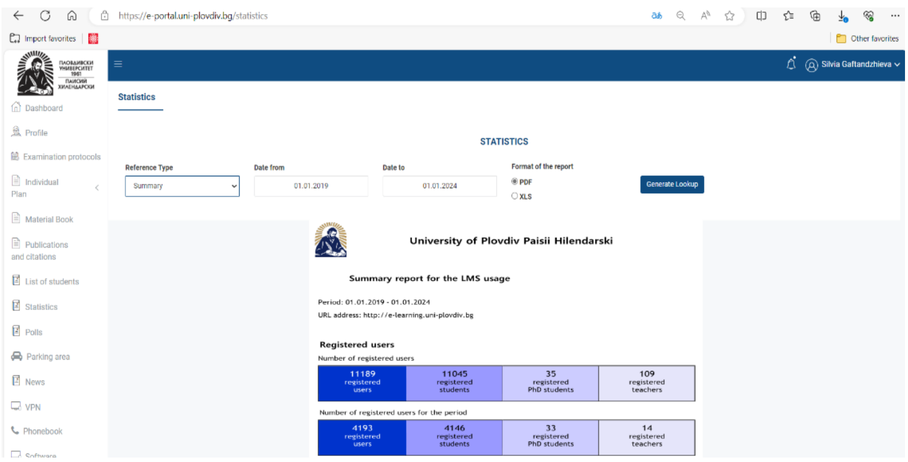


Fig. 8. Summary report for the LMS usage

Fig. 9 presents excerpts from a generated dashboard of registered users for the period, which presents summary data for registered teachers. The data shows that a large part of teachers registered between 2012 and 2014 ran pilot courses that they did not continue to use in their teaching practice. The highest percentage of active teachers was in the Faculty of Physics and Technology (64.29%) and the lowest in the Faculty of Education (11.11%). These results indicate the need to take measures to increase the interest of faculty staff members in the e-learning environment. Such measures can be organizing seminars and information meetings to introduce the new features of the LMS.

**Detail data for registered teachers**

| Faculty | Registered teachers (total) | Registered teachers (for period) | Active teachers (for period) |
|---|---|---|---|
| Faculty of Mathematics and Informatics | 28 | 6 | 6 |
| Faculty of Physics and Technology | 14 | 0 | 8 |
| Faculty of Pedagogy | 18 | 0 | 2 |
| Faculty of Biology | 7 | 1 | 2 |
| Faculty of Philology | 9 | 1 | 2 |
| Faculty of History and Philosophy | 9 | 3 | 5 |
| Faculty of Economics and Social Sciences | 8 | 0 | 2 |

Page 10 of 11

| Faculty | Registered teachers (total) | Registered teachers (for period) | Active teachers (for period) |
|---|---|---|---|
| Faculty of Chemistry | 7 | 1 | 2 |
| Technical college - Smolyan | 3 | 0 | 0 |
| Branch Smolyan | 4 | 0 | 1 |
| Faculty of Law | 2 | 2 | 1 |
| Total: | **109** | **14** | **31** |

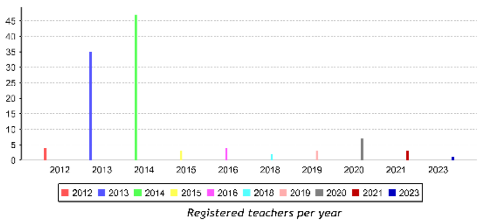


Fig. 9. Extract from a generated report with detailed information about registered users

Fig. 10 presents excerpts from a generated dashboard view of courses developed and updated during the period 1.1.2019-1.1.2024 by teachers in the Faculty of Economic and Social Sciences and the Faculty of Mathematics and Informatics. Summary data shows that although in some study programs, such as Mathematics, Informatics and Information Technology, and Applied Mathematics, a large part of courses were updated during the period (75.00%), in other study programs – no courses were updated. This fact indicates a need for more detailed research to show whether the reasons for this are a lack of need to change the course due to its current relevance or additional training to familiarise teachers with the possibilities of organizing learning in Moodle.

| Faculty | Study programme | Degree | Number of courses | Developed courses (in the period) | Updated courses (in the period) |
|---|---|---|---|---|---|
| Faculty of Economics and Social Sciences | Business Administration | Bachelor | 1 | 0 | 0 |
| Faculty of Economics and Social Sciences | Business Administration and Tourism | Bachelor | 1 | 0 | 0 |
| Faculty of Economics and Social Sciences | Finance | Bachelor | 4 | 0 | 1 |
| Faculty of Economics and Social Sciences | Business Administration | Master | 1 | 0 | 0 |
| Faculty of Economics and Social Sciences | International commerce | Master | 1 | 0 | 0 |
| Faculty of Economics and Social Sciences | Accounting and analysis | Master | 1 | 0 | 0 |
| Faculty of Economics and Social Sciences | Financial Management | Master | 1 | 0 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| Faculty of Mathematics and Informatics | Business Information Technology | Bachelor | 30 | 6 | 15 |
| Faculty of Mathematics and Informatics | Business Mathematics | Bachelor | 7 | 0 | 1 |
| Faculty of Mathematics and Informatics | Informatics | Bachelor | 31 | 2 | 14 |
| Faculty of Mathematics and Informatics | Informational technology, Mathematics and Educational Management | Bachelor | 6 | 0 | 3 |
| Faculty of Mathematics and Informatics | Mathematics | Bachelor | 15 | 1 | 7 |
| Faculty of Mathematics and Informatics | Mathematics and Informatics | Bachelor | 5 | 0 | 3 |
| Faculty of Mathematics and Informatics | Mathematics, Informatics and Information Technology | Bachelor | 4 | 0 | 3 |
| Faculty of Mathematics and Informatics | Applied Mathematics | Bachelor | 4 | 0 | 3 |

Fig. 10. Excerpt from a generated report with detailed information on developed and updated courses

Fig. 11 shows excerpts from a generated dashboard view of trained students, PhD students, and teachers in the 1.1.2019-1.1.2024 period. For each course, the dashboard presents detailed data on which faculty, study program, and degree is intended, and data on the total number of students trained and students trained during the period. The data shows that there has been an increased interest in the LMS in 2020 due to the move to online learning. The number of trained students decreased in 2021 after the return to face-to-face training. This result indicates a need to take measures to increase the interest of teachers in using blended learning courses in addition to traditional learning forms.

Detailed data for trained students

| Faculty | Degree | Study programme | Course | Number of trained students | Number of trained students (in the period) |
|---|---|---|---|---|---|
| Faculty of Mathematics and Informatics | Bachelor | Informatics | Basics of Computer Science | 5857 | 2222 |
| Faculty of Physics and Technology | Bachelor | Information Physics and Communications | Object-oriented programming | 275 | 16 |
| Faculty of Pedagogy | Master | Information and communication technologies in preschool education and the primary stage of secondary school | Computer networks and communications | 123 | 0 |
| Faculty of Mathematics and Informatics | Bachelor | Business Information Technology | Introduction in Computer Science | 3317 | 563 |
| Faculty of Pedagogy | Master | Educational Management | Organizational Management in Education | 18 | 0 |
| Faculty of Physics and Technology | Bachelor | Engineering physics | Crystal Physics | 111 | 18 |
| Faculty of Physics and Technology | Bachelor | Medical Physics | Statistical Data Processing | 57 | 28 |

Page 1 of 16

| Faculty | Degree | Study programme | Course | Number of trained students | Number of trained students (in the period) |
|---|---|---|---|---|---|
| Faculty of Chemistry | Master | Training on Chemistry at School | Basics of Chemistry - Organic Chemistry | 46 | 46 |
| Faculty of Chemistry | Master | Chromatographic and Spectral Analytical Control | Basics of Chemistry - Organic Chemistry | 1 | 1 |
| | | | Total: | 21266 | 8900 |

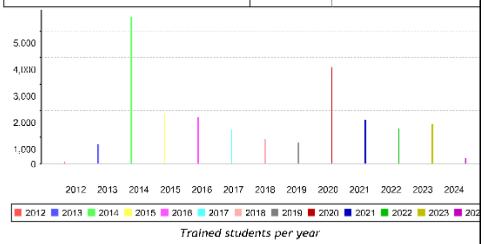


Fig. 11. Excerpt from a generated report with detailed information about trained users

## 5. Conclusion

The experiments proved that the developed module assists governing bodies in taking measures to increase teachers' interest in introducing blended learning and using the learning environment, which would be based not only on their management experience but also on the currently calculated values of key performance indicators.

The module presented in this paper is part of a suite of tools being developed to guide governing bodies in making informed decisions to enhance student success, career development, and research activity of academic staff, ensuring higher quality of teaching and service provision.

The current version of the module does not allow comprehensive tracking of the extent of usage of all LMSs in HEIs for the needs of all stakeholder groups. Its functionality could be extended to calculate the indicator values based on data extracted from all LMSs used in HEIs. To achieve this goal, the ways of forming the values of indicators from the model should be defined and appropriate dashboards developed. In the next step of the research, the tool functionality will be extended to meet the needs of other stakeholder groups (e.g., educators and LMS administrators). A possible extension in this direction is to provide teachers with the ability to track in detail student activity in the blended learning courses they use (number of visits to each resource, number of activity completions, number of participation in communication activities, etc.). Another extension will allow administrators to monitor system utilization (e.g., exact request time, bounce rate, daily activity, website presence time) and provide management with informed suggestions for new investments. These extensions will require analyzing the needs of new user groups, expanding the set of indicators, and designing and developing dashboards to track indicator values. Another possible extension is to integrate the developed module with the tool for monitoring student satisfaction in blended learning courses, created as part of a package of tools for quality assurance of education in HEIs [48].

The developed module can also be implemented in any HEI. For this purpose, HEI must edit the developed dashboard projects to extract data from the e-Learning environment used in the respective HEI.

***Acknowledgments*:** This paper is financed by the European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, Project No BG-RRP-2.004-0001-C01. The paper reflects only the author's view and the European Union is not responsible for any use that may be made of the information it contains.

## References

1. M u t h u r a m a n, S., R. V e e r a s a m y, T. C. N a b i l a. Blended Learning in Higher Education: A Critical Review. – The Online Journal of Distance Education and e-Learning, Vol. **8**, 2020, No 1, 18.
2. A g r e, G., D. D o c h e v, L. S l a v k o v a. Technology Enhanced Learning for Humanities by Active Learning − The SINUS Project Approach. – Cybernetics and Information Technologies, Vol. **12**, 2012, No 4, pp. 25-42.
3. B a s h i r, A., S. B a s h i r, K. R a n a, P. L a m b e r t, A. V e r n a l l i s. Post-COVID-19 Adaptations, the Shifts towards Online Learning, Hybrid Course Delivery, and the Implications for Biosciences Courses in the Higher Education Setting. – Front. Educ., Vol. **6**, 2021, 711619.
4. W e e r a t h u n g a, P. R., W. H. M. S. S a m a r a t h u n g a, H. N. R a t h n a y a k e, S. B. A g a m p o d i, M. N u r u n n a b i, M. M. S. C. M a d h u n i m a s h a. The COVID-19 Pandemic and the Acceptance of e-Learning among University Students: The Role of Precipitating Events. – Education Sciences, Vol. **11**, 2021, No 11, 436.
5. Z e q i r i, J., V. K a r e v a, S. A l i j a. The Impact of Blended Learning on Students' Performance and Satisfaction in South East European University. – ENTRENOVA-ENTerprise REsearch InNOVAtion, Vol. **6**, 2020, No 1, pp. 233-244.
6. S h k o d r o v a, R., D. D o c h e v. Distance Learning through Mobile Devices – Some Problems and Applications. – Cybernetics and Information Technologies, Vol. **6**, 2006, No 2, pp. 54-62.
7. G r a h a m, C. R. Blended Learning Systems: Definition, Current Trends, and Future Directions. – In: C. J. Bonk and C. R. Graham, Eds. Handbook of Blended Learning: Global Perspectives, Local Designs, Publisher: Pfeiffer Publishing, 2006, pp. 3-21.
8. G r a h a m, C. R. Emerging Practice and Research in Blended Learning. – In: M. G. Moore, Ed. Handbook of Distance Education. 3rd Ed. New York, Routledge Publisher, 2013, pp. 333-350.
9. H u a n g, Q. Learners' Perceptions of Blended Learning and the Roles and Interaction of f2f and Online Learning. – ORTESOL Journal, Vol. **33**, 2016, pp. 14-33.
10. H e i r d s f i e l d, A., S. W a l k e r, M. T a m b y a h, D. B e u t e l. Blackboard as an Online Learning Environment: What do Teacher Education Students and Staff Think? – Australian Journal of Teacher Education, Vol. **37**, 2011, No 7, Article 1. **https://doi.org/10.14221/ajte.2011v36n7.4**

11. D i e p, A. N., C. Z h u, K. S t r u y v e n, Y. B l i e c k. Who or What Contributes to Student Satisfaction in Different Blended Learning Modalities? – British Journal of Educational Technology, Vol. **48,** 2017, No 2, pp. 473-489.
12. Z e q i r i, J., V. K a r e v a, S. A l i j a. Blended Learning and Student Satisfaction: The Moderating Effect of Student Performance. Business Systems Research. – International Journal of the Society for Advancing Innovation and Research in Economics, Vol. **12**, 2021, No 2, pp. 79-94.
13. B a n s a l, P. Blended Learning in Indian Higher Education: Challenges and Strategies. – International Journal of Applied Research and Studies, Vol. **3**, 2014, No 2, pp. 1-13.
14. B a t i s t a-T o l e d o, S., D. G a v i l a n. Student Experience, Satisfaction and Commitment in Blended Learning: A Structural Equation Modeling Approach. – Mathematics, Vol. **11**, 2023, No 3, 749.
15. A b o u N a a j, M., M. N a c h o u k i, A. A n k i t. Evaluating Student Satisfaction with Blended Learning in a Gender-Segregated Environment. – Journal of Information Technology Education: Research, Vol. **11**, 2012, No 1, pp. 185-200.
16. G o n c h a r o v, V. V., D. I. S t e p a n o v a, D. V. K o v a l e v, T. A. K o v a l e v a, A. R. B a t y r s h i n a. Blended Learning Perspectives for Students (University Experience under Constraints due to the COVID-19 Pandemic). – Rev. Incl., Vol. **7**, 2020, pp. 288-300.
17. S i r i p o n g d e e, K., P. P i m d e e, S. T u n t i w o n g w a n i c h. A Blended Learning Model with IoT-Based Technology: Effectively Used when the COVID-19 Pandemic? – J. Educ. Gift. Young Sci., Vol. **8**, 2020, pp. 905-917.
18. P r i f t i, R. Self-Efficacy and Student Satisfaction in the Context of Blended Learning Courses. – Open Learning: The Journal of Open, Distance and e-Learning, Vol. **37**, 2022, No 2, pp. 111-125.
19. B r o a d b e n t, J. Comparing Online and Blended Learner's Self-Regulated Learning Strategies and Academic Performance. – The Internet and Higher Education, Vol. **33**, 2017, pp. 24-32. **https://doi.org/10.1016/j. Leduc.2017.01.004**
20. C h a i y a m a, N. The Development of a Blended Learning Management Model in Developing Information Literacy Skills (BL-ILS Model). – International Journal of Information and Education Technology, Vol. **5**, 2014, No 7, pp. 483-489. **https://doi.org/10.7763/ijiet.2015.v5.554**
21. O k a z, A. A. Integrating Blended Learning in Higher Education. – In: Procedia – Social and Behavioral Sciences, Vol. **186**, 2015, pp. 600-603. **https://doi.org/10.1016/j.sbspro.2015.04.086**
22. Z e i n, A. E., N. H i l a l, B. J i b a i, L. A t t i e h. Factors Influencing Students' Satisfaction in Online Learning Amid the Challenging COVID-19 Pandemic: A Case Study for Lebanese Educational Sector. – Resmilitaris, Vol. **13**, 2023, No 1, pp. 2923-2934.
23. A l-K a h t a n i, N., A. A l m u r a y h, A. V. S u b b a r a y a l u, T. S e b a s t i a n, H. A l k a h t a n i, D. A l j a b r i. Sustaining Blended and Online Learning during Normal and New Normal Conditions in a Saudi Higher Education Institution: Health Science Students' Perspectives. – Heliyon, Vol. **8**, 2022, No 10, e10898.
24. S h e, L., L. M a, A. J a n, N. H. S h a r i f, P. R a h m a t p o u r. Online Learning Satisfaction during COVID-19 Pandemic among Chinese University Students: The Serial Mediation Model. – Frontiers in Psychology, Vol. **12**, 2021, 743936.
25. A d e d o y i n, O. B., E. S o y k a n. Covid-19 Pandemic and Online Learning: The Challenges and Opportunities. – Interact. Learn. Environ. 2020, pp. 1-13. DOI: 10.1080/10494820.2020.1813180.
26. S e l v a n a t h a n, M., N. A. M. H u s s i n, N. A. N. A z a z i. Students' Learning Experiences during COVID-19: Work from Home Period in Malaysian Higher Learning Institutions. – Teaching Public Administration, Vol. **41**, 2020, No 1, 0144739420977900. DOI: 10.1177/0144739420977900.
27. L i, L. Students' Academic Achievement and Satisfaction in a Blended Learning Community of College English in China: A Quasi-Experimental Study. – SAGE Open, Vol. **12**, 2022, No 3, 21582440221119485.

28. G i a n n o u s i, M., N. V e r n a d a k i s, V. D e r r i, M. M i c h a l o p o u l o s, E. K i o u m o u r t z o g l o u. Students' Satisfaction from Blended Learning Instruction. – In: Tcc. TCCHawaii, 2009, pp. 61-68.
29. W u, J., W. L i u. An Empirical Investigation of the Critical Factors Affecting Students' Satisfaction in EFL Blended Learning. – Journal of Language Teaching and Research, Vol. **4**, 2013, No 1, 176.
30. N a j a f i, H., M. H e i d a r i. Blended Learning and Academic Achievement: A Meta-Analysis. – Q. J. Iran. Dist. Educ., Vol. **2019**, No 3, pp. 39-48.
31. G r ø n l i e n, H. K., T. E. C h r i s t o f f e r s e n, M. R i n g s t a d A n d r e a s s e n, R. G. L u g o. A Blended Learning Teaching Strategy Strengthens the Nursing Students' Performance and Self-Reported Learning Outcome Achievement in an Anatomy, Physiology, and Biochemistry Course – A Quasi-Experimental Study. – Nurse Education in Practice, Vol. **52**, 2021, 103046. **https://doi.org/10.1016/j.nepr.2021.103046**
32. Z h a n g, X., Z. P i, C. L i, W. H u. Intrinsic Motivation Enhances Online Group Creativity via Promoting Members' Effort, Not Interaction. – British Journal of Educational Technology, Vol. **52**, 2021, No 2, pp. 606-618. **https://doi.org/10.1111/bjet.13045**
33. N g o, J., A N g a d i m a n. Investigating Student Satisfaction in Remote Online Learning Settings During COVID-19 in Indonesia. – Journal of International and Comparative Education (JICE), 2021, pp. 73-95.
34. S h a n t a k u m a r i, N., P. S a j i t h. Blended Learning: The Student Viewpoint. – Annals of Medical and Health Sciences Research, Vol. **5**, 2015, No 5, pp. 323-328.
35. S t e i n, J., C. R. G r a h a m. Essentials for Blended Learning: A Standards-Based Guide. – Routledge, 2014.
36. A b b a s, Z. I. Blended Learning and Student Satisfaction: An Investigation into an EAP Writing Course. – Advances in Language and Literary Studies, Vol. **9**, 2018, No 1, pp. 102-105.
37. B u c k, E., K. T y r r e l l. Block and Blend: A Mixed Method Investigation into the Impact of a Pilot Block Teaching and Blended Learning Approach Upon Student Outcomes and Experience. – Journal of Furth. High. Educ., Vol. **46**, 2022, pp. 1078-1091.
38. D i e n, T., N. H a i, N. T h a i n g h e. Novel Approaches for Searching and Recommending Learning Resources. – Cybernetics and Information Technologies, Vol. **23**, 2023, No 2, pp. 151-169.
39. F a d d e, P. J., P. H. V u. Blended Online Learning: Benefits, Challenges, and Misconceptions. – In: P. R. Lowenthal, C. S. York, J. C. Richardson, Eds. Online Learning: Common Misconceptions, Benefits, and Challenges. Hauppauge, Nova Science Publishing, 2014, pp. 38-48.
40. R o m e r o-F r í a s, E., J. L. A r q u e r o. A View on Personal Learning Environments through Approaches to Learning. – The International Journal for Innovation and Quality in Learning, Vol. **1**, 2013, No 1, pp. 29-36.
41. T a g h i z a d e h, M., F. H a j h o s s e i n i. Investigating a Blended Learning Environment: Contribution of Attitude, Interaction, and Quality of Teaching to Satisfaction of Graduate Students of TEFL. – The Asia-Pacific Education Researcher, Vol. **30**, 2021, No 5, pp. 459-469. **https://doi.org/10.1007/s40299-020-00531-z**
42. M o z e l i u s, P., E. H e t t i a r a c h c h i. Critical Factors for Implementing Blended Learning in Higher Education. – International Journal of Information and Communication Technologies in Education, Vol. **6**, 2017, No 2, pp. 37-51.
43. N i k o u, S., I. M a s l o v. Finnish University Students' Satisfaction with e-Learning Outcomes During the COVID-19 Pandemic. – International Journal of Educational Management, Vol. **37**, 2023, No 1, pp. 1-21.
44. L u b i s, M., M. A. H a s i b u a n, R. A n d r e s w a r i. Satisfaction Measurement in the Blended Learning System of the University: The Literacy Mediated-Discourses (LM-D) Framework. – Sustainability, Vol. **14**, 2022, No 19, 12929.
45. H a b r u s i e v, V., H. T e r e s h c h u k, I. T s i d y l o, S. M a r t y n i u k, O. K u l y a n d a. Monitoring the Quality of e-Learning Implementation in Educational Institutions, 2021.

46. T a' a, A., M. B a k a r, S. C h i t, M. S o i d. Business Intelligence Model for Monitoring Blended Learning Usage. – Journal of Telecommunication, Electronic and Computer Engineering (JTEC), Vol. **9**, 2017, No 3-5, pp. 27-30.
47. M e r s h a d, K., B. S a i d. DIAMOND: A Tool for Monitoring the Participation of Students in Online Lectures. – Education and Information Technologies, Vol. **27**, 2022, No 4, pp. 4955-4985.
48. G a f t a n d z h i e v a, S., R. D o n e v a, M. B l i z n a k o v. A Comprehensive Approach for Monitoring Student Satisfaction in Blended Learning Courses. – Cybernetics and Information Technologies, Vol. **23**, 2023, No 4, pp. 181-198.

*Received: 06.03.2024; Second Version: 01.04.2024; Accepted: 12.04.2024 (fast track)*