# LEARNING ANALYTICS SOFTWARE TOOL SUPPORTING DECISION MAKING IN HIGHER EDUCATION

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**Abstract:** Learning Analytics (LA) and tools for intelligent analysis of data accumulated in the information systems used in higher education institutions (HEIs) provide an opportunity to increase the effectiveness of monitoring, management, quality assurance and evaluation of training delivered to all management groups which make decisions in higher education institutions - programme managers, faculty and university managers. The paper presents LA models and a correspondent software tool designed for the needs of decision making bodies in Bulgarian HEI (programme managers, deans and rector). The tool allows them to monitor the learning process and make timely data-driven decisions to improve institutional processes in many aspects. Research and experiments with the models and the LA tool under consideration are conducted on the basis of the information infrastructure of a typical Bulgarian university – University of Plovdiv “Paisii Hilendarski”.

**Key words:** Learning Analytics, Intelligent Data Analysis, Decision Making, Decision Support System, Higher Education

## 1. INTRODUCTION

Learning Analytics (LA) and tools for intelligent analysis of data accumulated in the information systems used in higher education institutions provide an opportunity to increase the effectiveness of monitoring, management, quality assurance and evaluation of training delivered to all management groups which make decisions in higher education institutions - programme managers, faculty and university managers.

LA tools are a possible way to ensure quality and improved efficiency, which is crucial for many HEIs [1]. Using such tools, academic managers can collect evidence to support informed decision-making (data-based) at each level in the HEI [2, 3, 4,

5, 6]. These tools deepen HEIs' awareness of the students' success rate [7] and allows them to track trends in training in programmes and courses. The governing bodies have access to aggregate data on student training in all courses [8], which can be analysed to improve the quality of education and students' support. These data allow academic managers to monitor students' progress [4, 5] and to identify students who fail to achieve satisfactory results during their training and have the risk to drop out [4, 9, 10, 11, 12, 23]. In this way, academic managers can identify the reasons for low grades and take measures to solve problems as soon as possible in order to help students complete their training successfully and reduce the drop-out rate [2, 9, 10, 11, 12, 13, 14]. The results of the annual analysis allow academic managers to determine whether the measures taken to retain students are effective and sustainable [15]. In this way, such tools bring financial benefits to HEIs and help HEIs to enhance their image and student satisfaction [16].

Software tools facilitate academic managers to find hidden patterns in educational information. In this regard, some universities [6, 17] integrate LA techniques with their decision support systems to help managers in developing decision-making process and collaterally improve student performance. The access to a summary of data for students' achievements and LA tools allows academic managers to compare students' average grades at the end of each academic year. The results enable academic managers to stimulate students to achieve higher results [9], to predict and improve their completion rate [9, 18]. LA tools help managers of HEIs identify courses and programmes that more closely match the students' needs and preferences [18] and manage the enrolment of new students [19]. By studying trends in enrolling students and their interests in different courses, managers can target resources [19] to programmes that are of the greatest interest to students. The use of these tools can be useful when academic managers evaluate higher education at university level. These tools help them to evaluate teachers' work, incl. assessment methods and feedback [9] and if it is necessary to take measures to improve the quality of the training and updating of the curricula [4]. Such tools can be used to improve the teaching staff selection, cost reduction, efficiency improvement, and achievement of the HEI's strategic goals [14].

Some of tools are standalone software tools, while others are modules or features included in LMS. In the basis of each LA tool is a model with a set of indicators, the data of which is extracted from the LMS used at the university. According to Kapros and Pierce [20], because each LMS has its bespoke reporting solution, these dashboard display might be unsuitable for academic managers, especially when they want to monitor the situation across various LMSs. Therefore, the study presented here is aimed at using LA techniques to analyse data from all data-sources related to training (different LMSs and information systems used by university teachers and students) to meet the needs of university decision making bodies from all levels.

The paper presents LA models and a correspondent software tool designed for the needs of decision making bodies in Bulgarian HEI (programme managers, deans

and rector). The tool allows them to monitor the learning process and make timely data-driven decisions to improve institutional processes in many aspects. Research and experiments with the models and the LA tool under consideration are conducted on the basis of the information infrastructure of a typical Bulgarian university – University of Plovdiv "Paisii Hilendarski".

## 2. LA MODELS WITH A SET OF INDICATORS

On the basis of a literature review in the field and an investigation of quality requirements in higher education are proposed 3 models with a set of indicators that serve as a business logic basis of the developed LA tool (see Section 3). Those models define what type of data should be collected from the institutional information infrastructure that decision making bodies of the institution will be able to use for continuous improvement and for ensuring more student-focussed provision of higher education. The three models are developed correspondingly for the needs of three different levels of the university decision making bodies – programme managers (PM), deans (D) and rector (R) – called bellow stakeholder groups. Each model consists of measurable indicators allowing the relevant stakeholder to track data for students' learning or training for different purposes, e.g. monitoring, analysis, forecast, intervention, recommendations, etc., but finally to improve the learning and teaching processes.

Models are built as hierarchies of indicators of different levels. Indicators from Level 1 indicators represent the activity/subject to which the collected and aggregated data relate – students' activity, teachers' activity, scheduling, students' success rate, quality of learning. These indicators group together a set of Level 2 indicators that allow the relevant stakeholder to track data in specific activities of that type. Each Level 2 indicator contains a set of measurable attributes whose values are extracting from the university information systems and LMS. Table 1 presents in general the proposed models and their indicators of Level 1 and Level 2 for each stakeholder group. Indicators of Level 2 that are part of the model for the relevant stakeholders are marked with "+".

## 3. LA TOOL DESCRIPTION

Based on the developed models, a corresponding standalone software system, called **L**earning **A**nalytics **T**ool for **ch**ief decision making bodies (LATch), i.e. university policymakers and institutional leaders, was designed and implemented.

As a result of an analytical review of software solutions for extracting, analysing and visualizing data from various information sources, technologies and tools for software development were selected. The LATch tool is developed by the integration of existing software solutions, namely *JasperReport Server* and *JasperSoft Studio* tools (developed by TIBCO JasperSoft and used in the university information infrastructure) and the software framework *Dynamic Presentation Framework* (developed by a team working at the University of Plovdiv).

*Table 1. Models for learning analytics from different stakeholders' perspective*

| Indicator – Level 1 | Indicator – Level 2 | PM | D | R |
|---|---|---|---|---|
| *1. Student activity during the training* | 1.1. Learning activities for communication and collaboration | + | | |
| | 1.2. Learning activities for assessment | + | | |
| | 1.3. Learning resources | + | | |
| | 1.4. Activity trends in courses | + | + | |
| *2. Teachers activity* | 2.1. Learning activities form communication | + | | |
| *3. Control of scheduling* | 3.1. Access to learning materials | + | | |
| | 3.2. Completion of learning activities | + | | |
| | 3.3. Student progress | + | | |
| | 3.4. Timely feedback and assessments | + | | |
| *4.Student success rate* | 4.1. Trends in assessment in course | + | + | |
| | 4.2. Students at risk | + | + | |
| | 4.3. Trends in student success rate | + | + | + |
| | 4.4. Expected learning outcomes | + | + | |
| | 4.5. Success rate in programme | + | + | |
| | 4.6. Interest in programme | | + | + |
| | 4.7. Graduation rate and percentage of graduate students | | + | + |
| | 4.8. Trends in student success rate in a faculty | | + | + |
| | 4.9. Trends in student success rate in a professional field | | | + |
| | 4.10. Percentage of drop out students | | + | + |
| *5. Quality of learning* | 5.1. Quality of learning materials | + | + | |
| | 5.2. Correspondence of the courses with students' needs and preferences | + | | |
| | 5.3. Variety of learning activities and resources | + | | |
| | 5.4. Workload in learning activities and resources (students) | + | | |
| | 5.5. Workload in learning activities and resources (teachers) | + | | |

The *JasperSoft Studio* provides a rich set of instruments for design of report templates which can be filled out with data retrieved from a variety of data sources (relational databases, big data sources, or other types of database systems). Along with JasperReport Server it can be used to create powerful report publishing workflows. *JasperReport Server* provides opportunities for organizing structured repositories, accessing data collections with a different type of organization (incl. custom - DB, XML, CSV, Hibernate, POJO) and using them as data sources for the needs of *JasperSoft Studio* when generating reports, storing reports and presenting them in the preferred by the user form. The server also offers powerful tools for integration with various software applications through shared web services.

*Dynamic Presentation Framework* (DPF) is a software framework for visualising dynamic user-driven views of digital objects in a web browser. DPF also allows connection to external sources through web services.

**The architecture of the LATch tool** (see Fig. 1) follows the standard type of 3-tier architecture with well-known three layers - Presentation, Application and Data layers.

In the basis of the *LATch Presentation Layer* is the software framework DPF, through which the user can request the generation of a report by a chosen template and view the result of the request (visualized report). There are currently three separate user roles: programme managers (PM), deans (D) and rector (R). DPF (using XML Parser and Style Control Module functionalities) allows users through predefined conditions to modify some view attributes such as color, font size, etc., to visualise the report in the web browser in a user-friendly way.

By the report templates design tool JasperSoft Studio is implemented the core functionality of the *Application Layer* of LATch and its business logic.

Key elements of this functionality are modelling of the three developed models for the needs of three different stakeholder groups (see Section 2) and acquisition of values for the models' indicators of different levels from digital footprints left by students and/or teachers during training in each course and/or by inspectors (responsible for programme training) in LMS, student information systems and/or other systems of HEI information infrastructure.

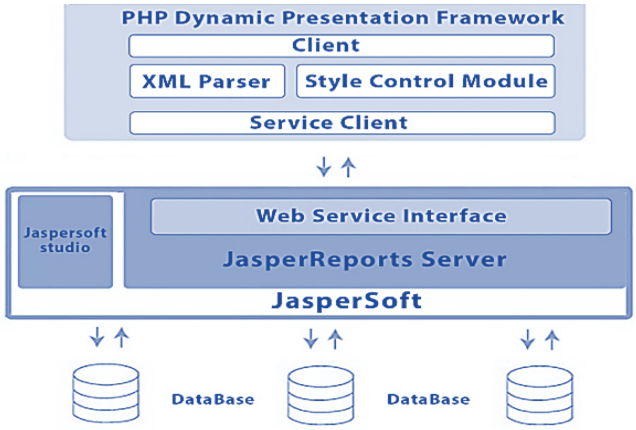



*Figure 1. LATch architecture*

Therefore, in the first stage, the institutional information infrastructure (including university digital repository, databases of university information systems, learning management systems Moodle, performance support system DIPSEIL [21] etc.) of a typical Bulgarian university (namely the University of Plovdiv "Paisii Hilendarski") has been analysed. The analysis has been done in terms of its use as a data source (about the training, the results achieved, etc.) when forming values of the indicators from the proposed models.

In the second stage, templates of reports were designed using JasperSoft Studio based on the proposed models as sets of indicators (see Table 1) for the needs of different stakeholders (programme managers, deans and rector) when making decisions for the management of the university processes. All developed templates of reports have been stored on the JasperReport Server. JasperReport Server plays an intermediate role between the three architectural layers:

- DPF requests the REST services of JasperReports Server to run a chosen template and generate a report through the Service Client;
- The JasperReports Server Web Service interface responds to HTTP requests from the client application.

*Data Layer* of the LATch application includes various databases of the institutional information infrastructure (student information system, Moodle, etc.) as well as the JasperReports Server repository itself. JasperReport Server addresses them to retrieve the necessary data when generating reports.

**The benefits of LATch** help university leaders to take operational, management level, or middle level management decisions.

This is because even though different models (see Table 1) have the same first and second level indicators, they differ in the indicators from the lower levels and this is embedded in the designed report templates in LATch. For example, for the ***Indicator 4.3. Trends in student success rate*** the related data sources for acquisition of values of the indicators of Level 3 and the indicators/values themselves for each user role will be different (see Table 2).

*Table 2. Indicators of Level 3 according to user role for Indicator 4.3. Trends in student success rate*

| User role | Input data | Output Values |
|---|---|---|
| PM (Programme Manager) | Study Programme<br>Course | Learning course<br>Average grade of students in the course<br>Average grade of students from the previous year |
| D (Faculty Managers: Dean, Vice Deans) | Study Programme | Year<br>Average grade of students in the current year<br>Average grade of students from the previous year |
| R (University Managers: Rector/Vice-Rector) | Faculty | Study programme<br>Initial year of study<br>Average grade of students in the current year<br>Average grade of students in the previous year |

From there the generated reports for different stakeholder groups provide different data (retrieved from the information systems) depending on the user's role in LATch (PM, D and R as mentioned above).

LATch allows for each indicator of the proposed models that is included in the models for more than one stakeholder groups, to be generated reports with retrieved different values from the information systems depending on the user's role in LATch.

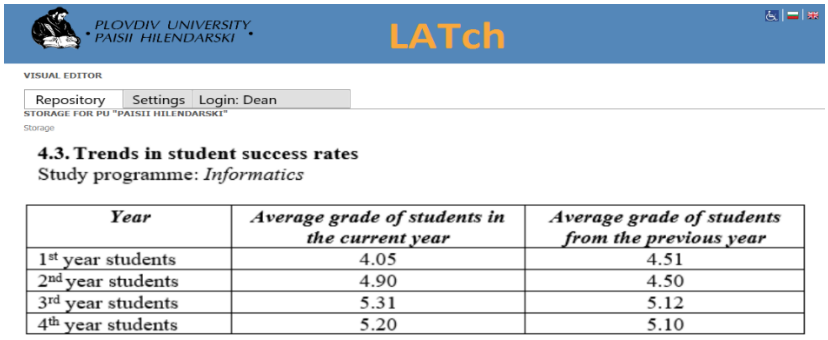
Generated reports contain tables and diagrams and allow users to perform various analysis on the retrieved data. For example, LATch allows programme managers to:

- track student activity in the learning activities for communication and collaboration (Indicator 1.1.) and in the learning activities for assessment (Indicator 1.2) during the training in each of the courses of the bachelor/master programme for which they are responsible;
- track the number of visits to the learning resources (Indicator 1.3) and e-courses (Indicator 1.4) during the training in each of the courses of the bachelor/master programme for which they are responsible;
- compare students' activities with students' activities during the previous year (Indicator 1.1, Indicator 1.2, Indicator 1.3, Indicator 1.4);
- track students' activity in all courses of the bachelor/master programme for which they are responsible (Indicator 1.4);
- compare the activities of the students in the courses of the bachelor/master programme for which they respond with the activities of the students in the previous years (Indicator 1.4);
- track teachers' activity in learning activities for communication added to each course of the bachelor/master programme for which they are responsible (Indicator 2.1);
- control of scheduling for studying learning materials (Indicator 3.1) and completion of learning activities (Indicator 3.2) for each course from the curriculum of the programme for which they are responsible and to take measures in case of delays in the schedule;
- track students' progress in learning activities (Indicator 3.3);
- track the feedback from the teacher (Indicator 3.4.);
- track student's grades in all courses of the programme and compare their results with those of other students on the course and students from previous years (Indicator 4.1);
- identify students who do not have satisfactory results at the earliest possible stage by comparing their results with the average results of students who have interrupted their studies and taking measures to provide support to students to complete successfully their training in the HEI (Indicator 4.2);
- monitor assessment trends in the courses and compare students' grades with grades of students during the previous year (Indicator 4.3) and take measures if the average grade of students in the current year is below the average grade of students during the previous year;
- predict and improve the student completion rate (Indicator 4.4);
- compare average grades of the student at the end of each academic year (Indicator 4.5);
- evaluate the quality of learning materials and training on the basis of the students' activity and their grades (Indicator 5.1);

- identify courses that more closely match students' needs and preferences on the basis of students' activity and achievements (Indicator 5.2);
- evaluate the variety of learning activities and resources in the courses (Indicator 5.3);
- monitor the workload of students (Indicator 5.4) and the teachers (Indicator 5.5).

LATch allows faculty (dean and vice-deans) and university managers (including rector, vice-rectors for quality of learning) to generate reports with summarized data for students' activity and results which allow them to track the learning outcomes of students and compare the results with those of students from previous years, identify programmes in which students do not have satisfactory results, monitor trends in students' success rates as compare average grades of students at the end of each academic year, track student grades in graduation, track the percentage of students who have dropped out of their training, etc. Generated reports for each indicator allow university managers from different levels to make informed decisions to improve the quality of training and the results achieved and determine whether the measures taken are effective and sustainable.

Figure 2 presents a generated report through the LATch tool for Indicator 4.3 by the Dean of faculty with input value *Informatics*. The report shows the statistically processed data - the average grades of students training in Informatics study programme for each year. Thus, e.g. if there is a significant decrease in the average student achievement during the year, the Dean can take timely measures to improve the quality of teaching and reduce the drop out of students.




| *Year* | *Average grade of students in the current year* | *Average grade of students from the previous year* |
|---|---|---|
| 1st year students | 4.05 | 4.51 |
| 2nd year students | 4.90 | 4.50 |
| 3rd year students | 5.31 | 5.12 |
| 4th year students | 5.20 | 5.10 |

*Figure 2. Generated report for Indicator 4.3.*

## 4. CONCLUSION

LATCH as a more LA projects [22] aims to move from small-scale research towards broader institutional implementation. For this purpose, LATch will be provided for real-time testing at the University of Plovdiv. The experiments will be carried out during the e-learning processes. On the basis of the results, users will take measures to improve the quality of training and students' achievements. Feedback

from the ongoing evaluation of the model and LATch tool by various stakeholder representatives will be taken into account in the development of the final version. The final version of LATch will be integrated into a single system, which will be the first for Bulgaria integrated system of intelligent analysis of education data, meeting the requirements and needs of all stakeholder groups as well as requirements for users' privacy and data protection [23, 24]. LATch tool can be adapted for the needs of each HEI, regardless of the type of the relevant university information systems and the diversity of the used LMS. For this purpose, it needs to identify LA purposes and map the context at the university.

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