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## AN APPROACH TO THE IMPLEMENTATION OF A COMPETENCY-BASED APPROACH IN THE LEARNING MANAGEMENT SYSTEM

*Andrii Kopp, Mykyta Parashchych, Herman Zviertsev, Yevhen Motalyhin, Anna Strelnikova*

*This paper solves the urgent problem of improving the tracking of the process of acquiring competencies by students through the means of analyzing the learning management system data and visualizing the results of the learning process. The object of the study is to track the process of acquiring competencies by students. The subject of the study includes software components for the implementation of a competency-based approach in the learning management system. The purpose of the study is to improve the tracking of the process of acquiring competencies by students by analyzing the data of the Learning Management System (LMS) and visualizing the results of the learning process. Thus, to achieve this goal, we analyzed the technologies for processing learning data from LMS, analyzed the features of modeling the learning process based on Petri nets and BPMN (Business Process Model and Notation), determined a data structure, and proposed an algorithm for building a model and visualizing the learning process data. The developed software components allow processing of learning process data from LMS, building models and visualizations of learning process data, saving the results to data warehouses, depicting the learning process model, and visualizing learning process data for further analytical processing.*

**Keywords:** *competency-based learning, educational process mining, learning management system, process modeling, data visualization.*

### INTRODUCTION

E-learning has become an increasingly popular approach to learning thanks to the rapid growth of web technologies. COVID-19 has forced countries to introduce online or hybrid learning to catch up with expected learning targets. However, many countries remain ineffective in the transition to online or hybrid education. In addition, while some countries are succeeding in improving student achievement (e.g., Italy increased student progress with online tutoring by 4.7% compared to traditional instruction), some others are not achieving the same results with online learning. Recently, however, education industry

leaders have begun to identify use cases for using process intelligence to improve online learning platforms, teaching methodology, and student learning habits [1].

The Internet and related web technologies offer excellent solutions for presenting, publishing, and sharing learning content and information. This is special software called a Learning Management System (LMS). Learning management systems such as Moodle are a popular tool in higher education. They allow teachers to present their courses virtually. In these virtual courses, they can provide learning objects such as lecture slides or videos, quizzes, or forums where students can interact with each other.

Many LMSs offer instructors descriptive statistics to evaluate their courses. However, these statistics usually only provide insight into individual learning objects, such as how often a quiz was accessed. But there is a lack of information and data on the acquisition of competencies within a particular course or a particular topic.

The result of human development is the acquisition of skills that represent the person and are important for employment. The personal ability of a specialist to solve a certain class of professional tasks, in other words, a set of knowledge and skills of a person is defined as competence. Today, more and more companies are choosing a competency-based approach and each vacancy has a specific list of competencies that must be possessed. Therefore, when choosing a particular course and material to take, there is a need to know which competence can be acquired in order to plan the path and trajectory of studying the materials.

The main goal of the study is improving the tracking of the process of acquiring competencies by students through the means of analyzing the learning management system data and visualizing the results of the learning process.

The study solves the following tasks: determining the advantages of Educational Process Mining (EPM); analysis of Petri nets and BPMN (Business Process Model and Notation) process models [2]; determining the features of using Petri nets and process models in EPM; determining the advantages and disadvantages of the competency-based approach in the learning management system; analyzing the advantages of microservice architecture in LMS; developing an algorithm and software components for building a model and analyzing learning process data in the learning management system.

## METHODS AND MATERIALS

The Internet and related web technologies offer excellent solutions for presenting, publishing, and sharing learning content and information, as they do in many other areas. Specialized software called a Learning Management System is commonly used in most institutions that provide online learning. Most universities combine modes of learning using one of a number of commercial or free LMS [2].

Educational Process Mining (EPM) is the practice of using tools to identify useful information in

educational data that comes from different sources and is stored in different formats. Today, with the growing use of Information and Communication Technologies (ICT) in education, online learning solutions that generate large amounts of data are becoming increasingly popular [1].

To conduct a study on improving the tracking of the process of acquiring competencies by learners by analyzing the data of the learning management system and visualizing the results of the learning process, it is proposed to use a sample of real anonymous data from a real company [4].

These data are obtained from various sources (such as the database of Human Resource department employees, activities and tests in the Moodle LMS within courses, course data, course evaluations, and recommendations) [4].

Each record of the original LMS dataset [4] can be described as follows:

*Trace = tags, types, mandatory,  
difficulty, employess, grade, time, trials,  
assessment, recommend),*

where *tags* – tags that characterize the courses, *tags* ∈ {*legal, office, email, tableau, sharepoint, presentation, CRM, time management, people management, product management*}; *type* – course type, *type* ∈ {*basic, ict, soft skills, manager, agent*}; *mandatory* – whether the course is compulsory, *mandatory* ∈ {*yes, no*}; *difficulty* – level of complexity of the course, *difficulty* ∈ {*basic, advanced*}; *employee* – employee identifier, *employee* ∈ {1,2,3, ...}; *grade* – course grade, *grade* ∈ [0,100]; *time* – time spent on the course, *time* ∈ {1,2,3, ...}; *trials* – number of attempts to pass the course, *trials* ∈ {1,2,3, ...}; *assessment* – evaluation of the course by the student, *assessment* ∈ [1,5]; *recommend* – whether the student would recommend the course to others, *recommend* ∈ [1,5].

Let us consider the general scheme of the proposed approach to solving the problem of improving the tracking of the process of acquiring competencies by students through the means of analyzing the learning management system data and visualizing the results of the learning process. According to this scheme, the LMS accumulates statistical data on the use of learning objects related to teachers and students, as well as courses, tests (exams, etc.), lectures (videos, presentations, etc.).

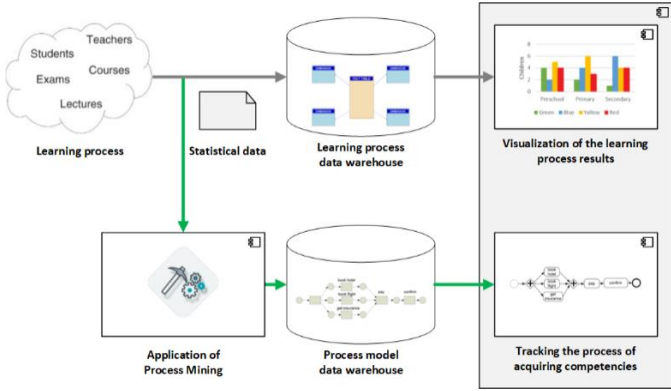


Fig. 1. The proposed approach diagrams

An appropriate algorithm (Fig. 1) for building a model and visualizing learning process data includes the following steps:

- 1) downloading the event log in CSV (Comma Separated Values) format from the learning management system (LMS);
- 2) determining the initial data for building a learning process graph - based on course tags (tags attribute) or based on course types (type attribute);
- 3) building a multiset [5] of competence acquisition sequences:

$$F = \{(f, mult(f)): f \in F\};$$

where  $F$  – multiple sequences of competence acquisition;  $f$  – the sequence of competence acquisition extracted from statistical data;  $mult: f \rightarrow \mathbb{N}$  – a function that defines for each element of the multiset (in this case, for each sequence of competence acquisition) a certain natural number;

- 4) building a learning process graph on the basis of the obtained multiset  $F$  of competence acquisition sequences:

$$PM = (T, E, G, g, L, l, S);$$

- 5) saving the constructed  $PM$  graph of the educational process to the process model repository;

- 6) preparation of statistical data by determining the indicators according to the following generalized expression:

$$\frac{1}{|Traces|} \sum_{trace \in Traces \wedge trace.attribute=x} Avg(attribute,x)(y) = y,$$

where  $Avg$  – average value;  $attribute$  – the name of the attribute of the original dataset by which the average values are grouped;  $x$  – the value of the attribute by which the average values are grouped;  $y$  – the value of the attribute by which the average values are

calculated;  $trace$  – record of the original data set from the LMS;  $Traces$  – a set of records of the educational process log,  $trace \in Traces$ ;

- 7) uploading statistical data to the learning process data warehouse;

- 8) demonstration of the learning process model in graphical form;

- 9) visualization of learning process data for further analysis based on the indicators calculated in step 6.

## RESULTS

Let us examine the results of tracking the process of acquiring competencies obtained with the help of the developed software. Fig. 2 shows a graph of the process of acquiring competencies built by course tags. Fig. 3 shows a graph of the competence acquisition process by course types. To build a process graph, we use the PlantUML service [6], since the software allows us to obtain sequences of connecting process steps only in text form. The constructed learning process graphs demonstrate the sequences of studying courses in the LMS:

- 1) by course tags (“legal”, “product management”, “office”, “email”, “sharepoint”, “tableau”, “office”, “presentations”, “crm”, “time management”, “people management”, “product management”);

- 2) by course types (“basic”, “ict”, “soft skills”, “manager”, “agent”).

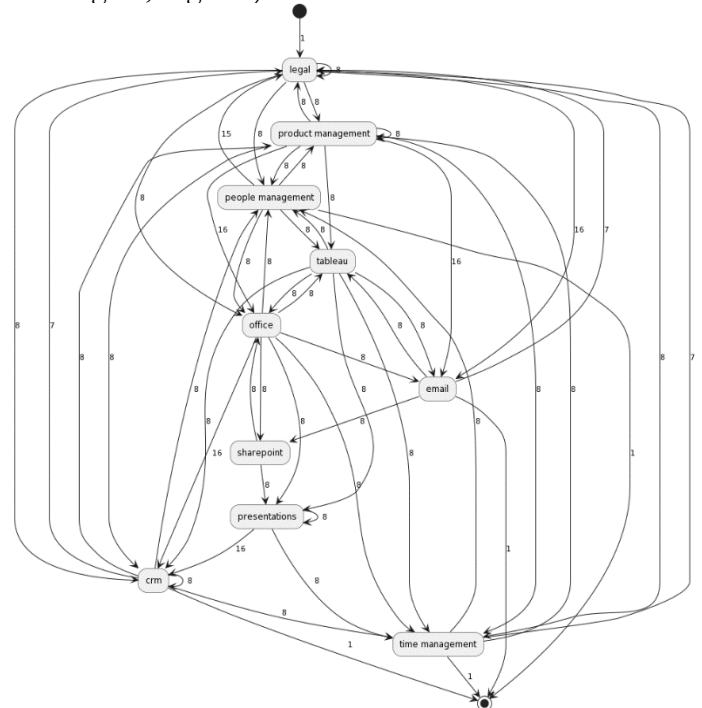


Fig. 2. Learning process model (built by course tags)

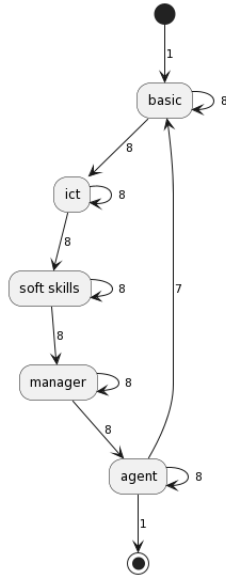


Fig. 3. Learning process model (built by course types)

For example, if we analyze the graph of the learning process, which is built by type of course (Fig. 2), we can draw the following conclusions:

- 1) all students start their studies with basic courses;
- 2) after basic courses, all students take ICT courses;
- 3) then students study courses that allow them to acquire soft skills;
- 4) after which they study managerial courses;
- 5) then students study courses for further career development (agent);
- 6) after which, in 7 out of 8 cases, they return to studying basic courses.

Fig. 4 below demonstrates the application developed in Microsoft Power BI for analytical processing of educational process data.

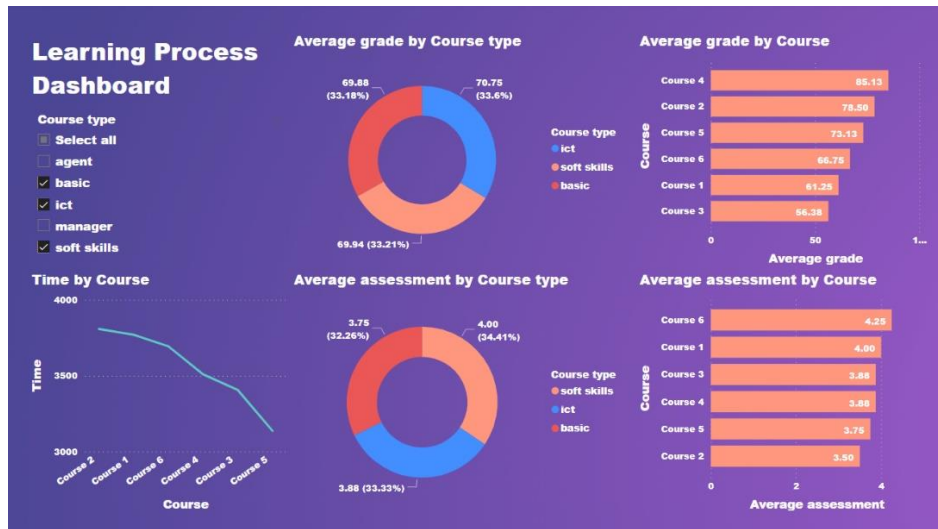


Fig. 4. Learning process data visualization dashboard

Based on the data downloaded from the learning process data warehouse, the following visual indicators are displayed on the dashboard:

- 1) switch for selecting data for analysis by course type;
- 2) line graph of time spent by students on courses;
- 3) pie chart showing the average grades received by students in the courses, broken down by course type;
- 4) pie chart showing the feedback (on a scale of 1-5) left by students, broken down by course type;
- 5) horizontal bar chart showing the average grades received for all courses;

- 6) horizontal bar chart showing the average feedback values (on a scale of 1-5) for all courses.

### CONCLUSION

This paper solves the urgent problem of improving the tracking of the process of acquiring competencies by students through the means of analyzing the learning management system data and visualizing the results of the learning process. The developed algorithm and software components allow processing learning process data from LMS in the form of a CSV file, building models and visualizations of learning process data, saving the results to data warehouses, depicting the learning process model, and visualizing learning process data for further analytical processing.

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### ПІДХІД ДО ВПРОВАДЖЕННЯ КОМПЕТЕНТІСНОГО ПІДХОДУ В СИСТЕМІ УПРАВЛІННЯ НАВЧАННЯМ

Ця стаття вирішує актуальну проблему покращення відстеження процесу здобуття компетенцій студентами за допомогою аналізу даних системи управління навчанням та візуалізації результатів навчального процесу. Об'єктом дослідження є відстеження процесу здобуття компетенцій студентами. Предметом дослідження є програмні компоненти для реалізації компетентнісного підходу в системі управління навчанням. Метою дослідження є покращення відстеження процесу здобуття компетенцій студентами шляхом аналізу даних системи управління навчанням (LMS) та візуалізації результатів навчального процесу. Таким чином, для досягнення цієї мети ми проаналізували технології обробки навчальних даних з LMS, вивчили особливості моделювання навчального процесу на основі сіток Петрі та BPMN (модель бізнес-процесу та нотація), визначили структуру даних і запропонували алгоритм побудови моделі та візуалізації даних навчального процесу. Розроблені програмні компоненти дозволяють обробляти дані навчального процесу з LMS, будувати

моделі та візуалізації даних навчального процесу, зберігати результати в даних складах, зображати модель навчального процесу та візуалізувати дані навчального процесу для подальшої аналітичної обробки.

**Ключові слова:** компетентнісне навчання, аналіз навчального процесу, система управління навчанням, моделювання процесу, візуалізація даних.

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