Assessing students' SQL knowledge and skills in gamification manner

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***Abstract* - The interest of educators in the game based education and gamification in university educational process grows in the last years. The paper discusses some approaches towards assessing students' SQL knowledge and skills and the application of some techniques to prevent cheating during the assessment process. In addition, assessment tools integrated in e-learning environments to test students' SQL skills are analyzed. An approach to students' self-assessment in gamification manner is presented. To support this approach a system for automated generation of the test questions in QTI format for e-learning environments is presented.**

Keywords - component; formatting; style; styling; insert (key words)

I. INTRODUCTION

Contemporary society is more and more influenced by Information and communication technologies (ICT), and this is a stable trend. Nowadays many students want to obtain knowledge and skills in ICT as a primary or complementary part of their academic study, and in this way to have a successful professional career. Moreover, according to ACM Curricula Recommendations [1], the comprehensive database course including SQL is required in computer science, software engineering, and information systems majors. In other majors with some influence of ICT, a database course with basic knowledge of SQL is proposed as elective or some topics in this field are included in other courses. Unfortunately, some students simply follow this ICT trend, instead of being deeply involved in the field, and university lecturers are challenged to teach effectively such kind of students.

Furthermore, the ICT influence in everyday live changes the personal habits in communication, perceptions and learning preferences of nowadays students, as they are deeply involved in virtual worlds of gaming and Internet. They prefer to be online and access lectures and other learning materials in the same way they access social networks or play games through their mobile devices.

ICT innovations rapidly influence higher educational institutions. A great number of universities provide e-learning services for students in different modes – from simple support for face-to-face classes, through blended learning mode to pure distance learning programs. Game-based learning and gamification have also become popular at university level education. Unfortunately, the development of interesting serious games for university students is not so easy and one very popular alternative is to implement some game elements in teaching, i.e. apply gamification, preferably through e-learning environment.

The aim of this paper is to present an approach for gamified self-assessment of students' SQL knowledge and skills developed with respect to new students' learning profile. The paper is organized as follows.

II. RELATED STUDIES

A. Gamification in higher education

The gamification is "an example of a modern teaching method that can be used in any sphere of human activity, and is applicable to each age group" [2]. In the last 5 years, studies and papers have related to the problems of gamification in higher education growth in scientific database such as SCOPUS, Science Direct, ACM and IEE. In Table I. some statistical data are presented. The data was collected on 26.01.2020.

The documents with key words "gamification + higher education" are about 10% -11% of all documents with a key word gamification. For the last five years the

TABLE I. DOCUMENTS FOUND IN SCIENTIFIC DATABASE WITH SPECIFIC KEY WORDS

Database	SCOPUS		Science Direct		ACM		IEEE	
Key words	All	2015-2020	All	2015-2020	All	2015-2020	All	2015-2020
gamification	6070	5195	1965	1812	2526	1950	1098	904
gamification + higher education	627	569	253	231	174	143	42	37
gamification + university education	18	14	21	20	15	12	3	2
gamification + university education +SQL	10	10	1	1	3	3	0	0
gamification + higher education+ SQL	0	0	4	4	10	10	0	0
teach SQL	10	7	4	3	13	9	1	1
teach SQL + gamification	1	1*	1	1	0	0	0	0

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documents on the topic "gamification + higher education" increase up to about 90% of all documents on the topic.

This topic sets challenges in front of university lecturers and students [3]. It is an innovative approach for education at all educational levels [4].

The studies are directed to the implementation of the gamification approach in different educational areas: computer science, medical and nursing education, entrepreneurship, teacher education etc. In the field of computer science the focus of the studies is on programming and software engineering. A few papers discuss problems with gamification in Database courses, topics related to SQL (Figure 1 and Figure 2). Less than 0,67% of all papers related to gamification in the mentioned databases discuss gamification in higher education Database courses, topic SQL.

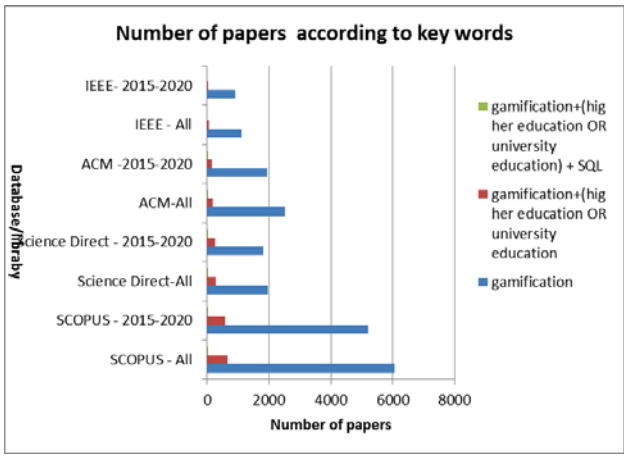

Figure 1. Number of papers related to key words "gamification", "gamification+(higher education OR university education)", "gamification+(higher education OR university education) + SQL" in SCOPUS, ACM digital library, Science Direct, IEEE Xplore

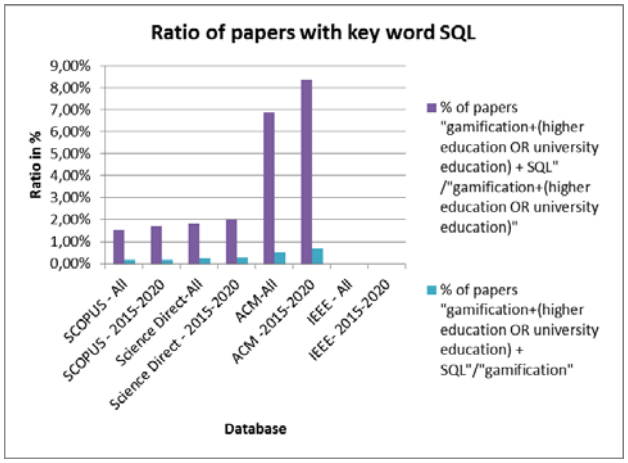

Figure 2. Ratios of number of papers with key words "gamification+(higher education OR university education) + SQL" to key words "gamification", "gamification+(higher education OR university education)"

B. Assessment and gamification in e-learning environments

Assessment is a driving engine in the educational process. In pedagogical literature, two main types of assessment are identified – criterion-referenced and normative-referenced assessment. According to Gronlund [5], criterion-referenced assessment measures students' individual achievements with respect to the set of learning objectives. On the other hand, normative-referenced assessment measures individual achievements against the achievements of other students. In e-learning environments, the use of badges or points combined with a conditional moving to the next level/module based on the awarded badges or points is an example of applying gamification with criterion-referenced assessment. The badges or points together with a leaderboard implement a normative assessment.

In [6] the authors present an approach for the evaluation of students' software projects via gamified peer assessment using badges and leaderboard. They have developed a Moodle plug-in for this purpose. The authors state that gamified peer assessment enhances students' understanding about the positive and negative aspects of their projects.

III. ASSESSMENT OF STUDENTS' SQL KNOWLEDGE AND SKILLS IN E-LEARNING ENVIRONMENT

The traditional database course consists of at least four major topics - data modelling, database models (by default a relational model), data normalization, and SQL as a language for database creating, maintaining and querying. The assessment of the knowledge and skills by default is based on solving tasks with open (textual or graphical) or short answer, multiple choice and Yes/No questions, filling gaps in template, and development of an individual or group project. Assessing open answer question and projects is a very complex task and is not suitable for automated assessment [7].

On the other hand, multiple choice and Yes/No questions are very suitable for automatic assessment and are implemented in any e-learning environments with testing capabilities. To prevent cheating during the assessment procedures, a question set used in each student's quiz or exam is selected randomly from a question pool. Moreover, shuffling of the questions and their answers is used too. Despite these techniques, to be successful against cheating, the question pool has to be big enough.

Four approaches suitable for on-line assessment of students' SQL problem-solving skills can be identified [7]:

- Creation of a SQL query from scratch in order to receive a specified result from a database with a given schema;
- Filling the missed part/s in a template of SQL query in order to receive a specified result from a database with a given schema and optionally state;

- Selecting the appropriate SQL query from the list of queries to receive a specified result from a database with a given schema and state.
- Evaluation of the SQL query result (number of rows returned) from a database with a given schema and state.

An interesting solution for on-line creation of SQL query from scratch as a part of the self-training and/or formal assessment procedure is presented in [8]. The authors state that this style of self-training and testing is close to the way professional developers create SQL to solve real tasks - starting from scratch and continuously refining their query up to the moment it becomes syntactically and semantically correct. In addition, the authors have developed an AsseSQL on-line tool for self-training and examination.

The AsseSQL tool provides on-line environment for creation of a SQL query and its execution against a training database in a particular state. During the process of creation, students can run the SQL query they have created as many times as needed, and receive feedback about its syntactical and semantical correctness. In the initial version of the tool, the semantical correctness was checked by comparing the desired result with the result from the execution of the SQL query against a current database state. In this way, any SQL query that returns the desired result is accepted as semantically correct, even though the result could be correct only in this database state. To avoid this weakness, in the next version of the tool, the query has been executed against two database states. In the end, the query is considered correct, when it can be executed without errors and returns the desired results with two different database states. [9]

Other tools also provide similar functionalities - SQLator [10], testSQL [11], and SQL Tester [12]. All of these tools are able to assess single table queries (SELECT-FROM-WHERE) optionally with GROUP BY and HAVING clauses, two tables join and/or simple subqueries. They don't have any or have very limited gamification capabilities and are not compatible with the standards for exchanging learning content or information among e-learning environments like LTI [13], xAPI [14], and CMI5 [15]. Being unique and very specific, they are not widely used in university teaching in SQL.

HackerRank [16] provides a good environment for self-training in programming languages and in SQL. Students can register and start creating SQL queries to solve problems and to obtain points for every correct solution. According to their personal achievement, students can move through the levels, receive awards (stars) and be ranked in a leaderboard. The lecturers may create a contest for the students as an element of self-training or assessment. Unfortunately, HackerRank cannot exchange the learning content and information about the students' achievements with other e-learning environments and in this way to be a part of the e-learning ecosystem.

The creation of SQL queries from scratch is used in some on-line games for SQL learning such as SchemaVerse [17], SQL Island [18], and GalaXQL [19]. These sites can be used only as supporting tools. Moreover the tasks cannot be changed or tuned according to the learning goals of the particular syllabus.

The second and third assessment approaches - filling the missed part/s in template of SQL query or selecting the appropriate SQL query from the list of queries in order to receive a specified result from a database with a given schema and state, can be easy implemented in e-learning environments. Their implementation can be done by using multiple choice questions and short answer questions. In addition, these approaches are widely implemented in many web sites for self-training and self-testing such as w3schools.com [20], sqlquiz.com [21], etc.

The approach for assessing the students' SQL skills by evaluation of the SQL query result as a number of rows returned from a database with a given schema and state can be implemented easily in the e-learning environment in the form of short answer questions. Because the answer is a number, any SQL query – from a very simple to a very complex one can be used in the assessment process. However, this assessment approach is not popular in the on-line systems for self-training and self- assessment, probably because it needs a database schema with a state provided. [7]

IV. GAMIFICATION IN E-LEARNING ENVIRONMENTS

Gamification features in e-learning environments can be classified in three types, according to the way they are implemented:

A. Core functionalities

These features are delivered with basic distribution of the e-learning system. By default, the basic gamification features included are: badges and points mark the individual achievement and progress of every student; levels to control the access to the learning content which guarantee the students' access to the next topic after passing the cut-off level of knowledge and/or skills; ranking (scoreboard) to compare the individual achievement of the student with those of other students.

B. System specific extensions

System specific extensions – practically every e-learning environment has its own mechanism to extend the core functionality by adding modules/plugins developed in specific for the particular environment way. Instead of the options to develop a special gamification extension for a particular purpose, many environments have a library of free or commercial extensions for gamification, such as scoreboards, leaderboards etc. For example, Moodle's extension module Level up! [22] enhances core gamification capabilities. Features such as leaderboard are used to display the ranking of the students; interface is used to display the current level and progress towards the next level and control is provided over content regarding the reached levels. This module has free and commercial versions.

C. *Standard-based extensions*

Standard-based extensions are extensions developed with respect to SCORM [23], LTI [13], xAPI [14], and CMI5 [15] standards. SCORM based extensions (named SCORM packages) can be "played" in all SCORM-compatible e-learning environments. The other three types of standard extensions can be used as externally provided services. An external provider can be a system developed for this purpose. In case of LTI resources the external provider can be another e-learning system. For example, badges in Canvas [24] are implemented as external LTI resource provided by Badgr [25].

V. APPROACH FOR SELF-ASSESSMENT IN GAMIFICATION MANNER

Teaching SQL nowadays is not an easy process. As was stated before, not all students are deeply involved into the ICT area. They prefer to learn in the same manner as they act in social networks or in game environment. In this way, traditional approaches on class training for solving SQL problems have become not so effective. Students want to have access to learning materials whenever and wherever they want to learn and train.

SQL knowledge and skills need to be built sequentially because each topic is based on the knowledge and skills obtained in the previous one. According to this, the lecturer has to be sure that the students have successfully completed the basic requirements for each topic. This can be done by a test after each of the SQL topics. To increase the students' achievements and avoid discouraging in case of bad test results, a set of tasks for on-line self-training and self-testing could be provided as a complementary part of the learning process. However, additional motivation is needed to involve the student in this extra training. Just informing the students that there is some useful training is not enough to motivate them to participate in it. The authors think that gamification can add the motivation needed as well as some fun in the self-training and self-assessment. This will help to build the students' SQL problem-solving skills more effectively.

Our approach for adding gamification in the self-training and self-assessment processes includes a scenario for gamification and SQL question generation system. We have decided to use evaluation of the SQL query result (number of rows returned) from a database with a given schema and state, as tasks for self-training and self-evaluation (Figure 3).

The students have to solve a randomly generated test for each SQL topic starting from the very first one. Questions from the current topic are included in the test. The test can be generated many times, each time selecting random questions, and the students can solve it as many times as they want. To obtain access to the next topic the student has to solve the test with more than 50% correct answers at least once. This proves that the students have obtained basic problem-solving skills for this topic and will be able to solve the problems in the next one as well. To gamify self-training and testing, badges are used for achievement of 50%, 70% and 90% correct answers. For each topic, a particular Bronze, Silver or Golden badge can be awarded according to the corresponding level of

Figure 3. Evaluation of SQL query result test question, implemented in Moodle

achievements listed above. A badge leaderboard is used as an element of gamification as well. As extra stimulus, the students can take part in a pre-exam procedure instead of a final exam for final grading if they have collected silver or gold badges for every topic. If a student has collected all golden badges, extra points to the final grading can be awarded.

The Moodle e-learning environment is used for implementation of the scenario. As Moodle allows points and other rewards to be awarded automatically only after passing one cut-off per activity (there is only one level of passing), badges are collected manually by the students. A corresponding link becomes active when the student reaches 50, 70, or 90% of correct answers. Special bronze, silver and golden badges are prepared for each topic. After obtaining all silver badges, the student is awarded with a pre-exam badge and with an extra-point badge if all golden badges are collected. A Badge Ladder plug-in module is used as a leaderboard, where the students can compare their current performance with the other students anonymously.

As self-training is out of the class activity and gives some advance in grading, we have to use question pools big enough to prevent collective works and re-using of results. For this purpose, a system with automatic evaluation of SQL queries and generation of test questions in an appropriate format is developed. The system allows to evaluate sets of queries using the same database schema but in different states and to sequentially generate sets of test questions. The different versions of the question pool at different states for the same database schema allow the use of the database schema used for self-training in formal assessment procedures but in different states. The schema will be familiar to the students. The question pool can include the same questions but results will be different according to the database state used. In addition, the SQL

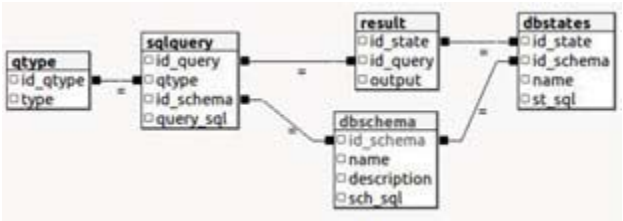

Figure 4. Database schema used to store database schemas, states and query sets used for automatic generation of question sets.

query code is presented as an image in order to avoid direct execution in an external system in case of leaks in a database state. During the formal assessment procedures, a database schema and state are given on paper.

VI. WEB-BASED SYSTEM FOR AUTOMATIC GENERATION OF SQL SHORT-ANSWER QUESTIONS

The first version of the web-based system for automatic evaluation of SQL queries and generation of test questions [7] has the following capabilities:

- Storing and managing relational database schemas and states;
- Storing SQL query sets related to the stored database schemas;
- Automatic execution of stored query sets using related database schema in different states;
- Converting the SQL query code to an image file before including it into a generated question.
- Generation of the short-answer questions in Moodle XML format for uploading in Moodle or other compatible e-learning systems.

In fact, the first version of the system has some limitations. They are expressed in the technology stack used for implementation as there is only one output format. To fix these drawbacks, we fully reengineer the system keeping only the database schema (Figure 4). Instead of Python and PostgreSQL, we decided to use PHP with PHP Data Object extension [26] to provide a data-access abstraction layer which allows different relational DBMS to be used for an automatic execution. Thus, the new system can be deployed in a wide range of execution environments – from desktops to clouds. In addition, the generation of the short-answer questions in IMS QTI 2.1 [27] format is added as a new functionality. This allows a wide range of open source and commercial e-learning environments to be used to implement our gamification approach.

VII. SOME RESULTS FROM PRACTICAL IMPLEMENTATION

It was planned to implement the presented approach during the spring semester of 2020 academic year as a part of a face-to-face SQL training course. The training tests were organized in four topics – Single table queries with WHERE clause, Single table queries with GROUP By and HAVING clauses, Multiple tables queries with JOIN, and Multiple tables queries – Subqueries/Sets.

Due to COVID-19 crisis, only three weeks of the semester were on-site and the other 12 were completely on-line, including all formal assessment procedures. We were not able to distribute a paper part of the proposed approach (database schema in some state) so we decided to include in each test question a part of the database schema in the state needed for solution. We have tested this new question view (Figure 5) during a self-assessment training. About half of the 32 students enrolled in the course took part in this training.

The results from a self-assessment training attempts are presented in Table II. In general, the students' feedback is positive – students are satisfied to train with assessment materials close to the formal exam and to compare their results anonymously with other students.

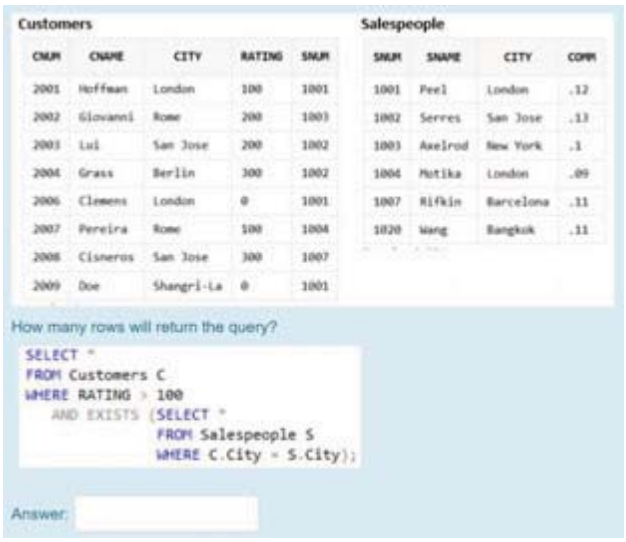

Figure 5. Test question with a part of the database schema in the state needed for solution, implemented in Moodle

TABLE II. SELF-ASSESSMENT REZULTS

SQL Topic	Attenders	Attempts	Bronze badge		Silver Badge		Golden Badge	
			Claimed	Achieved	Claimed	Achieved	Claimed	Achieved
Single table queries with WHERE clause	17	65	14	17	15	16	12	14
Single table queries with GROUP By and HAVING clauses	17	94	12	15	11	12	7	8
Multiple tables queries with JOIN	14	90	10	13	9	11	4	6
Multiple tables queries - Subqueries + Sets	11	42	7	10	7	9	4	6

Part of the students did not claim to obtain badges although they achieved appropriate results.

CONLUSION

This paper discusses the approaches towards the assessment of the students' SQL knowledge and skills and the application of useful techniques to prevent cheating during the assessment and self-assessment processes. The assessment tools integrated in e-learning environments to test students' SQL skills are analyzed. An approach to students' self-assessment in gamification manner is presented. To support this approach a system for automated generation of the test questions in Moodle XML and QTI formats for e-learning environments is presented.

The problems discussed can increase the students' motivation and achievements in database courses especially in SQL problem solving skills. Our future

works are directed to testing the approach with a larger number of students.

ACKNOWLEDGMENT

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