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QLearn: Towards a framework for smart learning environments

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Abstract

The new theory of education suggests that learner should be in the center of the learning process and the instructor playing an advising and facilitating role. Building smart learning environments supported by e-learning platforms is an important area of research. The rapid and continuous development of technology that has brought new learning skills for students forces the educational system to enter into a new era. This change is further justified by some unprecedented events that force students to learn remotely.

QLearn is an e-learning platform developed as a web based application which provides quizzes for students enrolled at Advanced Programming Methods course from Babeș Bolyai University (Romania) as part of their formative and summative assessment. The existing set of quizzes has been proposed by students throughout the last three iterations of the course in a collaborative manner with course instructor, and this data set is expanding continuously with every new generation of students. QLearn is a smart learning environment offering the students valuable feedback and a good preparation for the exam. Some metrics that quantify the coverage rate of the course syllabus attained by students or their understanding level of knowledge are provided by QLearn. The Artificial Intelligent component of QLearn application uses these measures to make predictions for students’ outcomes at the exam, to find out which topics need to be practised more and to recommend learning plans according to students’ individual needs.

The contribution of the paper is therefore twofold. Firstly, we propose a new learning design, based on students’ involvement in a collaborative manner. The second contribution of the paper is QLearn, a software application that provides support (implementation) for the proposed learning process design. Not only does QLearn platform provide a smart learning environment for students, but it also ensures the knowledge transfer from instructors to students in an efficient and effective way.

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1. Introduction

In an ever-changing world, we face with a future that brings all sorts of opportunities and challenges every single day. It is estimated that almost half of current occupations and jobs will become obsolete and just vanish. The focus in educational system needs to keep up with the times changes, but the challenge is stark.

A shift in education theory to a more student-centered approach using active learning methods becomes a necessity. In this respect, active learning’s main drive is to put the responsibility of learning at the hands of the learners themselves and to delegate the role of facilitator to the teacher [9, 6].

A student-centered approach encourages students to “discover” knowledge by themselves, working at their own individual speed or in groups in a minimally guided environment, with the lab instructor offering support, encouraging their imagination and creativity [10]. Also, these active learning methods should facilitate for the students to acquire knowledge and competences in teamwork, communication, active listening, interactive presentations, conflict management and related issues.

As we begin our journey into the 2020s, things are going to change in a way that forced all of us to step into a new era of education over night. The unprecedented event regarding the Coronavirus (Covid19) switches our physical classes with online classes. Thus, the actors of education and people from IT and technological industry have to join their force for moving the educational system into a virtual learning environment (VLE). This solution should be designed in such a way that reinforce students motivation for learning and improve their learning experience [18]. The learning design integrated into a VLE system is obviously based on active learning methods. Technological forces lead by artificial intelligence will interact vigorously to create Smart Learning Environments (SLE). Smart speakers will also be there. Assuring the learning process following a student-centered approach will be a common task in a SLE system.

In order to achieve the above mentioned deziderates, the current paper proposes an innovative solution which is two folded: firstly, we propose a new learning design based on active learning methods; secondly, it aims to developed a collaborative E-learning platform, named QLearn that integrates a SLE based on the proposed learning design. The QLearn platform was designed for students enrolled at Advanced Programming Methods course from our faculty as part of their summative and formative assessment. The collaborative feature of the QLearn resides in the fact that students build a questions pool. The proposed questions cover the concepts contained in the course syllabus. The questions pool evolves with every new academic year and it is public for the students. In order to assure a quality standard and a level of difficulty imposed by course objectives, the proposed quizzes go through a repeated process review by course instructor, students receiving feedback to improve their questions. The questions pool is used to generate quizzes for students to keep track of their learning progress and to prepare for their exam. Also, valuable feedback is provided for students according to their individual needs.

Solving a sufficient number of quizzes with varying and progressive difficulty do not only offers a good preparation for the exam, but also a deep understanding of the concepts and their transfer to long-term memory, the students being able to operate with these concepts whenever needed in practice. Also, such a collection of quizzes and the solutions offered by students can help for making future prediction regarding their academic performance also to recommend learning plans according to students’ individual needs.

The rest of the paper is organized as follows. Section 2 describes the particularities and specificity of the analyzed course that the proposed E-learning platform is based on, emphasising its contents and objectives. Section 3, presents the proposed active learning process that are integrated into QLearn. Section 4 describes the the proposed QLearning platform. Section 5 discusses some related work found in literature. The conclusions are drawn in Section 6.

2. Course structure

The Advanced Programming Methods – APM course, described in this paper, is the third course from a package of five introductory courses linked to Software Engineering (SE) domain, that are being taught at our faculty within the Computer Science Curriculum for all undergraduate students. In what follows we present the course objectives and the competences we aim to develop for students to achieve the objectives.
2.1. Course objectives and competences

The main objective of the Advanced Programming Methods course, comprised in the course syllabus [16], states that “Students have to be able to develop small to medium applications using the main concepts and mechanisms defined by object orientation programming paradigm - OOP, together with design strategies expressed in terms of principles, heuristics and rules, and use/build well defined software architectures for these applications.” The necessity to build software systems that meet principles, heuristics and rules of a good object oriented design comes as a necessity. Nowadays, software systems are very large and complex applications that have to support the ever changing requirements of the business. The code becomes more and more complex and drifts away from its original design. A small change in one part of it could propagate unforeseen effects in completely other parts, leading to potential disasters. In order to prevent this, developers have to assure the quality of software design during its development lifecycle [17,15]. Therefore developing students’ appropriate competences and skills in writing quality programs is a premise in achieving the above mentioned desiderate.

Summarizing, students’ competences comprised in the APM course are:

1. Ability to use the concepts, mechanism and principles of object oriented analysis and design.
2. Good programming skills in Java and C# programming languages.
3. Ability to apply design patterns in different contexts.
4. Ability to build software projects with clear separations on architectural layers and by following the main phases in software applications development.
5. Ability to assess software quality.

In what follows we refer to these competences as software engineering related competences as they are very specifics to SE domain. In order to develop these competences for our students there are two other types of competences that serve as prerequisite: technical competences: computational thinking, abstraction, modeling, optimization, AI and machine learning, and meta-cognitive competences: discipline/self-discipline, an entrepreneurial mentality, autonomy, a designer-type thinking.

To meet the above mentioned software engineering related competences the question that comes in our minds is: “What are those methods and tools that should be applied and used in order to achieve these competences?” The Section 3 designed a response for this question.

2.2. Course content

The course meets formally three times a week: 2 hours are for lectures classes (9 lectures using Java programming language and 5 lectures are in C#), 2 hours are for seminar classes and 2 hours are for laboratory classes. The semester has 14 weeks of classes. Seminars are for problems solving from the course topics while laboratory classes are dedicated to incremental development of a software. The laboratory project evolves at the same time with the course: new topics are learnt, new project requirements, both functional and non-functional (design, architecture, quality attributes) are identified for students to implement them.

The main topics comprised in APM course syllabus are stated as follows:

- Introduction to Java platform: platform, language syntax, primitive data types, arrays, classes, interfaces, packages, enums, overriding, overloading, exceptions.
- Collections and Generic Types: anonymous classes, polymorphism, casting.
- IO, NIO: binary and character oriented streams, files, channels and buffers.
- Functional programming: lambda expressions, streams.
- GUI: Java FX components, event handling.
- XML: schema, documents.
- GUI (cont.): FXML, CSS. Metaprogramming.
- Concurrency.
- Introduction in C# and .Net.
- Collections in C#.
- IO operations in C#.
- GUI in C#.
- LINQ.
3. Designing a smart learner-centered environment

Studies related to learning process has shown that the brain neuron-networks stay linked when they are used repeatedly, meaning that the brain is actively engaged [13].

Students are required to take on new learning roles and responsibilities beyond taking notes, listening to teachers teach, and passing exams. Active learning methods [18] become a solution in this respect. They are embedded in a learner-centered environment which effectively implement multiple teaching and learning techniques to enhance students’ higher education experience and provide them with greater control over their academic learning [1, 4].

In what follows we present the active learning methods proposed for APM course that are integrated into QLearn platform.

3.1. Inquiry based learning - Quizzes

One of the task defined at APM course by the course coordinator empower the students to propose questions from the course syllabus topics in order to be used by students in the learning process as a formative assessment [10] during the semester by solving quizzes build up from these questions. Also, the questions are used by the course coordinator for the written exam at the end of the semester. This is a multiple choice written test sustained in the exam session period, as part of their summative assessment [10, 12]. During the semester, each students has to come up with at least one multiple choice question from a given course topic and having into account the course objective described in Section 2.1.

The active learning method that support this task is Inquiry-based learning meaning that the learner explores a given theme, develops a plan of research and comes to solutions, although an instructor is usually available to provide help and guidance when needed [10].

3.2. Collaborative based learning

A collaborative aspect involved in the proposed e-learning platform refers to the fact that students build their learning process design, each students coming up with his own contribution to improve the course. This activity is supported through the E-learning platform in order for course instructor to assess the quizzes proposed by students and to offer a valuable feedback and review. The e-learning platform facilitating collaboration between students in order to find out for every quiz some important aspects: i) what are the concepts identified in the course syllabus that are covered by the proposed quiz? ii) How many stars can be granted for a given quiz? Justify. iii) Are the concepts implied in the quiz used in a normal scenario or there is a tricky question?

What have the students gained? Collaborative learning is one of the active learning methods that can facilitate learner’s critical thinking. Peer interactions during collaborative learning can be helpful for the learner’s development of critical thinking [10] [11].

3.3. Game based learning

Game based learning or gamification can be defined as the use of elements which are game-based in a learning environment. This methods has gained popularity being a new approach in learning due to the increasing of motivation of students and their involvement in the process of learning [8].

The impact of gamification in educational environment has been already studied. It makes the entire process of learning interesting and learners are more involved as they find fun in using the game-based elements like badges, progress levels etc., for their formative assessment in learning [2].

3.4. Putting all together into a smart learning environment

Out aim is to integrate the active learning methods described in Sections 3.1, 3.2, 3.3 into a SLE, the proposed QLearn platform offering an instance of a SLE system in this respect. In this approach we considered a SLE as being an adaptive system that brings the learner at the forefront, by putting the responsibility of learning at the hands of the learners themselves and delegating the role of facilitator to the teacher. A SLE system aims to improves the
learning experience for the learner, to increase the degree of engagement, knowledge access, feedback and guidance. It uses rich-media with access to information, on-the-go mentoring, with high use of AI, neural networks and smart-technologies to continuously enhance the learning environment.

In what follows, we emphasize the main features that our proposed SLE aims to provide, as they are identified in [19, 7]:

- **Task support**: providing learners with tools, knowledge, and skills to perform a task.
- **Adaptive and instant learning support**: providing meaningful and timely feedback to a learner based on the learner’s progress and profile – personalizing learning to the learner.
- **Tracking the learning progress for students**: the SLE can track the learning status of learners to enable a more accurate support for learning.
- **Connecting learning community**: learners will be connected to learning communities to enrich the learning experience.

4. QLearn - The proposed SLE platform

QLearn is an e-learning collaborative platform that enhances the traditional learning system by engaging students in an active learning process. The proposed platform offers support for students to design questions in order to build quizzes (tests), to solve quizzes with varying and progressive difficulty, covering the topics from the course syllabus, to receive feedback regarding their results (formative assessment), to keep track of their learning progress, to learn from others students that share their experience and to debate certain problems.

The advantages of using QLearn platform resides not only in a good preparation of students for their exam, but also in a deep understanding of the concepts and their transfer to long-term memory, the students being able to operate with these concepts whenever needed in practice. Also, such a collection of quizzes and the solutions offered by students for these quizzes can help to make prediction of the academic performance of students. When our data set will get a consistent dimension, predictions and recommendations based on Artificial Intelligence algorithms would be very accurate. This can optimize the students learning process in order to assure a high coverage rate of the syllabus topics and attaining a deep level of learning according to students abilities and motivations.

In the following sections we resume the main functionalities of the application, some measures that are introduce to quantify different aspects, like for instance students’ progress, and a short overview of the system architecture.

4.1. Domain analysis

In this section we present the conceptual model of the QLearn emphasising the main functionalities of the application. The class diagram of the model can be seen on Figure 1. The main principle of QLearn is that of providing an accessible, transparent and verified content for both teachers and students, and also to provide support to extend the content through a collaborative way. Therefore the following user roles are established: student role, teacher role and admin role.

The main functionalities of the proposed QLearn platform address the following aspects:

- **Collection of questions.** The core element of the application is the Question entity. The Question is the root of the domain classes hierarchy and the lowest domain class with an atomic meaning (information could be extracted without outside context). An entity is associated with one or more categories. A category is a specific topic of learning from the course syllabus (e.g: collections, java, streams, etc.). It is used to describe questions so that an user has a customized experience on the platform and also to monitor coverage rate of the syllabus concepts learnt by students. A category of the question can have one of three difficulty levels: EASY, MEDIUM and HARD. The referred subdomain can overlap (e.g: a question can be (stream, easy) and (java, medium) at the same time), but an unique name must be given to a category tied to a difficulty level. The course is the highest level of abstraction and contains all data for a given professor and his students. It sets a boundary between different learning domains.
• **Review process.** one of the collaborative aspect of the platform resides in the fact that the students have to propose questions in order to build a questions pool that is used for their formative and summative assessment. After a student proposes a question, it is submitted for a repeated review process made by the course coordinator. The student receive feedback to improve the question in cause in order to be modified accordingly to some standards and difficulty level imposed by the course. Once a question passed the review process it is added to the questions pool and can be used to create quizzes. In this way, the database contains a continuously expanding questions pool.

• **Categorisation.** The problems are categorised by topics comprised in the course syllabus, and also tagged by difficulty. Each category has a short description that contains a summary of the theoretical results concerning the topic.

• **Feedback.** the course instructor reviews all the questions proposed by students and offer them feedback regarding those questions; during the semester the course instructor can offer feedback for students regarding their activity on the platform with the help of some assessment metrics that is automatically computed for each student.

• **Question pool and Quiz.** A question pool is a container of different questions. It can be used to separate exam questions from those offered from the user. The quiz is a set of questions offered to the user. A quiz is generated by specifying a number of categories and for each category, the number of questions. The questions are randomly selected in this version of the platform.

Questions are also used to create quizzes both for the final exam and for training the students during the semester as a formative assessment. There are three main types of quizzes:

1. **Given quizzes:** are created by a professor by specifying a variable number of ”categories” and their difficulty. Each student has access to a given quizzes set. Figure 3 is one of the QLearn screens highlighting this feature.
2. Reiterative quizzes (that are generated by the platform based on the lowest answer questions): are quizzes tailored for a specific student and are formed by questions from categories that the platformed deemed the student did not understood completely.

3. User requested quizzes (tailored for the student by the ”categories” chosen by him): are generated by the platform for the student from categories requested by him. The user interacts with a chatbot that parses input and collects keywords from which categories are generated.

QLearn also provides analytic support for both the student and the professor. The student received an estimated grade based on his results on the taken quizzes by comparing the answered questions with the questions from the exam pool. On the other side, based on the students response and the question available for the exam, a professor can see for a specific set of questions the Gaussian distribution of the grades to offer the best possible exam. Figure 4 is one of the QLearn screens highlighting this feature.

4.2. Assessment metrics

Detecting meaningful patterns from the educational processes is of great interest in academic environments, since it would be useful for understanding the students learning activities, as well as improving the learning outcomes [5].

Thus, the platform aggregates a different number of metrics, such as: student’s coverage rate of concepts from the course syllabus, the number and the type of badges achieved, user satisfaction, quiz efficiency, question efficiency and student eagerness for learning.

The coverage rate of the syllabus concepts metric is defined as the number of concepts that appear in quizzes taken by the student divided to the total number of concepts from the course syllabus. Similarly, we can define the coverage rate of a given course. The students receive badges if the coverage rate of a given course is equals to 100 percents or if the student succeeds to pass a difficult test. The badges achieved by a student are a good indicator of student’s progress (Figure 3 right side).

User satisfaction metric is generated based on student’s review on taken questions. The student is given the option to rate a question from one to five stars and also leave the review. Then the average of the feedback is taken and the text feedback is data input into a sentiment analysis machine learning model to determine the state of satisfaction of the user.

Quiz efficiency metric is measured by the number of correctly answered question on a quiz. For a better estimate of the efficiency of the quiz, each difficulty type is assigned number, representing the weight of the question. EASY questions have 8 points, MEDIUM questions have 13 points and HARD questions are 21 points.

Question efficiency is measured by the number of times the students have repeated a question divided by the number of distinct users that have given an answer to it. A small ratio means that a questions is possibly hard and that a professor may increase it’s difficulty level to better reflect the reality of a question. A high ratio represents an ambiguous that students might find difficult to understand or wrongly marked correct answers.

Student eagerness for learning is measured by the number of quizzes the student requested to be generated and by the number of questions he submitted for review by the professor.

4.3. AI component

As we have mentioned earlier, a smart learning environment is able to offer instant and adaptive support to learners by immediate analyses of the needs of individual learners from different perspectives (e.g., learning performance, learning behaviors, profiles, personal factors). Moreover, it can provide various personalized support to the learners, including learning guidance, feedback, and learning tools, based on their needs. To archive these desiderata, the proposed platform integrates an AI component which aims to provide the following main features:

• Predicting the students’ academic performance. All the metrics defined in the previous section influence the student’s outcome at the exam; thus, they are used as predictors in a machine learning algorithms to make prediction; for instance to predict if the student will pass or not the final exam.

• Sentiment Analysis – using Natural Language Processing. The feedback received for each questions is analyzed to decide if is a positive or a negative feedback, using also natural language processing.
• Chat bot – text commands are also supported by QLearn; “Hy, I want a quizz that include the concepts streams, xml and concurrency”
• Integration with the smart speaker Google Assistant in order to offer voice commands based support

4.4. Technical description of system architecture

The application uses a 3-tier layer model consisting of the presentation layer, the server layer and the data layer. This model was chosen as it provides a modularization between user interface, business logic and data. Some details regarding the system architecture and the technologies used are emphasized in Figure 2.

Fig. 2: Three tier layer model

Fig. 3: Student dashboard.

5. Related work

Nowadays there are different e-learning systems. All these systems, offer for students students courses’ contents in different formats (text, image, sound), as well as interact with teachers and/or colleagues, via message boards, forums, chats, video-conference or other types of communication tools.
learning methods, both students and teachers are involved in the learning process design. Such a platform, empowered
developed by us, which provides a set of configurable features, in order to allow the creation of online courses, pages of subjects, work groups
and learning communities.

Similar systems to our idea are [3, 14] The most widely used open-source e-learning platforms is Moodle [3]. It provides a set of configurable features, in order to allow the creation of online courses, pages of subjects, work groups and learning communities.

In spite of all the features provided by the existent e-learning platforms, there still is a need for another feature that should be provided: that of facilitating the learning process design via a collaborative way. By means of active learning methods, both students and teachers are involved in the learning process design. Such a platform, empowered
the students to compose/solve quizzes that ensure a good coverage of the concepts comprised in course syllabus and a deep understanding of them. Also, it provides for students the possibility to learn from their colleagues, to share their ideas in a efficient way.

In relation to existing e-learning platforms, our approach offers implementation to sustain the above mentioned feature. As far as we know, such an approach have not been implemented so far.

6. Conclusions and future work

The new theory of education suggests that learner should be in the center of the learning process and the instructors playing an advising and facilitating role. A shift in education theory to a more student-centered approach using active learning became a necessity for nowadays.

The paper proposes a new learning design based on students involvement through a collaborative way. The proposed learning design is integrated into QLearn, the e-learning platform developed by us, which provide quizzes for students enrolled at Advanced Programming Methods course as part of their summative and formative assessment.

Our experience allowed us to distill a set of lessons learnt and to use them to further improve QLearn platform in the future. In this respect, we register the difficulties encountered by students every year and use them in appropriate context as support for the students in the next iteration. This task is also automatized through the proposed e-learning platform.

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