A Model of an Online Evaluation System for STEM Education

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***Abstract* - To achieve better learning results, students should be motivated for continuous learning. This is particularly important in areas such as STEM, where for the purpose of understanding the new content students have to master the topics that precede them. This paper describes a work in progress with the aim to develop an online evaluation system for STEM education based on the principles of Education Recommender Systems. The structure of the proposed system includes a domain model, student model, activity model, and a recommender. Domain model will represent concepts of subject matter. Student model will be built on data gathered during continuous evaluation together with students' learning styles and foreknowledge about digital tools. Activity model represents items that will be recommended: learning materials, tasks for learning using digital tools, and colleagues that can help in mastering particular subject content together with materials needed for knowledge assessment. The recommender will include original pedagogical rules for generating recommendations. The proposed model should encourage and motivate students for continuous learning and consequently lead to better learning results.**

Keywords – formative evaluation; evaluation system; knowledge assessment; STEM; Educational Recommender System

I. INTRODUCTION

In the last three decades much research has focused on exploring different motivational strategies for STEM (science, technology, engineering and mathematics) education [1, 2, 3, 4, 5, 6] but also on evaluation techniques and the way they could be implemented in teaching and learning processes [7, 8, 9, 10]. Evaluation approaches using online systems for their implementation have shown the possibility of using these systems as a motivational platform [4, 7]. Also, since assessment results and grades achieved by students through evaluation processes have a great impact on different aspects of student life (such as career and academic opportunities of a student [8]), evaluation approaches must be carefully planned and implemented [10].

Evaluation approaches can generally be divided into two types: formative and summative. In formative assessment, student work is measured during the semester and its main purpose is to provide feedback to both the students and the teachers regarding the results of the teaching and learning process. On the other hand, summative assessment is conducted at the end of the instructional periods (such as midterm and final exams) with the main purpose of grading and verifying the effectiveness of learning and teaching during the semester [7, 11].

While exploring possibilities for introducing adequate educational motivation strategies for STEM students at the University of Rijeka, it was observed that majority of students that participated in conducted research approach their study in a non-continuous way [12, 13]. Usually, students concentrate their learning efforts in a short period of time before a midterm or final exams. The observed problem was researched in detail through the use of paper-based questionnaire surveys. Obtained results showed that students lack the necessary motivation and that they expect to be additionally motivated for learning by their teachers.

In aforementioned research, Educational Recommender System ELARS was used in order to promote the use of digital tools for collaborative learning. ELARS was designed, built and tested in real educational environments [12, 14, 15]. Introduced digital tools and their use for learning was positively accepted by students and influenced their motivation for subject content. Unfortunately, this motivation strategy did not succeed in motivating students to start to learn continuously.

This paper proposes a model of an evaluation system for STEM education that addresses the observed problem. The system will combine methods and techniques of recommender systems [16] with continuous formative and summative assessment adequate for STEM education purposes in order to motivate STEM students to work continuously. The structure of the model will include a domain model, student model, activity model, and a recommender. Such a structure will enable the generation of timely appropriate feedback information about students' progress together with recommendations that will be based on achieved assessment results and other students' characteristics.

II. KNOWLEDGE ASSESSMENT IN STEM

In STEM, many topics require proficiency in mathematics in order for students to understand presented concepts [17]. Also, when theoretical knowledge is transformed into a practical implementation in STEM some form of mathematical procedures and computations are commonly used. Assessment of acquired knowledge (both formative and summative) includes solving math-based tasks using predetermined steps in well-established math procedures with a certain number of intermediate solutions.

In university courses, summative assessment in STEM is commonly conducted through several midterm exams and/or projects with a final exam at the end of the semester. Due to various reasons, it was observed that a great number of students concentrate their learning efforts in short time periods just before the midterm exams or set deadlines [15, 18]. By approaching their learning in this non-continuous way, students miss out the opportunity to acquire a deeper understanding of the material that can be achieved over longer time periods. In this way, students approach their learning in so-called surface approach [19] where the main intention is to complete the task and memorize information without distinction between new concepts and already acquired knowledge. Because of that, when new material is presented for learning, students can find themselves in a situation where they do not possess an adequate understanding of the already completed materials needed to grasp and understand the new concepts. This lack of deeper understanding can affect their assessment results and their grades, thus influencing their future academic and career possibilities [8].

Formative assessment in STEM is used during the semester for providing students with quick feedback about their current level of knowledge. Because of the number of students, especially in basic courses of university study programmes, formative assessment can be overwhelming for the teachers if done in a traditional way (offline, in paper form). Also, in that case, students have to wait for feedback about their results, thus minimizing the positive aspects of this type of assessment method [8]. Research results indicate that students prefer online assessment possibilities versus traditional paper-based assessment approaches because online assessment addresses these issues and offer acceptable solutions expected by students: possibility for conducting assessment in environment that resemble recreational activities, easiness of use with quick feedback but also flexibility regarding time management of their study obligations [20, 21].

Todays' evaluation systems regarding math-based tasks usually focus on the final solution of the set task (in the form of multiple choice questions or numerical question type [22]) thus neglecting intermediate results that lead toward it. As students progress through the content of a subject, they are faced with increasingly complex tasks that encompass elements from the related previous subject content. In order to successfully solve the set task students need to master that related subject content. By focusing on intermediate results that students provide during the evaluation process, it should be possible to determine which parts of the subject content student needs to study more thoroughly in order to master it on an expected level.

III. A Model of Proposed Online Evaluation System

The proposed model of an online evaluation system for STEM education is built around the idea that intermediate results in math-based tasks can provide additional information regarding students knowledge.

Using the system, teachers will have to define the order of the course activities that will also include online assessments with math-based tasks. These tasks may have several intermediate results and one final result. If student inputs the wrong answer as one of the intermediate results that information can be used in order to determine which part of the subject content should have been mastered by the student to correctly solve that part of the set task. Also, from the wrong answer can be concluded that student either lack expected foreknowledge about related previously learned the material or hasn't learned new material which is evaluated by the set task. By providing feedback about these two possible causes for the wrong answer given as an intermediate result, the proposed model can help students to focus their learning activities at the subject content that they must master (both from previously finished and recently taught learning materials).

To further enhance student experience while using the system, the model includes *recommender* in order to generate adequate recommendations. In this way, the proposed model will not only give simple feedback to the students regarding parts of the subject materials on which they have to focus their learning activities, but also provide

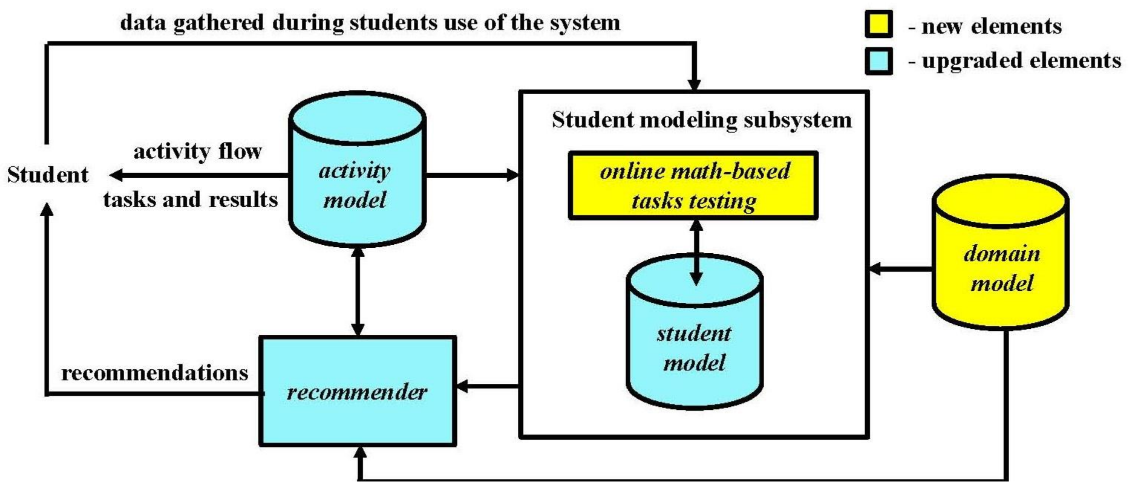

Figure 1. A model of an online evaluation system for STEM education

them with individual recommendations aimed to help them to learn these materials.

A proposed model of an evaluation online system for STEM evaluation is presented in Fig. 1. The model consists of a *domain model*, *student model*, *activity model*, and a *recommender*. In *domain model* concepts of subject matter are represented. *Student model* is built on data gathered during continuous evaluation together with students' foreknowledge about digital tools and their learning styles. *Activity model* represents items that will be recommended: learning materials, tasks for learning using digital tools, and colleagues whose knowledge is at the level that they can offer their help in mastering that content. Also, in the activity model order of the activities and materials needed for knowledge assessment is included. The *recommender* will include original pedagogical rules for generating recommendations.

By combining evaluation procedures with capabilities to generate individual recommendations, the proposed model should be able to influence students' approach to learning an motivate them to start working in a continuous way. Thus, the proposed model will be used as a tool for implementing a motivational strategy aimed at helping students to achieve a deeper understanding of the course material that can only be gained through continuous learning.

IV. Implementation

In order to implement the proposed model of the evaluation system, educational recommender system ELARS will be used as a base.

ELARS model consists of an activity model, student model and recommender [15]. Activity model represents learning design components (planned activities grouped in learning modules) and items that can be recommended to students (optional e-tivities, possible collaborators, tools, and pieces of advice for successful participation in e-tivities). Student model consists of four elements used for modeling students and groups of students (level of initial knowledge, preferences of digital tools, learning styles according to the VARK model, and level of activity during student use of the system). Recommender includes algorithms based on pedagogical rules for generating individual and group recommendations.

To implement the model presented in Fig. 1., some of the structural elements of the ELARS system will be upgraded. Also, since the proposed system will include an online evaluation of students' knowledge, adequate structure elements must be introduced to the system during its implementation.

As can be seen from the model structure shown in Fig. 1, one of the new elements is "*online math-based tasks testing*" for carrying out an online assessment of student knowledge. This part will include tasks with related intermediate and final solutions.

The other new element is the *domain model*. It will contain a representation of concepts of a subject matter and learning outcomes that will be used by Student modeling subsystem and *recommender*.

Activity model is part of the ELARS system that has to be upgraded with representations of new items that could be recommended. Those are learning materials, tasks to be solved using digital tools, and colleagues that have sufficient knowledge and can offer help in mastering particular subject content. In addition, a new type of activity "solving mathematical tasks" will be added to the activity model in order to allow the teacher to include online assessment in the course activity flow. *Activity model* will be connected with Student modeling subsystem and *recommender* in order to provide quick feedback about the accuracy of their intermediate and final assessment results and generate a recommendation.

Existing *student model* will be upgraded with new student's characteristics. Assessment results will be used to represent the student's knowledge of concepts from the *domain model*. In addition, student's foreknowledge about digital tools and data gathered during students use of the system (e.g. accepted recommendations, number and duration of system use, etc.) will be stored in the *student model*. Therefore, the subsystem for student modeling is connected with the *activity model* and the *domain model*.

The existing *recommender* will be upgraded with new algorithms and pedagogical rules for generating recommendations. Data gathered through students use of a system will be used in order to create an as accurate model of each student. Correct and incorrect results of an assessment sessions together with data regarding the duration of system use and type of recommendation that student chooses to use will be utilized for this purpose. This data will be combined with information stored in the *activity model* and the *domain model* in order to generate individual recommendations. Recommendations relating to learning materials and colleagues that can help in mastering particular subject content can help a student in carrying out a more traditional approach to learning. On the other hand, recommendations relating to the use of digital tools for solving appropriate tasks aim to promote the use of digital tools for learning.

V. Conclusion and Future Research

The model of an evaluation system for STEM education was designed to address the problem of non-continuous approach to learning that was observed during previous research. The system will be used for continuous formative and/or summative assessment and to promote the use of digital tools for learning. Used as a motivational tool, the system should be able to motivate students to work more continuously thus creating the precondition for students to achieve better learning results.

The proposed model is built around the structure of the educational recommender system ELARS. ELARS was used as a starting point and its structure was expanded with the domain model and the "online math-based tasks testing" for carrying out an online assessment of achieved learning outcomes. To generate appropriate individual recommendations, several components of the ELARS system needs to be upgraded. These are activity model, student model, and recommender. Data gathered from assessment sessions will be included in the student model and used to determine parts of the course material that is not yet mastered by a student at the expected level. This information will be given as feedback to the student but also used to generate appropriate individual recommendations. Through three types of generated recommendations, the system will have the potential to help students to focus their learning efforts at the specific area that they need to master.

Further research steps will primarily focus on building a prototype of the system and testing it in a real educational environment within STEM education.

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