INNOVATIVE TEACHING METHODOLOGIES FOR AN ONLINE ENGINEERING MATHEMATICS COURSE

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Abstract

The fast evolution of distance learning tools such as Open Educational Resources (OER)) is an evidence of a shift in the way teaching and learning are understood. Several Higher Education Institutions are trying to increase their efficiency, competitiveness and expand their potential public by investing in the development of online courses, which can offer more interaction and support and be accessible to a larger number of students from a wider sort of backgrounds. The adaptation of a face-to face course into an online one is not simple, as it is not just about uploading lecture videos, sets of notes or lessons, it is necessary to consider the student's needs, the instructional design and the best digital educational tools in order to support learning and teaching process.

A partnership between Higher Education Institutions from six European countries, connecting more than twenty lecturers from distinct knowledge areas, is working on a European Erasmus+ Project, EngiMath, Mathematics online learning model in engineering education. These are developing a shared online platform for teachers to teach Mathematics in the first years of Engineering degrees and, on the other hand, to support student-centric learning and to encourage students to actively engage in the learning process to construct their own learning, addressing the recent requirements for an open, independent, competitive and innovative education. In this context, several new methodological and development issues of the online course will be presented, as well as students' perceptions and feedback about the pilot course conducted by each institution partner of the project.

Keywords: Innovation, Technology, Interactive Learning Materials, Higher Education, Online Learning, Distance Learning, Engineering Education.

1 INTRODUCTION

In recent decades, the development of competencies and competitive workforce has been an important topic in the academic world [1]. Higher Education Institutions (HEI), particularly those devoted to Engineering education strive to prepare their students for today's global workplace since there is also a growing variety of skills that engineering students should have [2]. From a basis and general point of view it is a common practice among these institutions ~~is~~ to incorporate mathematics knowledge and skills into engineering education [3]. However, there seems to still exist little consensus among academics on what kind of mathematical skills an engineering student should acquire during their academic educational path [4]. The recurrent problems when dealing with mathematics teaching and learning are well documented not only in EU, but also worldwide (e.g. [5], [6], [7]). Here, the use of Information and communications technology (ICT) support in this process revealed several alternative educational procedures and practices giving space for the development of numerous projects like "Future Mathematics" [8], "LearnIT" [9], "Open Discovery of STEM Laboratories" [10] or "MatActiva" [11], among many others, and led to the emergence of the Erasmus+ EngiMath in late 2018 [12].

The EngiMath project idea has sprung up from long-term practical needs and experiences, and a strong communication flow, of several lecturers and investigators that became project associates. All partners had previous experience in ICT, curricula development, teaching methodologies, and research. Interest and leadership for investigating engineering mathematics and ability to work in an effective cooperative way between educational institution actors, brought together all partners. The project included lecturers from the TTK University of Applied Sciences/TTK UAS from Estonia (project coordinator), the

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Letterkenny Institute of Technology/LYIT from Ireland, the Polytechnic Institute of Porto/P.PORTO from Portugal, the Technical University of Cluj-Napoca/UTC from Romania, the Koszalin University of Technology/PK TUK from Poland and the University of the Basque Country/UPV/EHU from Spain. In September 2020, the Spanish partner left the project and a new partner, also from Spain, entered the Project: The Polytechnic University of Catalonia.

2 ENGIMATH

The use of ICT has grown exponentially in the course plans in the most diverse areas of knowledge in HEI, because digital competencies, literacy and skills are essential to the core structures of the working world [13]. The promotion of a full and better use of ICT should introduce improvements in the quality of educational systems, the enlargement of research performance, the support of innovation and knowledge transfer. From an academic view, the role of technology must be to facilitate teaching and to promote learning in an authentic situational manner, as this is essential to develop and support a real "student-centred" learning. To foster and promote an active learning ethos, one of the most important features to assure is “prompt feedback” since it provides reinforcement, guidance, confirmation of learning and encouragement. This feature is the most difficult to grant and guarantee in a distance/on-line learning model and it is the core and general goal of EngiMath – Mathematics online learning model in engineering education.

2.1 The course sections

The project started with the identification of common mathematics topics and the discussion of contemporary pedagogical principles. Analysis of the structure and teaching specifications of subjects related to mathematics in partner's institutions has been developed. Due to several differences among all the partners’ curricula including number of credits, period of teaching, different syllabus in similar subjects, different number of hours for one ECTS etc, the consortium has formulated a common core for all partners and possible particularities depending on the characteristics of the country or of the degree. The detailed overview with comparative needs analysis has been published in 2019 [14].

One of the main productions of this project is the development of a 3 ECTS on-line course on Mathematics for Engineering and other degrees. which is been created from the scratch in the Moodle TTK UAS (https://moodle.tktk.ee/) learning environment in 6 different languages. The aim of this course, defined by the consortium, is to promote the development of basic and structured knowledge and practical skills in the mathematical area of Linear Algebra, specifically in the sub-areas of Matrices and Matrix Calculus, Determinants and Linear Equations Systems related to Engineering. The direct target groups of the Project include students in engineering mathematics programs at higher educational institutions, academic staff teaching engineering mathematics in tertiary programs and research academics in the areas of technology-enhanced learning and on-line learning.

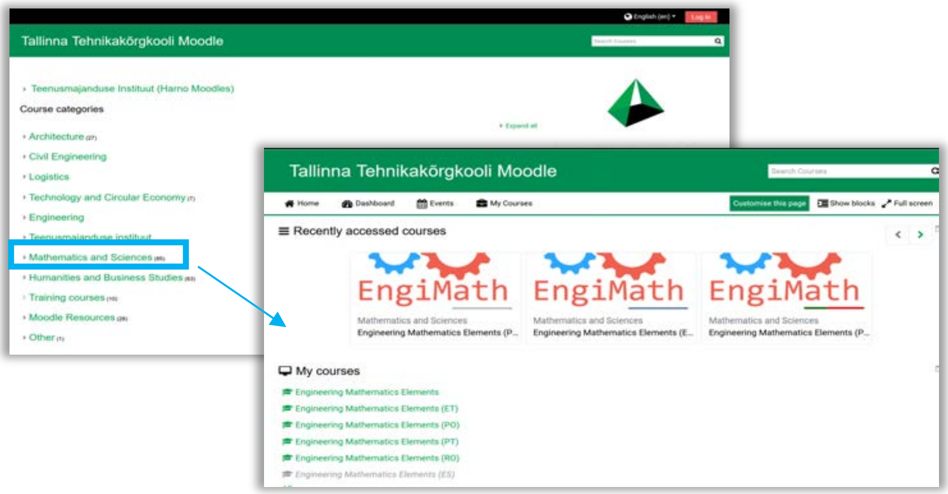

Figure 1. Moodle TTK UAS (print screen)

Being an online course, where the user's autonomous navigation is assumed, and in view of the topics covered and its extension, it was decided to make a "natural" division into three major theme sections: (1) Matrices and Matrix Calculus, (2) Determinants and (3) Linear Equations Systems (Fig, 2).

An important fourth section is being developed and it would be an introductory one, where the students/users will be confronted with some important Algebra applications to the Engineering field anticipating an answer to the recurrent students' question: "Why do I need to learn this?".

In each of the three sections of the course program, the methodologic path was sequentially defined as (1) Lesson, (2) Quiz, with a one to one connection. The assessment blocks will be developed only by section, that is, 3 assessment tests one for each theme section (Fig. 2).

Matrices and Matrix Calculus section comprises 14 Lessons and Practical Tests, for Determinants section there are 8 and for Linear Equations Systems another 4, which makes a total of 26 "blocks". In each of these "blocks", there is a clear description of the corresponding predefined leaning objectives.

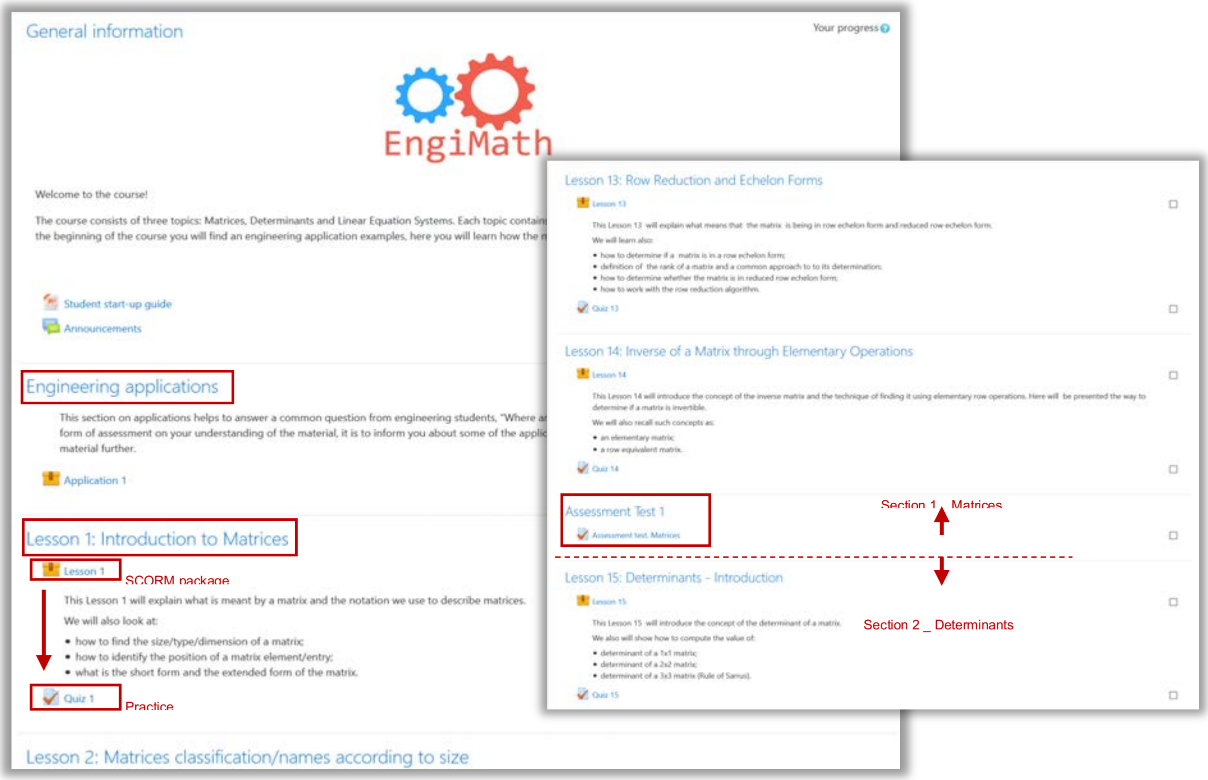

Figure 2. Course Sequence

2.1.1 Lessons – Theory Component

The theoretical materials were created by the Portuguese team. The iSpring Suite 9 Software was used to introduce interactions, dynamic examples and exercises in these materials, stimulating users to interact with them – promoting progressive and free navigation, with a hidden menu bar and several other animations (see Fig. 3) and answering sequential quizzes (Fig.4).

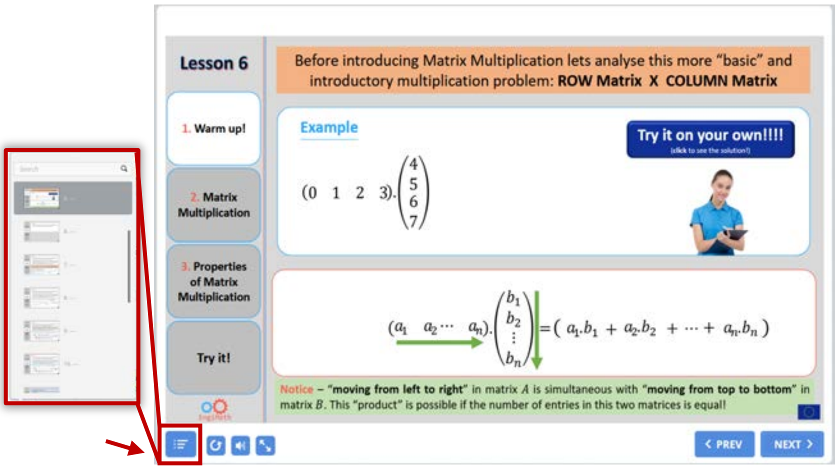

Figure 3. EngiMath Lesson navigation bar

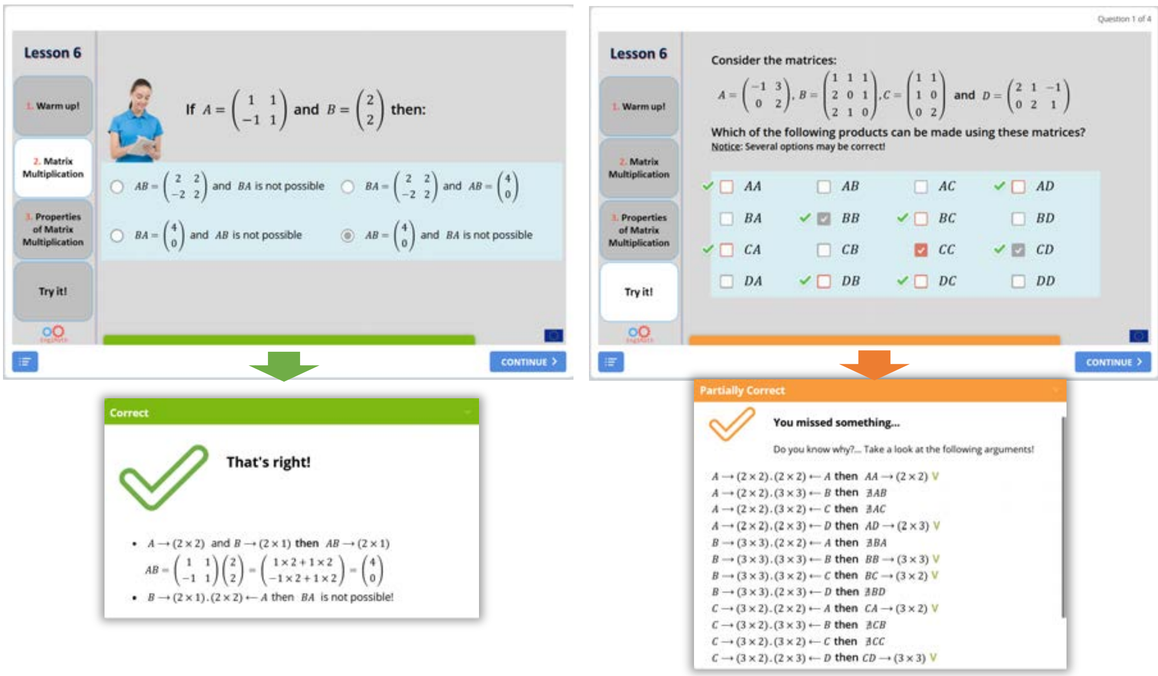

Figure 4. EngiMath Lesson sequential quizzes

With iSpring, the 26 Powerpoint lessons were transformed into e-courses, producing 26 SCORM packages that were uploaded into Moodle platform for testing. In these 26 lessons, there are more than 400 slides with over 3900 animations. The "Try it" quizzes, inside each and every lesson, were specifically constructed for this purpose and comprise a total that goes over 120 questions (from different types: multiple choice, correspondence, matching, true or false, etc). Each question has a proposed step by step solution that is showed to the student/user, even when they get the correct answer (Fig.4). A comprehensive overview of the principles and workflow of creating learning materials was published in March 2020 [15]. All these lessons, and respective SCORM packages, were firstly developed in English and, afterwards, all were translated into the other 5 partner's languages: Estonian, Polish, Portuguese, Romanian and Spanish.

It must be mentioned that, from previous experience of the Portuguese team, there was a felling towards avoiding video lectures [12] since, on the one hand, it is almost impossible to achieve a professional editing quality necessary to the project and on the other it is hard to avoid the "expertise reversal effect" [16], when dealing with this type of multimedia resource, and it should be minimized in theory introduction and presentation.

2.1.2 Exercises – Practical Component and Formative Assessment

Regarding the practical materials, with the background experience applied to the frame of Erasmus+ project EngiMath, a huge question bank has been developed for the online engineering mathematics course by the Estonian team (Fig.5). Special attention was paid to the development of STACK (System for Teaching and Assessment using a Computer Algebra Kernel) questions and step-by-step teaching tasks that give students a certain logical sequence of mental actions that must be performed to solve the problem [17]. Based on the objectives of the practical quizzes for each lesson, a testing model was compiled: a technological matrix containing competencies selected for practice and testing. For each competency, questions were created. When writing the questions, authors followed several guidelines for creating tests (e.g. [18], [19], [20]). Regarding the variability, in order to ensure the development of different practice experiences and tests, and also to allow randomness in the definition of the practical quizzes, each of these questions has, in average, 10 versions. Some questions and question versions were created using the STACK question type, which generates a different version of the same question each time it is opened or downloaded or the quiz is (re)started, since each STACK question has an individual pre-defined data range. The entire question bank, developed in English was also translated into the other 4 of the 5 partner's native languages (see example in Fig 6. where Spanish version is not available for now, since it is recently on the hands of the new project partner).

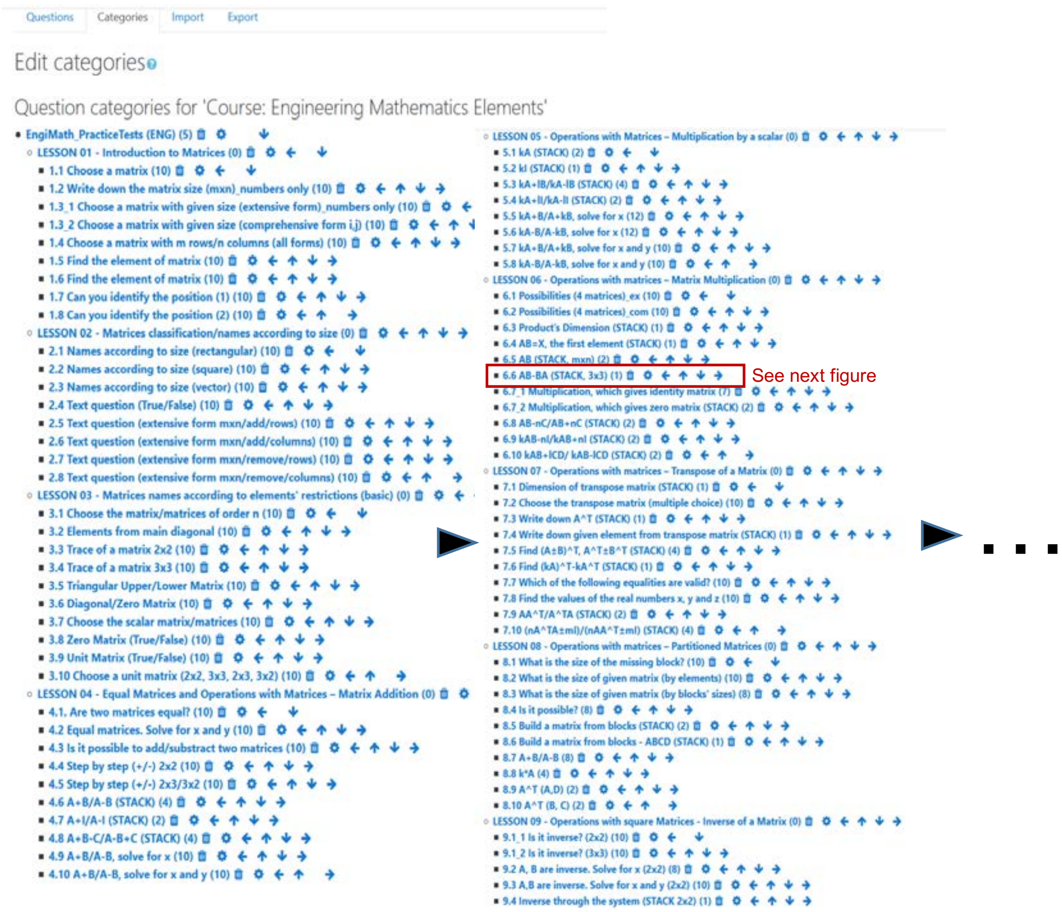

Figure 5. Short view of EngiMath Question bank – English version TTK Moodle

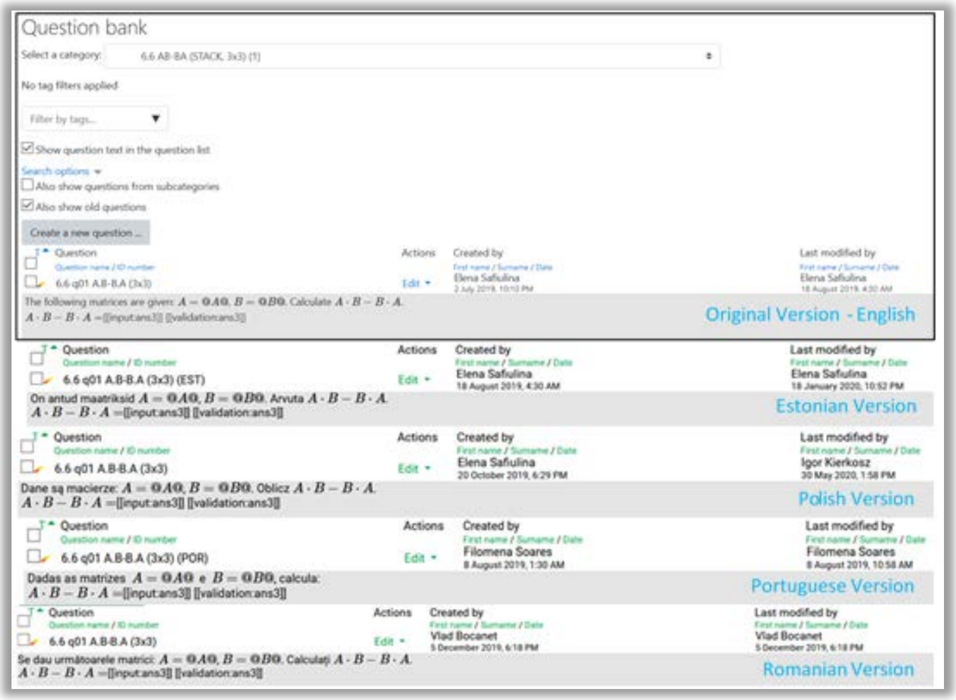

Figure 6. One question example - EngiMath Question bank – E/ET/PO/PT/RO

The question bank consists of more than 250 questions. So, in total considering, the number of questions' versions there are more 2500 items in question bank. There are over 50 close-ended type questions and more than 150 open-ended type questions. Exhaustive feedback has been provided for each question.

In Fig 7. an example of a STACK question is presented. Notice the feedback with a step by step proposed solution – this example shows the stack potential when developing Math question banks since just one question generates endless versions of the question which is crucial for practice purposes (regardless of the language showed, the question base is the same but matrices are distinct).

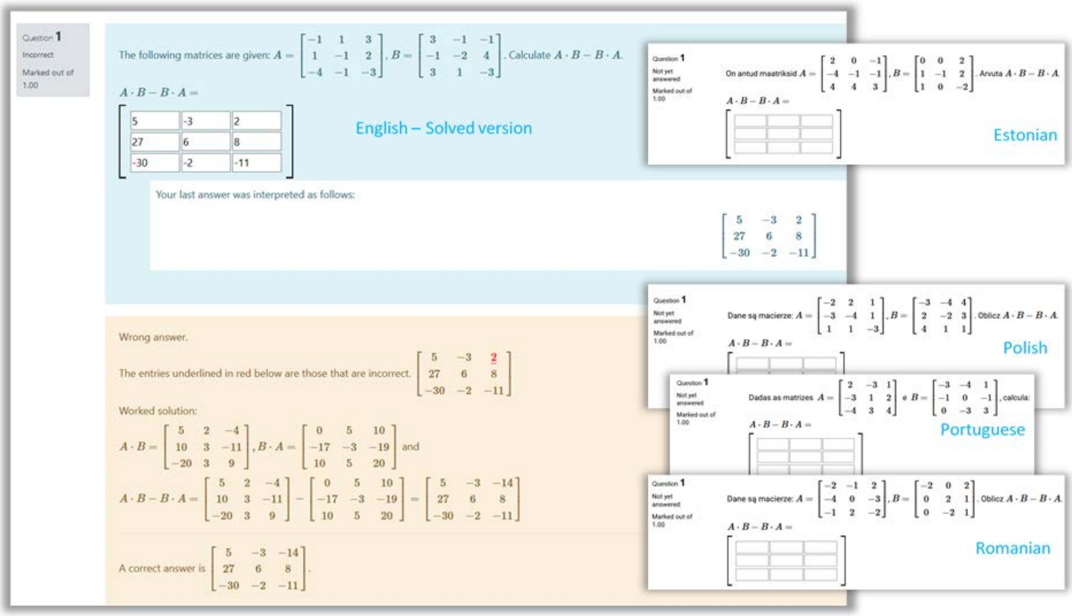

Figure 7. STACK question versions - example

2.1.3 Assessment Materials - Summative

Assessment materials are a consequence and interconnected to the previous activities. All the investigation done around this important section for the EngiMath online course was published in October 2019 [21]. As one important role of on-line technology is to facilitate teaching and promote learning and in the context of EngiMath online course (or any other online assessment task) only the student/user can know if the learning requirements are being fulfilled. In this sense it is necessary to ensure a form of summative assessment (as well as already mentioned for the case of training in the previous section) that validates the work developed without too much entropy caused by issues external to the contents covered. As mentioned in [21], approximately 90% of question types used within Virtual Learning Environments are selected response such as Multiple Choice Questions (MCQ). This option avoids problems with data entry when symbolic notation is required (where students incorrectly enter an invalid or unrecognized parameter) that is frequently mentioned by students as a barrier to progress. However, when using MCQ the assessor must be careful that the result cannot be deduced from the options provided.

The assessment materials have returned in September 2020, to the development phase, switching from Spain to Estonian team responsibility, relying on their expertise in the assessment field [22]. After piloting the course, all the Project team members felt the question selection developed for this section was not in accordance with all the support theory and practical materials and did not meet the minimum required quality. Authenticity of the assessment is fundamental to the learning process, combined with the requirement for objectivity in e-assessment that should try to imitate the actions of the human assessor, which has an added difficulty in the area of Mathematics.

2.2 Piloting Phase

In order to assess the quality of the course materials a study was done among students that took part in the pilot test. An online questionnaire was developed in English and distributed to all partner universities that translated it to the respective native language, in order to avoid “lost in translation” issues regarding the question interpretation. At the end of the pilot course, students got the link to the online questionnaire and had to fill it, voluntarily. The results were gathered by using a Google Form. The pilot courses were performed between September 2019 and February 2020. When gathering the questionnaire results for analysis there was a total of 95 available answers from Estonia, Portugal, Poland, Romania and Spain students.

Beside the socio-demographics, questions were created to assess the student’s interaction with the theory, practice and assessment materials. Most items used in the questionnaire used either 6-point or 7-point Likert scales. Students were asked to report their level of agreement with certain aspects of the course but open ended questions were also asked to get customized feedback from students. A short Piloting report is already published by the Project consortium [23].

It is important to mention that the piloting process was not “homogeneous” since not all the materials were tested in all the Project partner countries. First, at the piloting implementation timing, only 22 of the 26 final lessons and respective practice tests were available (in any language). Second, since the objective was to get students’ perception and opinion about course methodologic scheme and flow, there was a common felling that half of the first section was enough for the purpose. So, only Portugal did the complete available pilot course (22 lessons) since it was “inserted” in one real Math course and in the other countries only the 7 first lessons were in the piloting process. Finally, some assessment materials were still missing for some parts which led to some “independent” development for assessing Portuguese students.

The piloting phase was very revealing as it showed several important strengths and weaknesses [23]. In Fig. 8, there is a word cloud generated from the students’ answers to the question: How the course can be improved? Most words showed appreciation for the material but they also indicated the desire for more exercises and examples.

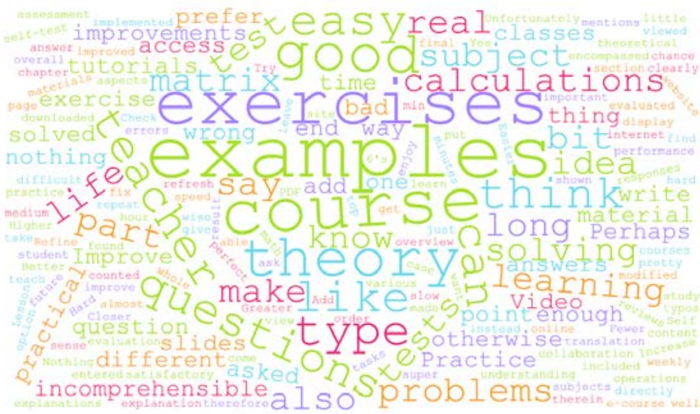

Figure 8. Word cloud - Pilot results - Image source:[23]

The results of the pilot course suggest that the materials are of high quality and that students had a pleasant experience interacting with them. Nevertheless, some lessons have been learned on how to better improve these materials for future courses.

3 FINAL COMMENTS

The EngiMath Project online course model construction has already completed the first “round” established by the ADDIE model (Analysis of Design Development Implementation and Evaluation) [15]. With the lessons learned from the piloting results and all the experiences, the course is now in a stage of refinement and ready to launch its beta version in English. The translations of the new and corrected materials will be taken care in the next few months.

The results and findings from all the course development, and connected investigation, have provided crucial information regarding priorities for the pedagogical design of the shared program materials. On-line assessment tools in the project are being improved and processed with the best available resources, however there is a general feeling among partners that the equivalence of the human assessor is not yet possible in the Mathematic area.

The methodological focus of the pedagogical model design, in the EngiMath course, is centred on student interaction within the learning environment, always addressing social, language, cultural and national concerns in a shared, collaborative programme while working under the boundaries of mathematics. Course materials, systems, and processes are truly transnational with each partner identifying particular issues to their own culturally accepted social norms.

One could not end without mentioning that the work amongst each partner team and institution was seriously affected by the COVID19 outbreak situation. All the extra work, unrelated to the project, has put pressure on the team members and their involvement in the project. Although the risks were identified at the beginning of the project, and appropriate strategies put in place, some risks like this pandemic stage are unpredictable. The Project work plan was successfully adapted to accommodate all these random and unfortunate events and all seems to be “in place” at the moment.

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