

## Research Article

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# Development of a Mathematics On-line Project in Engineering Education

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**Abstract:** Embracing tertiary education system represents the beginning of a transition and adjustment period for several students. Most of these have just finished high school where the environment is strictly defined, controlled, stable and attendance is mandatory. Higher Education changes the role of students' responsibility and this can cause stress and difficulty in the transition to self-directed learning and autonomy promotion. The purpose of this paper is to present an Erasmus+ project that brought together six Higher Education Institutions from different European countries and to describe its current stage. This project aims to develop a shared understanding of engineering mathematics at an early stage of tertiary education and to raise awareness of cultural, professional and educational issues. The initial focus of the work is on the partners' mutual interest in active learning, particularly the application of Information and Communication Technology in the field of engineering education. When finalised, the project hopes to provide students with a new authentic engineering mathematics subject which meets their needs. This is also the core reason why the on-line

course will be composed using innovative pedagogics and ICT tools, as appropriate pedagogics supports students' procedural, conceptual and application understanding in mathematics and enhances digital competencies, literacy and skills.

**Keywords:** Technology Enhanced Learning, Mathematics, Online Learning, Multinational Cooperation, Engineering Education.

## 1 Introduction

As reported by the Europe 2020 Strategy (European Commission, 2010) smart growth points to strengthening knowledge and innovation as driver forces of our future growth. This introduces improvements in the quality of educational systems, the enlargement of research performance, the support of innovation and knowledge transfer, the promotion of a full and better use of information and communication technologies and the assurance that new ideas can be turned into different products and services that generate growth, quality jobs and help to face global social challenges. Therefore, the starting point for the project is an open, centralized core system of accessible theoretical, practical, and assessment materials and techniques, which will be of maximum benefit to students and academics. New didactic methods and best practices for developing engineering mathematics on-line courses were chosen and mathematics on-line assessment systems were examined for this purpose.

The Erasmus+ EngiMath project idea has sprung up from practical needs and long-term communication with the partners. All partners have previous experience in new teaching methodology, ICT, curricula development, 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 partners' desire

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is to build an on-line course on the lessons learned in those assignments for the specific area of engineering mathematics basis. A student competition will be set within this context to bring international dimension to their studies. The students' competition in this project will connect learners from different countries through common tasks. It tries to create an open international space, where students can deal with assessment "stresses" in an indirect and spontaneous manner, promoting, through gamification, their self-confidence when dealing with on-line tasks, tight schedules or even working "against the clock", motivating them to complete the course and to avoid dropout behaviours.

### 1.1 The knowledge partnership consortium

The EngiMath Project consortium involves six Higher Education Institutions from six distinct European countries, namely, TTK University of Applied Sciences/TTK UAS (Estonia), Letterkenny Institute of Technology/LYIT (Ireland), Polytechnic Institute of Porto/P.PORTO (Portugal), University of the Basque Country/UPV/EHU (Spain), Technical University of Cluj-Napoca/UTC (Romania) and Koszalin University of Technology/PK TUK (Poland). All partners are experienced in implementing ICT and innovative practices in math education and several have been engaged and collaborated on informal projects and knowledge dissemination through conferences, seminars, and staff exchanges.

## 2 Project Approach and Development

In recent decades, the development of competencies and competitive workforce has been an important topic (Learreta, Kober and Tan, 2014). The recurrent problems when dealing with mathematics teaching and learning are well documented not only in EU, but also worldwide, and many governments have been addressing this issue as a matter of urgency (She, Stacey & Schmidt, 2018; OECD, 2016a; OECD, 2016b). The starting point for the project is an open, centralized, core system of accessible theoretical, practical and assessment materials and techniques, which will try to ensure maximum benefit to students and academics. There have been other projects that dealt with the use of ICT and teaching mathematical skills. The partnership is aware of those projects like, for instance, "Future Mathematics", "LearnIT", "Open

Discovery of STEM Laboratories" or "MatActiva" (e.g., Kinnari-Korpela & Rinneheimo, 2017; LearnIT, 2017; Adorno et al., 2018; Torres, Lopes, Babo & Azevedo, 2017, among others). Project partners also noticed that the assessment of mathematic skills and competences (as well as in many other subjects) using ICT is increasingly appearing in many programs, since digital competencies, literacy and skills are essential to the core structures of the working world (Wilson, Scalise & Gochyyev, 2015). However, the extent of resulting negative behavioural attributes does not seem to be considered as a primary concern within the design of ICT enabled programs (Hu, Gong, Lai & Leung, 2018; Hoogland & Tout, 2018). But, this fact cannot be neglected since a smooth transition to HE depends on the institutions' recognition of how digital competence in educational contexts is addressed in a supportive way to help students in their own sense of readiness to become self-directed learners. In EngiMath project construction and development there is a constant concern with analysing and converging the results and conclusions of previous projects and research and using them as a basis and taking their results into consideration for developing the current project.

### 2.1 Needs Analysis

Following and in accordance with this line of reasoning, one of the first steps of the Project was the development of a needs analysis and data gathering from all partner countries and institutions and specifying needs of assessment within Engineering Mathematics. According to McCawley (2009), a "needs assessment is a systematic study of the state of knowledge, ability, interest or attitude of a defined audience or group involving a particular subject".

The main reason for the inclusion of a needs' analysis within this programme of work was due to the development, testing and deployment of a novel paradigm in the technology enhanced learning mediated environment in six geographically, socially, and culturally separate institutions. Provisional outcomes that formed the basis were gathered and a proforma report structure was developed, where each partner conducted a needs analysis based on their own experiences and curriculum guided by the proforma. All data were gathered in a national database. It should be mentioned that this full educational "needs analysis" was not a trivial task and took many resources and hours to be completed (see Brown et al., 2019).

## 2.2 Project Target Groups

The project focus is targeting, fundamentally, two groups that can be distinguished through the way the project will address and reach them: the direct and the indirect target groups.

The direct target groups will include:

- Students in engineering mathematics programs at higher educational institutions;
- Academic staff teaching engineering mathematics in tertiary programs;
- Research Academics in the areas of Technology Enhanced Learning (TEL) and on-line learning.

Indirect target groups may include:

- Academic staff at secondary level;
- Other educational institutions wishing to use the materials, knowledge and expertise generated within the project to enhance their own curricula.

## 2.3 Project Quality Assurance

The quality of project's activities and results will be constantly monitored and evaluated. All partners are involved in this process, but the lead partner, UTC, will act as an independent quality assurance testing and validating organization. The aim of quality assurance is to guarantee the overall good quality of all project implementations. There are several important features in the quality assurance that should be emphasized, namely:

- Quality assurance plan – This plan was written at the beginning of the project and gives guidelines and requirements for all quality assurance activities of the project. The plan also sets the schedules and methods for quality assurance activities.
- Quality of project management activities – The activities are checked every 6 months. This is done via questionnaire conducted among all project partners. Project management activities are general project management, communication, conflict resolution, meeting practices, etc. The results are analysed, and corrective actions are taken accordingly.
- Document management and control – This is an important part of both internal and external project communication. Therefore, a quality system for managing these documents was set up. Version management and easy access were some important quality measures that were taken for document management and control. This is also checked, by collecting feedback from partners, every 6 months.

- Quality of reports and deliverables – The project results are only as good as the reports and deliverables it produces. To check the quality of the reports and deliverables, the project uses peer review.
- Success of dissemination activities – These are checked in different ways according to the nature of the dissemination activity. In determining the quality of dissemination activities, the project monitors the visits to the website, activity on social media, participation of stakeholders in workshops and seminars and success of press releases and articles.
- Risk analysis – Each activity coordinator makes the respective risk analysis of the activity. Project partners together find solutions to minimize the risks. The risk analysis is also checked every 6 months to make sure none of the risks have materialized and to minimize the corresponding impact.
- Quality of implemented project activities – The activities quality will be checked via feedback from participating students and staff. The feedback will be used for corrective measures and procedures, if needed. All the engagement/learning analytics tools available on the online platform of the project will be used to monitor users' behaviour and learning outcomes, offering the stakeholders a constant view of the project activities progress.

## 2.4 The on-line course

The aim of this project, as already stated, is to create a shared interface of mathematics resources for engineering students with support for procedural understanding, conceptual understanding, and application understanding, encompassed within an integrated environment of authentic learning and assessment.

The pre-established purposes and all the work developed, and to be developed (Brown et al., 2019), will lead to some intellectual output from the project, such as:

- 3 ETCS (European Credit Transfer and Accumulation System) on-line course in engineering mathematics in seven different languages – Basque, English, Estonian, Portuguese, Polish, Romanian and Spanish;
- Mathematics on-line assessment model to promote students' engagement, proactive behaviours, autonomy and contribution to the learning process in a more dynamic and direct way.

The first hard task the project partners had to deal with was to agree on the common core of the course. It was noticed that, even with all the global Educational System

the European Community aims to implement, this mission is far from being accomplished. As shown in Brown et al. (2019), despite all programmes at level 6 in the partner universities, representing 60 ECTS/year, the credit points for the mathematical topics in the first year of study vary in each partner institution from 10 to 28 ECTS. In this sense, partners had to struggle to get compromise basis to work with – the course common core.

## 2.5 Piloting Materials

After this common core agreement, the development of all the Theoretical, Practical and Assessment materials and activities started, with the all the task distribution between partners, according to the Project Proposal. All project resources are being developed in English and will later be translated into the other six languages mentioned above.

For the pilot course, which will start shortly in at least four of the six countries, the following resources were developed:

- 22 interactive lessons – These lessons were built by developing SCORM (Sharable Content Object Reference Model) packages based on animated PowerPoints with interactive questions generated in the Quiz segment of i-Spring software, acquired by the Project for this purpose.
- 22 practice quizzes – A database of questions on the project coordination Moodle Platform was created from scratch with the following characteristics:
  - Each quiz has between 8 and 12 questions, depending on the theme;
  - Each of these questions has at least 10 versions, several of which are STACK (System for Teaching and Assessment using a Computer algebra Kernel) questions, which allows a considerable number of distinct practical quizzes to be performed;
  - In all questions, including the STACK ones, the student is presented with the step-by-step resolution.
- 7 Assessment Tests – These Assessment activities, that group several lessons and practical quizzes, were first developed using i-Spring quiz extension but are being “transferred” to Moodle Assessment tools due to some grading restrictions.

All these materials have thus far been translated into, at least, Estonian, Portuguese and Spanish.

## 3 Conclusions and Future work

Still in its early stages, EngiMath Project already has the major part of the model construction completed. This ended up representing a vast amount of workload, which included its plan, task distribution, scheduling, content development, etc., to its first pilot implementation, for now, only in the testing phase. The scientific rigor and pedagogical suitability revision of all the developed resources have been guaranteed by external individuals, who are not part of the project. At this stage, project partners are building their own national models and soon EngiMath will enter the pilot phase.

Materials, systems, and processes are truly transnational with each partner identifying issues particular to their own culturally accepted social norms. The Project intellectual outputs have been openly and completely shared amongst, with and via the partners considering their specific needs, which is sometimes not easy given the existing cultural differences but, at the same time, it has been extremely rewarding. This work distribution and completeness contributes to maximize the potential to disseminate and share knowledge and materials even outside of the project partnership.

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