Research Article

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# DriVE-MATH: Reimagining Education

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**Abstract:** In this paper we provide a description of the project DrIVE-MATH, highlighting the main goals, intellectual outputs, outcomes, the involved partners, and activities and reports from the three-years' project. At the end we discuss the impact of the new proposed Education models at various levels, from students, to HEIs, to stakeholders.

**Keywords:** DrIVE-MATH; Education models; activelearning techniques; Agile education; eduScrum; JigSaw; Think-Pair-Share, Buzz.

## 1 Introduction

The entire world is living in a time of a dramatic and profound change with the Fourth Industrial Revolution. Development of new technologies (e.g., artificial intelligence, automation, intelligent robots, self-driving cars, genetic editing) sets the pace of human-kind evolution. Opportunities and challenges are just around the corner. Nevertheless, problems may arise with respect to future unemployment, from non-technological persons, poverty, lack of sustainable technologies, insufficient resources... To thrive in this ever-changing world, governments, stakeholders, families, must act together to prepare the present for their children, and most important to provide them with the essential tools for their future.

A substantial curiosity in Education and the most effective teaching methods to motivate students to learn, at all levels of knowledge, has been observed in the last decades. Knowledge is no longer perceived as a mere acquisition process and has become an actively constructive undertaking. The student is meant to be the owner of his/her knowledge, thus making the learning process more student-centred. This approach to education directs the focus to the student, his/hers learning needs, as opposed to the traditional way of teaching, centred around the teacher' input. Changes in the classroom theater also promoted distinct assessment techniques. Measuring students' academic abilities went from a purely summative practice, characterized by an individual written exam to a variety of tools, including formative assessment with feedback. Students are aware of their progress towards academic proficiency in a specific area, in a sustained way. Assessment can be used as means to motivate and uplift students' learning [29, 42, 43].

Students are requested to be active players in their learning process, to develop critical thinking, problem solving skills, curiosity, imagination, collaborative work, communication, soft skills extremely essential to the continuously challenging workplace. Alvin Toffler argues in his book Future Shock (1970) that *'The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn'*.

Students may struggle with Mathematics contents and, specifically, with the level of abstraction of the concepts. In 2016, a study from Magalhães [22] brought to light the difficulties of freshmen in a Calculus course at ISEP. What was identified poor prior knowledge acquisition, which translated to errors, inadmissible at this level of education. This deficiency constituted major obstacles to further development of more complex abstract mathematical contents. Another study from Viamonte *et al.* [52] promoted students' engagement using gamification techniques in a Linear Algebra and Analytical Geometry course, with the aim of reducing students' dropout. Bearing these ideas in mind, we idealized a plan to promote and develop essential competences in engineering students, key to their future professional success, by promoting new teaching methodologies to teach Math courses. The DrIVE-MATH Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees project was submitted to the Erasmus+ KA203 call in March 2017, Key Action: Cooperation for innovation and the exchange of good practices, Action Type: Strategic Partnerships for higher education. It was approved and financed with an EC Grant of 288400,00 EUR. DrIVE-MATH started officially

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in September 2017 and ended in February 28th 2021. The Project Reference is 2017–1–PT01–KA203–035866. Highlighting topics: Quality and Relevance of Higher Education in Partner Countries; New innovative curricula/ educational methods/development of training courses; Recognition, transparency, certification.

The website of the project is DrIVE-MATH and Erasmus+ site

The teachers involved in the project strongly believe that the implemented active-learning (AL) methodologies provide better scientific and soft skills' support to current students and future professionals.

From the second semester of 2019/2020 all the students worldwide were suddenly, and with no prior warning, thrown to a fully online teaching environment. This is defined as emergency remote teaching (ERT). This unexpected change has and will have consequences in the near and distant future for learning quality, students' motivation and engagement, and others. This constituted an additional challenge to the professors directly involved in the DrIVE-MATH project. All pre-scheduled activities had to be shifted to fully online, namely multiplier events, short-term joint staff training events, and the project final meeting.

Bearing the aforementioned ideas in mind, in the following sections, we describe in more detail the Goals, the involved Partners, the Dissemination and Exploitation activities, and the Impact of the DrIVE-MATH project.

## 2 DrIVE-MATH Goals

The goals of DrIVE-MATH were defined in three main intellectual outputs, described as follows.

### O1: Curricula Update

This intellectual output was devoted to the curricula update, concerning the revision and re-structuring of the Math courses' syllabus. This constituted a key point to bring together the innovative pedagogical tools, specifically active-learning (AL) teaching tools, including problem-based learning, hands-on, eduScrum, CaseStudies, Buzz, Q& A, Think-Pair-Share, among others.

The tasks assigned to each partner included the selection of some Math courses, from one or more Baccalaureate and/or Master degrees. These Math courses were then adapted, taking into consideration the required baseline Math competences, contents, and other relevant issues. Each partner proposed the adaptation of their own Math courses' syllabus. The proposed syllabus was then discussed among the other partners and with other colleagues from the Math Departments at each Higher Education Institution (HEI), as to ensure the most effective way to achieve an effective implementation of AL. This meant that the working groups at each HEI had to discern what knowledge individual learners have acquired, to decide whether to move forward with covering the curriculum, applying the new learning or reviewing existing material in greater depth. This process represented a significant transformation for which HEI are expected to be prepared.

During the three-year project, several Math courses were selected for modernization and pilot implementation of the AL teaching model. They included Statistical Models, Linear Algebra and Analytical Geometry, Computational Mathematics, Differential and Integral Calculus.

This was the first step to the effective design of a new profile for a future professional in Engineering or other areas, related to the degrees provided by the Partners' Universities. This new profile was intended to help the students respond in an effective way to the challenges of the new lifestyle, due to the technological developments of the Fourth and (almost here) to the Fifth Industrial Revolutions.

Throughout the project, curricular evaluation meetings (see subsection 4) provided the partners with a place to exchange knowledge and experience in revising curricula, according to the new methodologies. Relevant stakeholders were invited to the discussions.

### O2: Adaptation and Modernization of Pedagogical and Working Material

In this intellectual Output, each partner was responsible for the adaptation of existent pedagogic materials, to accommodate the novel AL teaching model. The topics were selected according to their appropriateness to the AL environment ( eduScrum methodology, handson, problem-based-learning, case-studies, project-basedlearning, challenge-based-learning), and to their adequacy in helping students achieving the learning goals. All teachers involved in the project reviewed and selected theoretical and practical exercises, worksheets, other assessment materials, including written tests, and problems. Teachers worked both individually and in the scope of the DrIVE-MATH team. As such, every partner was able to gain and receive valuable insights from the accumulated experience of every other member in reviewing and recommending materials.

Substantial pedagogical materials have been adapted and compiled at all partners' Universities.

### O3: Peer-learning Methods

Peer-learning is an expression commonly used when students learn with and from each other, viz. learn with and from their peers [9]. In the scope of DrIVE-MATH, this expression was 'abusively' applied for the interchange of activities and knowledge between the teachers involved in the project and other teachers at theirs and foreign universities. The aim was to disseminate and promote the exploitation of the new teaching models, added to the adapted and novel pedagogical materials, among other HEI's teachers. The focus was on the increase of students' learning confidence and to assist students in developing collaborative learning partnerships. This was all promoted in an agile education classroom.

Each partner was responsible for the adaptation and modernization of previous peer-learning activities to the new Education models. The former was implemented through a series of training workshops for University teachers. Activities and topics covered:

- Training and Teaching Methodologies for Teaching Staff I, II;
- Curricula Modernization and Adaptation I and II;
- Innovative Pedagogical Evaluation Workshop;
- Case Studies Evaluation Workshop;
- Presenting the results of the Implementation of Hands-On and PBL Experiences in Math Curricula for Engineers;
- Workshop on Application of eduScrum Methodology in Math for Engineers;
- Evaluation Methodology Training;
- SWOT Analysis on the Evaluation of ActiveLearning Methodologies;
- Workshop on the Role of Active Learning in Math Curricula for Unmotivated Students;
- Third-year Mid-term Curricular and Evaluation Methodology Activity;
- Final Curricular and Evaluation Methodology Activity.

The list of the publications in the scope of the DrIVEMATH project is at the end of this paper [7, 8, 14– 20, 23, 24, 26–28, 30–32, 35, 37–41, 44–47, 49]. This Special Issue constitutes a compilation and a probable guide for teachers all around the World to give the first steps towards a more Agile way of thinking and transforming Education. The future is here, is not around the corner any longer.

## 3 Partners

### 3.1 Polytechnic of Porto Coordinator

The HE System in Portugal is organized around universities and Polytechnics, which have a special status. These schools offer the Bachelor degree after 3 years of studies, or the Master degree after 5 years of studies. These institutions have recently been permitted to deliver Doctoral diplomas. In order to do so, they must establish a partnership with a university. Therefore, most universities are 'classical' universities, while engineering schools take the role of 'technical' universities.

The Porto Polytechnic (P.PORTO) is the largest and the most dynamic Polytechnic in Portugal, occupying the first position in the ranking of the Polytechnics. In conjunction with major universities, it is placed in the upper reaches of the ranking of National Higher Education. Its mission is to be the leader of the Polytechnic subsystem in Portugal, assuming its social responsibility in the presence of the community and society, in an international frame of reference, demanding for excellence. It includes eight schools, which are located in three Campuses, 30 research centers, more than 18,000 students, 59 undergraduate degrees and 70 masters' degrees, covering different scientific areas: Engineering, Accounting and Administration; Education; Music and Performing Arts; Media Arts and Design; Hospitality and Tourism; Management and Technology, Health.

P.PORTO has 24 scientific research centers and groups, distributed across its eight Schools. The School of Engineering of the Polytechnic of Porto (ISEP) is one of the top schools of technology in Portugal. ISEP has been pioneering education and research in Engineering since 1852. Its goal is to contribute to the achievement of sustainable development, by creating and transmitting applied knowledge. Future engineers graduating at ISEP can produce creative solutions for present or upcoming challenges, becoming agents of global progress.

ISEP offers a wide range of programmes in different fields of Engineering. With more than 6000 students, each one is unique and has the ability to excel. ISEP's role is simply to channel their potential with the spirit of entrepreneurship, team work, out-of-box thinking (or thinking like there is no box) and technical expertise, key competences for a successful international career.

ISEP is also a trademark of Porto [2]. This modern European city, known for its beauty, booming cultural agenda and strong traditional roots, is the Portuguese academic capital. Porto is also known for the friendly and cosmopolitan environment, which helps explain the large attraction of international students.

Along with renowned institutions, such as MIT (Massachusetts Institute of Technology), ISEP is a member of the international consortium CDIO (Conceive Design Implement Operate) and has more than a hundred partnerships within the European Space of Higher Education. Studying at ISEP is an invitation to interpret and solve tomorrow's challenges. There are 11 research centers at ISEP. ISEP offers 13 Bachelor degrees, including:

- Automotive Engineering;
- Biomedical Engineering;
- Bioresources;
- Chemical Engineering;
- Civil Engineering;
- Electrical And Computer Engineering;
- Electrical Engineering Power Systems;
- Geotechnical And Geoenvironmental Engineering;
- Industrial Management And Engineering;
- Informatics Engineering;
- Mechanical Engineering;
- Systems Engineering;
- Telecommunications And Informatics Engineering. and 15 Master degrees, namely:
- Biomedical Engineering;
- Bioresources;
- Chemical Engineering;
- Civil Engineering;
- Development Practice;
- Electrical And Computer Engineering;
- Engineering And Industrial Management;
- Geotechnical And Geoenvironmental Engineering;
- Mechanical Engineering;
- Medical Computing And Instrumentation Engineering;
- Sustainable Energies;
- Artificial Intelligence Engineering;
- Computer Critical Systems Engineering;
- Electrical Engineering Power Systems;
- Informatics Engineering.

## 3.2 Université Claude Bérnard Lyon I

The Higher Education System in France is organized not only around universities but as well around Engineer Schools which have a special status. These schools are often independent and usually don't belong to a university. Their training is limited up to the 5th year after national Baccalauréat Degree or equivalent. These institutions are not permitted to deliver Doctoral diplomas by themselves. In order to do so, they must establish a partnership with a university. Most universities are 'classical' universities, while engineering schools take the role of "technical" universities.

### 3.2.1 Engineer training at Lyon

Higher Education players in Lyon are gathered into the Université de Lyon consortium that comprises 129 000 students and 11 500 researchers. This model is under work right now (2019) and the following description might be soon out of date.

Université Claude Bernard Lyon 1 is the science and technology university of the Université de Lyon. There are 3 000 researchers for 68 research laboratories and 40000 students in 13 teaching departments.

University studies leading to the 'licence' (LMD) are structured into six semesters (3 university years). They are organised into domains, in the form of standard initial and continuing training courses. These courses lead to the awarding of various "licences" that confirm a validated level by obtaining 180 European credits. They allow the awarding, on the intermediate level, of various types of national diplomas validating a level corresponding to 120 European credits.

UCBL hosts the engineers school Polytech. It belongs to a network of 13 engineering schools embedded into universities. The school in Lyon was founded in 1992 and joined the Polytech network in 2009. It grew to become quite an alternative to more classical engineering schools. The recruitment of Baccalauréat students (aged around 18) is done at a national level through a common procedure, shared with other 29 engineering schools: the Geipi Polytech competitive exam awarding more than 3000 students a ranking into the affiliated schools from which to make a choice. Polytech Lyon majors are chosen by around 200 of them per year.

The two first years are preparatory, following the program of other classical preparatory schools but inside the university.

There are 6 majors in Polytech Lyon, rooted in the scientific workforce in UCBL:

- Biomedical engineering;
- Computer science;
- Materials sciences;
- Modeling and applied mathematics;
- Mechanical engineering;
- Industrial engineering and robotics.

These majors are backed up by research laboratories of the UCBL in which the teachers belong as researchers. Most of these laboratories are associated with CNRS

(French National Agency for Research). For mathematics, it is the Institut Camille Jordan UMR CNRS 5208 (ICJ). Two six months internships in industry or research laboratory are performed in the fourth and fifth year of study. International training is mandatory, whether as a student or as an intern.

## 3.3 Chemnitz University of Technology

The engineering training at the Chemnitz alma mater has more than 175 years of tradition. In 1836 was founded the "Royal Gewerbschule Chemnitz", a reputable educational institution. In the past, several personalities, known for their significant contributions to science and technology, studied and taught in this faculty [5] . The decisionmaking bodies of the University include: Academic Senate, Extended Senate and University Council. University management is divided into five parts: President, Vice President for Transfer and Academic Qualification, Vice President for Academic and International Affairs, Vice President for Research and Junior Researchers and Chancellor [6] .

The programs are offered by eight different faculties:
- Natural Sciences;
- Mathematics;
- Mechanical Engineering;
- Electrical Engineering and Information Technology;
- Computer Science;
- Economics and Business Administration;
- Humanities;
- Behavioral and Social Sciences.

Added to these faculties are nine institutions, which provide different courses:
- Centre for Young Researchers;
- Federal cluster of Excellence MERGE;
- Research Academy;
- Saxony's Centre for Teaching and Learning;
- University Library/ Patent Information Centre;
- International Office;
- University Computer Centre;
- Foreign Language Center;
- Centre for Teacher Training-

### 3.3.1 Faculty of Computer Science

The Faculty of Computer Science offers academic programs in the fields of Embedded and self-organizing systems, Intelligent multimedia systems, and Parallel and distributed systems. The guiding principle of this faculty is the continuous innovation through advances in research. Thus, are promoted solutions to current problems and challenges, on an internationally competitive level.

This faculty provides 2 diploma, 4 bachelor and 10 master programs [4]. The faculty of computer science has 12 full professors, 2 junior professorships and an honorary Professor. The faculty strives to provide a maximum personal interaction between students and staff.

Some programs are totally offered in the English language. An example is the master program on 'Automotive Software Engineering' [1].

### 3.3.2 Professorship of Computer Engineering

The responsible person for the Computer Engineering Professorship is Univ.-Prof. Dr. Wolfram Hardt. The professorship research focuses on three main fields:
- Self-Organizing Systems.
- Re-configurable Systems.
- Robust Embedded Systems

The professorship of Computer Engineering offers 11 different courses to support bachelor and master levels.

## 3.4 Slovak University of Technology, Bratislava

Slovak University of Technology in Bratislava (STU) is the largest and best technical university in Slovakia, with 7 faculties and the Institute of Management. STU is a public university and offers education mainly in technical, technological, technical-economical, technicalinformation and technical-artistic fields of study. Modern methods of education, laboratories and practical training are routine practices. This aims at promoting future opportunities for students' employment at labour market. The studies at STU and its faculties are performed at 3 levels: the bachelor degree, the engineer or master degree study program, and the doctorate degree study program.

STU offers education in foreign languages, primarily in the following areas: civil engineering, mechanical engineering, electrical engineering, chemistry and food technology, architecture. STU in Bratislava strives to be an internationally recognized and important, research-oriented technical university. It seeks to provide a high quality, internationally comparable education to a broad spectrum of students from the young generation in promising fields, based on independent and critical thinking, entrepreneurship and creativity, with a view to practical application and success in life, and taking into account the human aspects of education and technological progress.

Faculty of Mechanical Engineering at the Slovak University of Technology in Bratislava is one from 7 faculties at the largest technical/ university in the Slovak Republic whose main role is to teach and graduate future bachelors and engineers for the various specialisations in the fields of mechanical engineering, automotive industry and mechatronics. Studies are delivered through seven bachelor programs of 3 years duration (leading to the Bachelor of Science degree, – BSc, (Bc. in Slovakia), and twelve 2year graduate programs leading to the Master of Science degree – MSc or Engineer -Ing., the academic degree acquired after successful completion of a master program in technology. This framework is still applied in a number of European countries and is fully equivalent to an MSc. A degree program at FME STU prepares graduates as professionals with a sound, technological training, analytical skills and valuable assets for the employment market. The Faculty maintains close links with international industries such as Volkswagen, Kia, Peugeot-Citroën, Siemens, BMinter alia, a strategic alliance contributing to the relevance of its academic programs and career prospects for its graduates. The Faculty of Mechanical Engineering offers also Bachelor studies taught in English for both Slovak and international students. All programs taught in the English language have the same curricula and the subjects have the same syllabi as courses taught in the Slovak language. Bachelor study programmes have prescribed structure for 3 years, and the program comprises 3 types of subjects assigned with ECTS credits according to their complexity. The first two years of bachelor programs consist of obligatory courses, compulsory elective courses and elective courses. Courses related to mathematics, namely Mathematics I in the first semester and Mathematics II in the second semester of the first year of study, which are of this survey interest, are obligatory courses. Elective courses related to basic mathematics are Additional exercises in Mathematics I and Additional exercises in Mathematics II. Numbers of contact teaching hours per week in semester and assigned credits for these courses are presented in the following table.

All courses are mostly delivered in the classical way. In the lecture theatres, where lectures for large groups of about 100 students are provided, using blackboard, whiteboard, or computer presentations, with basic formulas, definitions of basic concepts, and theorems, are developed by individual lecturers. Often interactive applets, animations and other relevant illustrations and visualisation materials are used to foster students understanding and showing them examples of various ICT tools and their utilities. Students have also access to electronic learning materials available in the Academic Information System of university. The Faculty library offers a wide choice of suggested books, lecture notes and collections of problems as literature for study, either in the special equipped study rooms, or available to borrow from the library for home study. Attendance at lectures is compulsory, as it is also for practical exercises. Practical exercises are scheduled by tutors, mostly in a traditional way, in smaller groups of 20-25 students. These are meant to practise solutions of problems based on theoretical knowledge from the lectures.Tutors can present a few typical examples of how to solve respective problems, then students can work either independently, or in a group. They can volunteer to present solutions on blackboard, or they can simply ask questions to receive hints on how to solve problems on their own. Assessment of their progress is realised through two written tests during the semester, where they can get up to 40 points that represent 40% of the total score required for passing examination. Tutors and lecturers provide consultations on a regular basis to all interested students during the semester and also organised consultation sessions during the examination period.

# 4 Dissemination and Exploitation

The results of DrIVE-MATH were disseminated through several means, including activities, promotional materials, presentation/publication of teaching experiences at several international conferences, workshops, journals, conference proceedings, amongst others [7, 8, 14–20, 23, 23, 24, 24, 26–28, 30–32, 35, 37–41, 44–47, 49].

Table 2 depicts the list of papers by country and year.

The promotional materials included a promotional video, a leaflet, the X-banner and a Facebook website.

Furthermore, a website to disseminate the outcomes and activities, was created at each partner university.

## 4.1 Activities

In this subsection we briefly describe the activities developed in the scope of DrIVE-MATH.

**Table 1:** Math Courses, contact hours and ECTS at STU.

| Course Name (T TP) | Contact hours | ECTS |
|---|---|---|
| **Mathematics I** | **4-4** | **10** |
| **Additional exercises in Mathematics I** | **0-2** | **1** |
| **Mathematics II** | **3-3** | **6** |
| **Additional exercises in Mathematics II** | **0-2** | **1** |

### 4.1.1 Training and Teaching Methodologies for Teaching Staff I

The project started with a meeting at ISEP/Porto, in November 2017, concerning Training and Teaching Methodologies for Teaching Staff I. Were discussed the main goals, development process, and expected outcomes of the project. Moreover, the coordinators promoted a Workshop to exchange the best teaching practices and experiences among the four institutions at that time. The goal was to better understand the conceptualization of pedagogy and review current practices. At ISEP, the new methodologies have been used at the Informatics Baccalaureate Degree, since 2010.

### 4.1.2 Curricula Modernization and Adaptation

The second meeting took place in Bratislava at Faculty of Mechanical Engineering of Slovak University of Technology in February 2018. The working groups of each University agreed to define structural curricula improvements and identified the areas more suitable to apply the new teaching strategies, viz. active-learning methods, including Problem-based learning, Project-based learning, hands-on, eduScrum.

Each partner University selected Math courses, Calculus I, Calculus II, Linear Algebra and Analytic Geometry, Probability and Statistics, from at most three BSc programs. The working group formed in every partner University from Math Departments assumed the task of revising the math component of the curricula using knowledge and recommendations obtained within Curricula Update (O1). The curricula must apply new learning and practice new skills in different situations and contexts. This also means that the working groups in each of the Universities must ascertain what knowledge individual learners have acquired, to decide whether to move forward with covering the curriculum, applying the new learning or reviewing existing material in greater depth.

**Table 2:** List of papers published in the scope of DrIVE-MATH, per year and per country.

| Year | Country | Reference |
|---|---|---|
| 2018 | Portugal | [27] |
| 2018 | Portugal | [38] |
| 2018 | Portugal | [30] |
| 2018 | Portugal | [41] |
| 2018 | Portugal | [26] |
| 2018 | Portugal | [31] |
| 2019 | Portugal | [28] |
| 2019 | Portugal | [39] |
| 2019 | Portugal | [40] |
| 2019 | Portugal | [32] |
| 2020 | Portugal | [8] |
| 2020 | Portugal | [23] |
| 2020 | Portugal | [35] |
| 2020 | Portugal | [37] |
| 2020 | Portugal | [36] |
| 2020 | Portugal | [25] |
| 2021 | Portugal | [7] |
| 2021 | Portugal | [24] |
| 2018 | Slovakia | [47] |
| 2018 | Slovakia | [48] |
| 2019 | Slovakia | [49] |
| 2019 | Slovakia | [49] |
| 2020 | Slovakia | [17] |
| 2020 | Slovakia | [18] |
| 2020 | Slovakia | [19] |
| 2020 | Slovakia | [50] |
| 2020 | Slovakia | [51] |
| 2018 | Germany | [14] |
| 2018 | Germany | [15] |
| 2018 | Germany | [20] |
| 2018 | Germany | [53] |
| 2018 | Germany | [45] |
| 2019 | Germany | [16] |
| 2019 | Germany | [54] |
| 2020 | Germany | [46] |

#### 4.1.3 Curricula Modernization and Adaptation

This was the third project meeting, which took place in May 2018, in France at Université Lyon 1 Claude Bernard. The main purpose was the Selection of Pedagogical Materials. The materials are key elements in planning educational activities directed to students learning, along with the organization of space and time. A major challenge in engineering education is to maintain quality while dealing with large numbers of students, with diverse skills and intellectual abilities. Generally, a typical class from an engineering institution has students from various knowledge backgrounds, with diverse motivation levels and learning styles. All partners took part of a class of a Linear Algebra course, attended by 2nd year students at UCBL. The responsible teacher was Pr. Luca Zamboni. The partners taught and guided students with the knowledge acquisition of three different methods (numerically algebraic or procedural ways) to solve the same linear algebra problems. All partners analysed the results of this experience, promoting better teaching methods by practicing them. The intellectual output produced since the previous and current meeting was reviewed, discussed, and amended.

#### 4.1.4 Innovative Pedagogical Evaluation Workshop

This short-term joint staff training event took place in June 2018, at Germany. It consisted of seminars where each partner presented to the others their perspectives on how to implement the new teaching methodologies, with respect to the production of corresponding teaching materials and curricula modernization. All participants exchanged opinions concerning the on-going pilotimplementation of the project. Partners discussed how to pursue with the implementation of the new methodologies at each course at their own institution. Pros, cons were evaluated. In addition the colleagues from Germany introduced the ESF Project Presentation ‘Digitalization of Teaching in Mathematics’, gave some practical courses on e-Learning based teaching examples at TU Chemnitz, and reported from the International RoboSchool, as part of the BMBF-Project ‘Individuelle Übergänge ergründen, beraten und gestalten (TU4U)’. This event contributed to upgrade partners’ educational system and implement innovative teaching strategies within their curriculum, which encouraged positive learning environments and raised the standard of the institutions.

#### 4.1.5 Training and Teaching Methodologies for Teaching Staff II (Second annual meeting)

This meeting took place in Bratislava in October 2018. The partners discussed and reflected on the progress of the project, with respect to teaching materials and modernized curricula. The tangible results of the application of pedagogical methodologies and assessment methods for future activities were discussed. In this process, all partners were involved, reflecting on the different interests and needs in order to provide the link between past and futures activities, and supporting improvements on the ongoing project.

#### 4.1.6 Workshop on Application of eduScrum Methodology in Math for Engineers Higher Education

This meeting took place in May 2019, at ISEP/Porto, were presented the results of implementations of activelearning experiences, namely Hands-on and eduScrum, and shared best practices for each type of content and level. Integrated in Intellectual Output O2Adaptation and Modernization of Pedagogical and Working Materials, we discussed details of the elaboration of the final book of the project, and the division of the tasks and deadlines to be met until the end of the project.

Considering the goal of creating educational content, the selection of the pedagogical material focused on: eduScrum methodology, hands-on, problem-basedlearning. Assessment materials selection involved written tests, worksheets, problems, e-assessment tools, amongst others. We had several discussion sessions of administrative issues concerning the remaining activities of the project, namely: on further developments of activelearning methods at the partners’ institutions Chemnitz; on further developments of active-learning methods at the partners’ institutions – Lyon; further developments of active-learning methods at the partners’ institutions – Bratislava; on further developments of active-learning methods at the partners’ institutions ISEP.

Plans for future and ongoing common articles were discussed and laid out. The intellectual output, produced since the last meeting and during the meeting was reviewed, discussed, and amended.

Additionally, the Oporto’s team organized the InsTead IV (see below).

#### 4.1.7 Evaluation Methodology Training

This meeting took place in Germany in June 2019. This activity aimed at discussing tangible results from the application of new teaching practices in the academic year of 2018/2019. In this process, all partners were involved, reflecting about the different interests and needs in order to provide the link between past and futures activities, and to support improvements on the ongoing project.

Each partner assessed the results of the pilotimplementation of the novel methodologies at their institution. Statistic tools were used to process the data coming from: post-tests, questionnaires for teachers and students, answers to open questions. Furthermore, teachers' and students' perceptions on several aspects, were analyzed, concerning the clarity of the stated educational aims and learning outcomes, perception of the usefulness of the curricula, curriculum's challenges and assessment criteria. Each partner assumed the compilation of a midreport.

#### 4.1.8 SWOT Analysis on the Evaluation of Active-Learning Methodologies

This meeting was held in France in December of 2019. A SWOT analysis of the implementation of the activelearning teaching methods was perfomed: strengths, weaknesses, opportunities, and threats, with respect to case study methodologies, pedagogical reforms. Comparison of math courses' teaching with respect to the use of exercises and resources, having in mind a longitudinal perspective, as well as the motivation of the participating students, were performed. Moreover, we discussed the mid-reports of the evaluation of the results, of the first year of pilot-implementation. In this meeting was started to devise the pedagogical strategies to discuss in the Workshop – The Role of Active Learning in Math Curricula for Unmotivated Students (E5).

Due to COVID-19 pandemic, the following scheduled meetings were done in an online way.

#### 4.1.9 Final Curricular and Evaluation Methodology Activity

This meeting was held online on May 2020. It constituted an opportunity to exchange all know-how and good practices, resulting from the implementation of the new teaching methodologies, by the partners involved in the project. Each partner learned from everyone else's experiences, knowledge and training was shared. Teaching experiences (materials, videos, lectures, slides) were presented and all partners learned and discussed on how to improve: the materials, the way the message is sent to students; on how to apply a student-centred learning, giving students the autonomy to develop the soft skills needed in this continuously changing world (Flexibility and adaptability, Global and cultural awareness, Information literacy, Leadership). ". . . if learners are not trained for autonomy, no amount of surrounding them with resources will foster in them that capacity for active involvement and conscious choice, although it might appear to do so"(Hurd, 1998, p. 72-73).

### 4.2 Multiplier Events and Workshops

In this subsection, we detail the multiplier events and workshops devoted to the dissemination of the outcomes of the DrIVE-MATH project.

The InsTead – Workshops on Innovative Teaching Methodologies for Math Courses on Engineering Degrees series have begun with the sole purpose of promoting the exchange of the best teaching practices and experiences in Engineering Courses. Topics included current conceptualization of pedagogy and review of teaching practices, as well as students' perceptions and expectations of their learning process, mathematics anxiety, soft skills, hard-skills, essential skills, active-learning frameworks, student-centered learning, teachers' role in education, online education, and many others. The role of engineers in industry and mathematical competencies and skills expected from engineering students in the Industry 4.0 and the upcoming 5.0 were also tackled.

There were six editions, until June 2020, of these InsTead workshops. Each has had a strong scientific program, with renowned national and international invited speakers in the area of Education. Scientific Committees included experts from different countries worldwide, namely Portugal, Germany, France, Slovakia, Norway, Italy, Ireland, Finland and USA. At each edition, there was a program slot devoted to the discussion of relevant topics from Education and Industry. Prominent personalities from the academic and business worlds were invited to contribute in a valuable way to a better understanding and interaction between these two worlds.

#### 4.2.1 InsTeaD I Case Studies Evaluation Workshop

This meeting took place at ISEP, on November 2017. A considerable number of successful case studies at ISEP and at the partners' universities was presented, involving new pedagogical methodologies, emphasizing the application of eduScrum, adaptation of course curricula, the problem-based-learning (PBL) approach, learning by doing (hands-on).

The later promotes the active learning teaching approach by working in real world engineering problems. The application of these new methodologies has had a positive impact in students' academic course at ISEP and the overall know-how of all partners involved will provide a solid ground and boost the beginning of the current project.

The first Workshop InsTead I was held in Porto on November 2017. Several talks were presented regarding different approaches to educational innovation: Projectbased learning (PBL) case studies, video on educational process, math modelling and art, teaching strategies and projects developed to enhance students learning and engagement.

#### 4.2.2 InsTead II

The Workshop InsTead II took place on June 2018 in Porto. Bringing together researchers from different countries for an entire day, topics discussed focused on Mathematical competencies for engineering students, interdisciplinarity in engineering teaching, the role of games, gamification and flipped classroom on math classes, digital assessment tools and feedback. This workshop ended with the round table entitled "The soft skills of the 21st century Engineers". A worthwhile discussion around this subject had the participation of academy and companies, namely, GROHE, HR Business Partner Bosch and Mota & Engil.

#### 4.2.3 InsTead III Presenting the results of the Implementation of Hands-On and PBL Experiences in Math Curricula for Engineers

This meeting took place at UNIVERSITÉ LYON 1 CLAUDE BERNARD from 11th to 15th of February 2019. The main goal was to exchange the best activelearning teaching practices (namely hands-on and PBL) along the pilot-implementation of the methodologies proposed in the project (academic year of 2017/2018). The meeting consisted of presentations on how to develop a framework to deliver classes using this new teaching strategies, to offer an efficient involvement of math subjects and engineering environments. This helped the main goal of education that is to develop students' competences on adaptability, communication, collaboration, initiative, analysis and conceptualization of information, curiosity and imagination. Students engaged actively in their learning process and the teacher acted as a guide, by proposing new research directions, methods, and tools. The partners agreed that an engineering education is acquired over a long period and in a variety of institutions, and that educators in all parts of this spectrum could learn from these practices.

#### 4.2.4 InsTead IV Workshop on Application of eduScrum Methodology in Math for Engineers Higher Education

The DrIVE-MATH coordinator from Porto organized the InsTead IV, in May 2019. There were very constructive discussions over different techniques and strategies for teaching Math courses, particularly, how this subject could be presented in a more engaging way, using gamification or funny mood videos, e.g. 'Mathgurl'. Some presentations were focused on the use of technological applications, virtual and remote labs. InsTead IV ended with a round table under the theme of 'New trends in higher-education' regarding different pedagogical approaches with the participation of members of different companies like HUMANITY UNITED, GROHE, EFACEC, MBA and renowned academic personalities.

#### 4.2.5 InsTead V Workshop on the Role of Active Learning in Math Curricula for Unmotivated Students

Due to the COVID-19 pandemic, the Workshop InsTead V, organized by the German partner of DrIVE-MATH, was held online, at the beginning of June 2020. Participants from Germany, Portugal, France, Slovakia and Mongolia presented very engaging talks related to formative assessment, visualization and manipulation of mathematical concepts, AL experiences (eduScrum and social platforms applications), digital transformation and integration in higher education, mentoring, monitoring, motivation in computer engineering education.

#### 4.2.6 InsTead VI

The final Workshop InsTead VI was organized, online, by the Coordinators of DrIVE-MATH, at the end of June

2020. A significant number of enthusiastic participants from Portugal, Spain, France, Austria, Slovakia, Germany, Netherlands, Finland, Russia, Ireland, Israel, Romania, Argentina and Mongolia, attended this workshop. It comprised two days of intensive work, with more than 20 scientific talks of high level in various fields of research: STEM and STEAM education, AL applications, Geogebra, augmented reality, physical and digital transformation and, pedagogy in online mathematics course in engineering education.

On the first day of InsTead VI there was a round table on the topic 'The Essential Skills of Engineering Students for Industry 5.0 and Challenges from Online Education'. This round table included a panel of renowned personalities from Academia and Industry, whose valuable and enlightening contributions, promoted a lively debate on these issues and enriched all participants. Participating industries: GENAN, EFACEC, Continental Advanced Antenna, Interthings GmbH. We highlight the special participation of Maria da Graça Carvalho, member of the European Parliament.

### 4.2.7 InsTead VII

The InsTead workshops have been so successful in terms of number of participants, valuable panel members, and recognition of invited speakers, that we are currently organizing the seventh edition, which will take place on July 5th 2021. It will have international renowned speakers and the round table will be around a hot topic, *How well are Higher Education Institutions training students to handle the VUCA world?*

Hoping to see you there!

## 5 Impact

The DrIVE-MATH project is expected to impact on several fronts, from students, teachers, stakeholders, schools, and Education itself.

From the students' point of view, we highlight the proved benefits of the new agile/active education models. Students are expected to develop competences such as critical thinking, agility and adaptability, communication, collaboration, initiative, capacity to analyze and conceptualizing information, curiosity and imagination. Furthermore, it is all-inclusive, and multidisciplinary [26, 37, 39]. Active-learning (AL) is student-centred and a viable alternative to the traditional teaching approach. It may be considered as one of the techniques/environments from the Agile Learning design. Agile learning is a teaching/learning framework which promotes speed, flexibility and collaboration [10, 11, 13, 34]. To summarize, these active/agile learning approaches will help to shape the future professionals, by promoting the development of essential skills (hard and soft skills) required to excel in the upcoming Fifth Industrial Revolution. As Pratik Gauri, India President, 5th Element Group PBC and Jim Van Eerden, President, 5th Element Group PBC, says The World needs a Fifth Industrial Revolution to flower like a new Renaissance Age. The impact of the new Education models in teachers is predicted to be significant. As is largely accepted, teachers play a vital role in their students' engagement and motivation [12, 21, 33]. Teachers' enjoyment and confidence in the classroom, their pedagogical efficacy, and guidance are ubiquitous in students' learning processes. The AL methods promote a classroom layout in which teachers award students with freedom to learn at their own pace, by using different assignment formats, accept personal devices, offer some customized lessons for individual students, and help. The teachers are asked to show some receptivity to these new ideas, to be open-minded and to start moving outside their own box, even if they are comfortable with their teaching habits and they believe these are still effective.

In terms of physical implementation, it is possible to start by a simple modification of the classroom design layout, by re-positioning the tables to allow students to work in small groups. It is also requested an internet access, for easy access to the pedagogical materials. As a last remark, most of the HEIs have all the resources available, if we/they are willing to make the move.

Regional, national and European levels HEIs benefit from the application of these Education models. The implementation is dependable solely on the willingness of the Presidents of the HEIs to slowly, but surely start to introduce these Agile/active learning models to their teachers. This can be straightforward by promoting Workshops, conferences, to exchange profitable experiences from other HEIs.

At international level, the application of these new Education models is based on the same principles as those for European HEIs. Are needed Agile thinking teachers and stakeholders, who *think as if there is no box*, who care deeply by their students and are willing to modify their teaching habits and invest on an efficient Education sector, able to respond to the quest of Industry 5.0.

Furthermore, special attention should be devoted to countries where internet access is difficult and where students lack access to computers, either owns or HEI's.

Stakeholder analysis was one of the key goals of the project. All relevant stakeholders were invited for the organized activities and workshops, to share and discuss information about these new Education models and their role in the implementation. Round-tables were also promoted to gather feedback from relevant Academia and CEO's and other representatives of companies, in order to achieve consensus in curricula and skills of future employees.

Other benefits from the application of these new teaching methodologies are:

– Design of new courses at international level;
– Develop and strengthen research collaboration in Academia;
– Provide new opportunities for student mobility;
– Increase capacity building in the developing working world;
– Apply for the EUR-ACE (European Accreditation of European Programs) to accredit joint courses.

## 6 Conclusions

In this study, we reviewed the main points regarding the Erasmus+ project DrIVE-MATH. It was a fantastic adventure, and like Rod stewart sang 'We are sailing storming waters... To be free', and we are proud to give our humble contribution to turn Education more Agile, more 'free'. The main lesson gained is to be resilient, and to pursue more effective Education models. The novel generation of students, known as Gen-Zers, were born in the digital world, being exposed to internet, mobiles, and social interfaces, since early youth. They feel comfortable with cross-information from several sources and to move quickly from online to offline environments. They need to be challenged, want to be trendy and to take advantage of their digital literacy, to learn new things and doing that in new environments. We have a generational opportunity to reimagine education. Let's take the leap to a higher quality Education, reaching every child, teenager, adult and sow the seeds on the Sustainable Development Goals.

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