SEFI UMBRELLA FOR TEACHING MATHEMATICS IN ENGINEERING

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ABSTRACT

Cooperation of mathematics teachers under the umbrella of SEFI Mathematics Special Interest Group (former and more proper - SEFI Mathematics Working Group) has brought many benefits and improvements of strategies adopted at various European technical universities for teaching mathematics courses. Many successful international research teams were formed during the group bi-annual seminars and SEFI annual conferences, which benefitted on grants awarded by the European commission that supported international programmes aimed to improvements in teaching/learning scenarios. Some information summarizing results and findings of 8 European projects accepted and supported in different European programme schemes (Socrates, Leonardo da Vinci, Erasmus) will be presented in a brief analysis about impact of these projects on the introduction of innovative teaching-learning scenarios of mathematics courses at the participating European technical universities. Paper will address several didactical problems revealed from students´ answers in didactical questionnaires as feedback and reactions from the "other side". The attitude of students as other actors in didactic situations who are encouraged to actively cooperate with teachers is often neglected when introducing various innovative teaching/learning methods, which are generally considered to be active.

1 INTRODUCTION

1.1 About SEFI MSIG

Special working groups were formed within SEFI organization at the very beginning of its establishment and operation in the European higher education and research area. Mathematics Working Group appeared among the first ones, and it has always belonged to the most active groups consisting of enthusiastic maths teachers engaged in teaching basic mathematics courses at higher technical institutions and universities in the majority of the European countries. Formed Steering Committee of the group organised various interesting activities for group members, while regularly held bi-annual seminars about engineering mathematics proved to be one of the most useful and enjoyable ones. Good tradition is kept until today, next year 2023 the 21st SEFI MSIG Seminar on Mathematics in Engineering will take place in Romania. Seminars serve as a free forum for exchange of best ideas, good examples and personal experience of maths practitioners gained in their mundane didactic life. Atmosphere at these seminars is traditionally very friendly, open and inspiring. The reason is probably the fact, though not very much optimistic, that mathematics courses generally do not belong to the most favourite parts of engineering study programmes anywhere. Very similar problems which lecturers face in their everyday practice form the fruitful platform for vivid discussions, stormy debates and enable the birth of many original ideas and non-traditional solutions leading to the continuous improvement of the used didactic methods and practices.

At the same time, such busy working environment creates fertile ground for the formation of stronger international cooperation between colleagues from various institutions and for the birth of research teams seeking to submit project proposal and obtain funding from European structures and funds.

In this paper, 8 international projects dealing with teaching mathematics courses to engineering students will be presented, while all project teams were formed, developed their project proposals and successfully defended project results under the SEFI umbrella. This environment therefore proves to be really very conducive to the development of engineering education and its constant direction towards future improvements, ambitious expectations and successful achievement of the goal to maintain "*Mathematics at the Heart of Engineering"*.

1.2 About projects

Among many research and educational programme schemes provided by the European Commission, e.g. Tempus, Phare, Grundtvig, Socrates, Minerva, Leonardo da Vinci, Comenius, Erasmus+ programme that is a funding scheme to support activities in education, training, youth and sport seems to be the most powerful and centralised action managed at the European level by the European Education and Culture Executive Agency (EACEA). Most of the recent educational programmes belong to this scheme under specific sub-classification as Stategic partnerships or Partnerships for cooperation. Programmes, we are going to analyse, will be presented as they were realised in the consecutive time sequence.

1. **EU Socrates programme project No. 90196-CP-1-2001-1-NO-Minerva-M**
   Xmath, years 2002 -2004, was coordinated by Hogskolen i Buskerud, Kongsberg, Norway and there were 6 partners cooperating – Universita Potificia Madrid, and Salamanca University from Spain, University in Kuopio, Finland, Munich software company from Germany, International Centre for Theoretical Physics in Trieste, Italy, and Slovak University of Technology in Bratislava, Slovakia. Project was aimed to explore the possibility of creating a database of mathematical modules available free on the Internet. Team of researchers was formed during SEFI conference and their cooperation was successfully fulfilled with development of one basic module on Differential Calculus, [1].
2. **Leonardo da Vinci programme project No. N/03/B/FF/165.011**
   dMath, years 2003 – 2006, coordinator: Hogskolen i Buskerud, Norway, was continuation and support of the previous project aimed to finalisation of the second module of Integral Calculus. There were also first trials to develop an on-line calculator (supported by Mathematica commercial software product) providing step-by-step calculations in a remote mode. This idea proved to be not very successful due to utilisation of an expensive software solution. Anyhow, both modules developed by means of innovative presentation of mathematical formulas using MathML coding in xml pages are still used as additional instructional materials for students at the participating universities, [1].
3. **Leonardo da Vinci programme project No. SK/06/B/F/PP-177436**
   EVLM – European Virtual Laboratory of Mathematics, years 2006 – 2008, coordinated by Slovak University of Technology in Bratislava was a very successful project that aimed to develop database of on-line electronic materials available on a freely accessible platform. 7 project partners were recruited among participants at the SEFI Mathematics Working group seminars: Paisii Hilendarski University of Plovdiv, Bulgaria, West Bohemian University in Plzeň, Czech Republic, Tulossilta Company from Tampere, Finland, Technical University in Miskolc, Hungary, University of Limerick, Ireland, Salamanca University in Spain, Coventry University from the United Kingdom. During 3 years of the project life a common EVLM portal was opened storing all developed materials in English, while all of these resources were translated and available in national languages of partners at their institutions. Portal is partially functioning at some of them even today, depending on the partner institutions interest and effort to keep the created materials available even after the necessary period at the end of the project, [2].
4. **Erazmus - Strategic Partnership project No. 2015-1-FI01-KA203-009044**
   Future Mathematics, years 2015 – 2018, coordinator: Tampere University of Applied Sciences, Finland. Three partners were - Polytechnic University in Madrid, Spain, Slovak University of Technology in Bratislava, Slovakia, and Technical University of Civil Engineering in Bucharest, Romania. Project was initiated to support modern-day teachers and students by providing a platform as well as resources for teaching and learning in digital form. Moodle environment was used at the platform, and the idea of step-by-step calculations available for students to

self-testing was realised by generated stack-exercises. Project fulfilled its aims to respond to the requirements of modern society and to make mathematics' learning and teaching more digitalized, effective and accessible, [3].

5. **Erazmus - Strategic Partnership project No. 2017-1-PT01-KA203-035866**
   DrIVE-MATH, years 2017 – 2020, coordinator: PTEI Porto, Portugal, was aimed to introduction of innovative active learning methods into the basic mathematics courses in engineering study programmes. Partners – Claude Bernard University, Lyon, France, TechnicaI University in Chemnitz, Germany, Slovak University of Technology in Bratislava, Slovakia – introduced various learning scenarios in their educational practise, as eduScrum, Problem Based Learning, Individual Projects, Gamification, Jigsaw Puzzles, Interactive lectures, hands-on-techniques. Results were analysed and compared, while all gained good and bad experience was presented in Project book with didactic instructions and recommendations, [4].
6. **Erazmus - Strategic Partnership project No. 2017-1-PT01-KA203-035866**
   RULES_MATH, years 2017 – 2020, coordinated by Salamanca University, Spain was a huge project with many partners – Paisii Hilendarski University of Plovdiv, Bulgaria, Slovak University of Technology in Bratislava, Slovakia, Ankara Haci Bayram Veli University, Turkey, Czech Technical University in Prague, Czech Republic, Polytechnic Institute of Coimbra, Portugal, Technical University Dublin, Ireland, Technical University of Civil Engineering in Bucharest, Romania, Spanish National Research Council, Madrid, Spain. The main objective of the project was to develop assessment standards for a competencies-based teaching-learning system for mathematics in engineering education. Project team was based on partnership from several previous projects, while the main goal was to bring practical ideas how to assess knowledge gained after successful completion of basic maths courses focused on development of mathematical competencies – concept developed and elaborated at the SEFI Mathematics Special Interest Group seminars. [5].
7. **Erazmus+ Partnership for Cooperation,**
   Project No. 2021-1-RO01-KA220-HED-000032258
   DIGI STEM, years 2021 – 2024, is a new project coordinated by Tampere University of Applied Sciences, Finland, and bringing together for further cooperation partners cooperating in the previous successful project Future mathematics - Polytechnic University in Madrid, Spain, Slovak University of Technology in Bratislava, Slovakia, and Technical University of Civil Engineering in Bucharest, Romania. This new project is going to develop further ideas partially elaborated 3 years ago, and its main goal is to lay the foundations of digital pedagogy and summarise experience of the two-year long distance education with heavy utilisation of digital technologies in on-line or hybrid teaching and learning during the Covid-19 pandemic throughout the whole world. Project is aimed more theoretically, its primary goal is to provide fundamental guide to maths teachers on how to adapt teaching/learning strategies to the paradigm of the 21st century – digitalisation of all aspects of social life, not excluding education and knowledge acquisition in general [6].

8. **Erazmus+ Partnership for Cooperation**
   Project No. 2021-1-RO01-KA220-HED-000032258
   PYTHAGORAS, years 2022 –2025, coordinator: Lucian Blaga University of Sibiu, Romania, partners: Aalborg University, Denmark, Karlstad University, Sweden, Porto Polytechnic, Portugal, Slovak University of Technology in Bratislava, Slovakia, University dela Laguna, and EVM Spanish Consultancy Company, Tenerife, Canary Islands, Spain, Hellenic Mediterranean University, Heraklion, Crete, Greece. This ambitious project strives to develop policies that will make learning Mathematics more inclusive, efficient, enjoyable and real, connecting Mathematics teaching with real life cases linked to the students' fields of study. All project outcomes and activities will be tailored to address the prerequisites of the partner institutions for undergraduate students regarding their fundamental mathematics background and these perquisites will be checked from all aspects: mathematical content, mathematical processes, views about the nature of mathematics, and personal and academic characteristics of students & teachers. Project expected intellectual outputs and results include: Toolbox for teachers on Education for Sustainable Development, Learning scenarios and guide for gamifying online and hybrid mathematics education at university level, and An online and open access Precalculus Course (MOOC) in English, [7].

Brief analysis of the presented projects´ methodologies and strategies, including summary of their results and outcomes articulated in published reccommendations are presented in the following chapters.

2 METHODOLOGY

2.1 Long 20 years of transformation

Time interval of 20 years between the first and the last presented projects that are dealing with almost the same problems and issues indicates how conservative might be our educational systems and institutions on one hand, while it also reveals their authenticity, stability and persistence of verified values they are representing on the other hand. Long-lasting journey and endless efforts are necessary to establish changes in the traditional educational practises that have to be overcome in order to introduce visible changes in educational approaches and used methods.

While the first two – three projects solved during 2002 - 2008 present just minor insignificant attempts to utilise information and communication technologies and available software products appearing at the scene somehow also in education, projects currently approved in 2022 bring forward a serious research efforts to define, develop and use in pedagogical practise digital methodology and didactics. The worldwide Covid-19 pandemic lasting more than 2 years was one of the main reasons of the rapid and almost complete switch from the "steady on-site" to "experimental on-line" teaching at all levels of education systems. This unexpected situation fostered the urgent need of digitalisation of all aspects of educational processes, from delivery of information, communication between teachers and students, through practising theoretical knowledge and formative assessments up to the summative assessment

and on-line examination solutions. Consequences of these fast changes reflected in the knowledge acquisition will be analysed in the currently solved projects [6], [7].

2.2 Project strategies

All referenced projects were aimed to introduce innovations into traditional university learning scenarios used for ages in mathematics courses – lectures for delivery of theoretical backgrounds, practicals for training solutions of related problems, oral or written examinations. Overall digitalisation of all social processes evoked legitimate attempts and efforts to rethink how mathematics is taught to engineering students. On one hand, ICT revolution enabled experimentation with different distance learning scenarios and enabled development of more versatile modes of instructional materials - on-line modules for self-study, stack exercises for step-by-step calculation training, electronic lecture notes available free on-line, didactic videos, animations, solved examples and applications as projects´ results.

On the other hand, these strategies were sometimes leading to even more passive behaviour of students than it was the case of traditional didactic situations, as learning was more personalised and depended on the involvement of students themselves and their inner motivation to study and acquire new knowledge. Teachers became more developers and authors of e-learning materials and moderators of the educational processes than their facilitators. Anyhow, this did not automatically led to activation of students, just the opposite. Teachers were often frustrated by the enourmous amount of work they had to put into developing innovative instructional materials, which was not adequately received by students, but led to their passive acceptance and even refusal to study all this materials as another hurdle they had to overcome in other to pass the exams successfully.

In all mentioned projects, research teams strived to receive feedback from both actors in the education process. Structured didactical questionnaires were used to perform opinion poll and to receive and analyse answers of respondents in realised didactic experiments at the partner universities. Cohorts of students were chosen on voluntary basis, sometimes there was an entire traditional Mathematics course transferred into a personalised distance learning module, or into a team work solving relevant applied problems by mathematical methods. Attempts to introduce active learning methods as eduScrum, Jigsaw puzzles and PBL methods were one of the most interesting, while the overall detailed analysis of the case studies was presented in articles published in educational journals and at the didactic conferences, see e.g. [8].

3 RESULTS

3.1 Statistical overviews

Most statistical data proving the first observations that “Less seems to be sometimes more” were obtained from the project *DrIVE-MATH*, [4]. Randomly chosen cohort of students in the basic course of Mathematics at the bachelor study engineering programmes participated in the experimental teaching strategy EduScrum. This method showed students a new way of work during tutorials, a teamwork in small

groups of 4-5 students, which they rated very positively. The aim of the experiment was to find out the level of knowledge acquisition and to compare abilities of students to solve mathematical problems independently, or as a collective work in the small groups. Anonymous questionnaire answered by students after completion of the experiment gave researchers a good feedback and overview of their opinions, from which they could compare their attitudes towards different teaching methods applied.

It has to be stated that students with weaker knowledge benefited more from the team work as practised in the randomly formed small group. Very good students helped their classmates to receive better marks and took a greater part of the work on their shoulders. On the other hand, team represented one unit as all members were supposed to be equally responsible for their common achievements. This was often a strong motivation and driving force encouraging both - good students and not that good ones to do their best and contribute to the team final success.

It is up to the teachers how they will introduce this method into their teaching. Team of maths teachers in the project was enthusiastic and keen to implement new active learning scenarios in their teaching practise. They worked with enjoyment and this pleasurable attitude was naturally transferred also to their students. Preparatory work and development of necessary didactic materials is a quite time consuming activity. It requires a real devotion of teachers who should plan carefully all activities in advance, support students with enough learning instructional materials and to be ready to help them with advice in mostly unforeseen situations that might occur during the activities.

Positive aspects of eduScrum method: possible continuous assessment of students' knowledge during the whole semester, from separate parts of curricula consequently; method eduScrum taught students to work in the team, to be responsible for their solutions, to be responsible for the whole team as a unit, to lead a constructive discussion about problems and to understand better the problem solution. As students pointed out in the interview, team work helped to more than 75% of them to understand learned content better.

Negative aspects of eduScrum method: random distribution of students to working teams based on their friendship after the arrival to university study, not on base of knowledge level from mathematics; weaker students learned how to "grasp" problem and how to start to solve it, appreciated help from better students with solutions of their own problems and acquired more points in their "score" from particular topics thanks to better students in their team; better students were a bit "constrained" by weaker students, they had to explain to weaker students how to solve their problems in order to receive as much points as possible for their own score so they solved entirely also problems of other students, with the same points for everybody; they often received less points on their "score" for not correct solutions of problems solved by weak students, as they could receive provided they had solved the problems themselves and correctly, or in another constitution of the working team; better students were willing to work, later during the semester, in smaller groups (2 - 3 members) and they agreed on finding solutions of all given problems in the time limit.

In connection to general recommendation for future broad general implementation of eduSrum method in teaching mathematics to the engineering students at the bachelor or master study programs, we suggest the following few ideas in order to support development of the best students:

– to recognise in each course of mathematics at least 2-3 teams of excellent students and "train" them as excellent teams to solve practical problems in their respective technical professional subjects
– to support healthy competitiveness between these teams of excellent students
– to build common worksheets for team work with problems that could be solved by these excellent teams of students, analyse the overall results consecutively, and contribute thus to better education of future European engineers in mathematics
– to organize at least one competitive teamwork session between excellent student teams inorder to support their higher need
– to appreciate achieved results of all teams, regardless their composition to support and encourage students with weaker results
– to monitor and carefully record results of all students and give them due feedback.

In general, none of the surveys carried in the terminated 6 presented projects proved that the greater efforts by teachers to support students lead to their exceptionally better results and better motivation to learn.

4 SUMMARY AND ACKNOWLEDGMENTS

We believe that, given the current state of knowledge of students, their basic working and methodical skills necessary for the study work at universities and the new roles of teachers in the educational process, the goal of teachers will continue to be focused on the quality and not the quantity of students who complete the subject.

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