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STEM: SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

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Abstract: *STEM is a broad term that groups together four academic disciplines: science, technology, engineering, and mathematics. STEM education is the teaching of science, technology, engineering, and mathematics in an academic context. Instead of training students in any one of these domains, STEM combines all four in an interdisciplinary and applied approach, to better equip students to have a career and consider real-world applications. You'll find STEM in all levels of education, from school curriculums, college subjects, and university degrees, right through to CPD courses and professional certifications. These four subjects are typically taught through hands-on learning and real-world projects – enabling students to prepare for a job in this growing field. STEM is an umbrella term that covers a range of subjects, and many academic disciplines that fall under this category. There are many skills you'll gain from studying STEM. STEM classrooms typically focus on project-based learning. Projects and activities conducted usually involve modern technology to accentuate the practical applications of science in the near future. Students get to apply the various domains of STEM in a context that helps them realize a connection between the classroom and the world around them. In order to be minimized by the effects of pandemic, teaching staff of universities should be trained to use pedagogical and digital methods for active students and instruments that support the development of the student's personal knowledge. Through STEM, students develop key skills including: problem solving, creativity, critical analysis, teamwork, independent thinking, initiative, communication, digital literacy. In this paper we will present the DigiSTEM project. The objective is to promote innovative utilization of educational technology, learning analytics and use of open educational resources (OERs) in online, classroom and blended learning, especially in HEIs STEM subjects.*

Keywords: *STEM education, educational technology, learning analytics, open educational resources*

INTRODUCTION

Several national and international studies have shown that higher education institutions (HEIs) need support to recover from the Covid-19 pandemic consequences such as decrease of students' competence level (2). During pandemic, universities have had to lower the competence requirements of the courses and to lighten their evaluations. In order to be minimized by the effects of pandemic, teaching staff of universities should be trained to use pedagogical and digital methods for active students and instruments that support the development of the student's personal knowledge. The primary context of the DigiSTEM project is STEM education. The objective is to promote innovative utilization of educational technology, learning analytics and use of open educational resources (OERs) in online, classroom and blended learning, especially in HEIs STEM subjects. The project aims to support professional development of HEI educators by increasing their technological and pedagogical skills and competence. The objective is to build HEI educators' competence of such instructional design that improves students' active learning, self-regulated learning and learning engagement with the help of educational technology and learning analytics to provide more effective and personalized support of learners (4). In Europe, there doesn't exist a framework or model for learning digital skills and pedagogy in HEI STEM education.

When teaching/learning STEM subjects, there are also special needs of digital tools/environments for example in presenting mathematical language, equations etc. The needs analysis of the project is based on literature review and educational research conducted in partner universities. Different educational research studies have highlighted that educators have an inadequate competence regarding effective use of digital tools and resources in education from both pedagogical and technological perspectives. The most common reasons for not to use digital technology in teaching/learning are a lack of confidence, a lack of competence and a lack of access to resources. The research has shown, that students would like to use digital learning possibilities and methods more widely in STEM courses (3). However, utilizing educational technology in STEM subjects is very limited and it lags behind the expectations, even though using instructional design that utilizes educational technologies has a great and recognized potential to increase students' motivation, attractiveness of subject, promote active learning and improve learning outcomes (3).

NEEDS ANALYSIS

The needs analysis shows that there is a clear need for instructional design that increase pedagogical meaningful use of digital learning possibilities among STEM education and academics must be trained to utilize such instructional design. These are also needed to ensure that universities can better recover from the students' passivation and decreased learning outcomes caused by Covid-19 pandemic (1).

Survey for HEI educators

The questionnaire was applied in the partner universities, and a number of 49 answers were obtained.

Asking the question "Which of the following assessment methods you are using in your own teaching?"

- Automated assessment
- Self-assessment
- Peer assessment
- Assessed group work
- Continuous assessment
- Exams
- Exercises
- Other

An interesting point of view was expressed: "many experienced educators tell that we spend too much time for assessments which is away from new learning & development. Can the student just rely that he/she masters the thing enough? Many topics are so new that it is difficult to know how to assess them. In work life, the assessment is simply: we got the project done or we did not. There is no point grading this between 0-5. Of course we should learn from mistakes and make it better the next time but there rarely is a next time in SW development".

In conclusion, most assessment methods used in teaching are: Exams, Exercises, Continuous assessment, Automated assessment, Self-assessment, Assessed group work and other like Course activity assessment, Measurement assignments (at home and in class).

The results obtained were, as shown in the graph below:

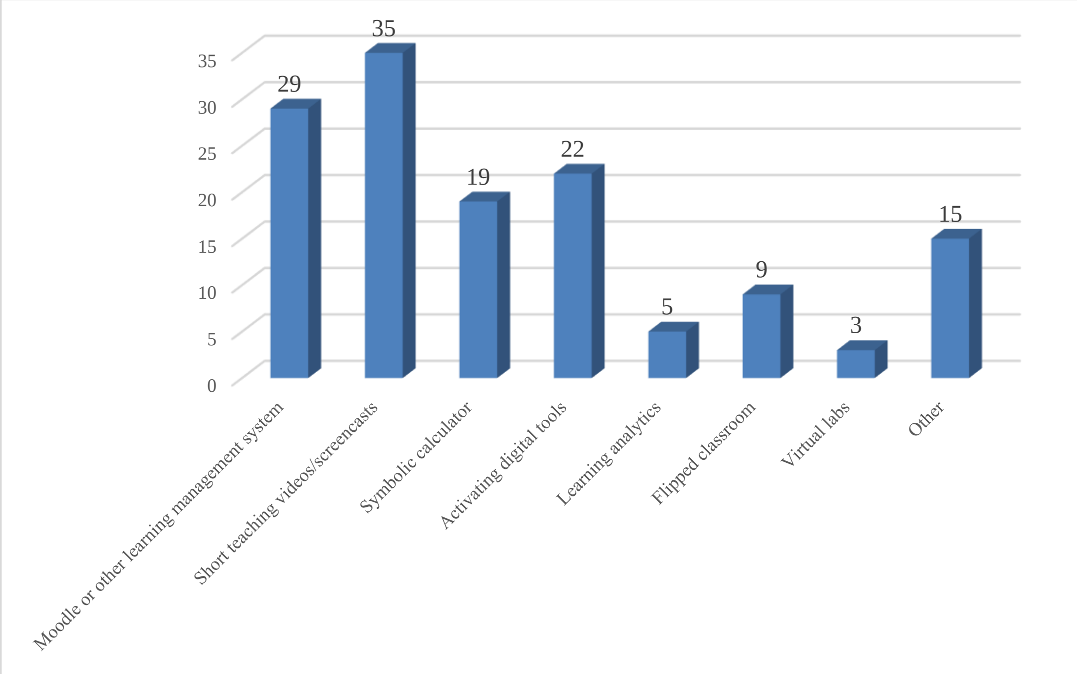


Fig. 1. Which of the following assessment methods you are using in your own teaching

Looking what are the most important for students' learning. Mark down numbers 1-5. (1=the most important, 2=the second most important, 3=the third most important, 4=the fourth most important, 5=the fifth most important).

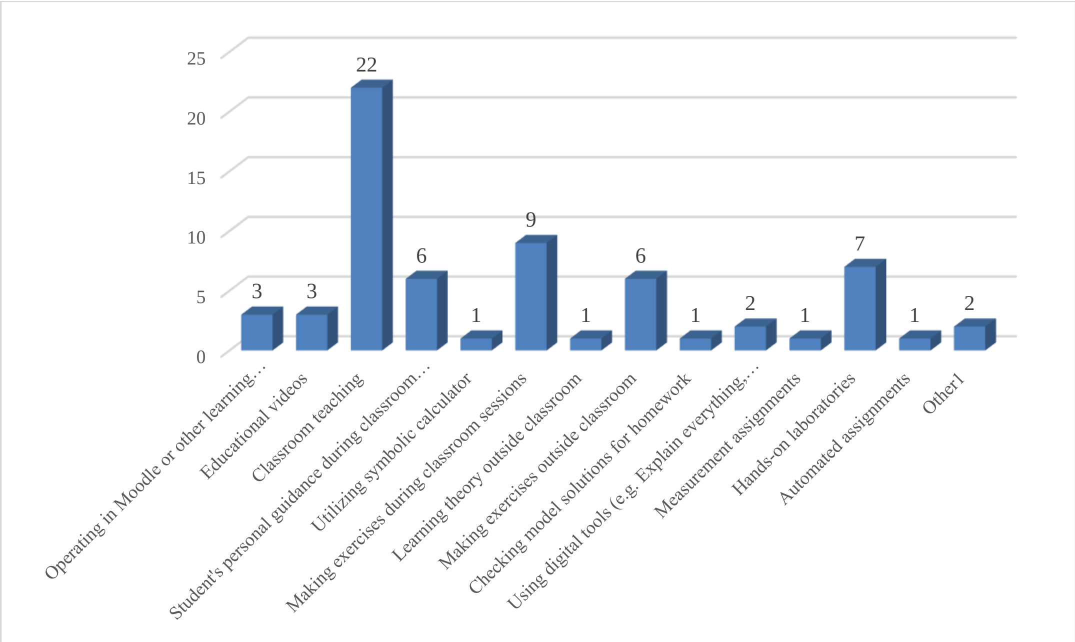


Fig. 2. What are the most important for students' learning

In conclusion, the most important for students' learning are Classroom teaching, Making exercises during classroom sessions, Hands-on laboratories, Making exercises outside classroom.

In others, there are some opinions: My students declare that going to school is really the best way for study. I share their opinion. This varies on diff. topics. I would trust the experienced teacher. Remote teaching. Student asking questions from his/her premises.

OBJECTIVES

The objective of the project is to increase digital and pedagogical competence of HEI educators and availability of digital resources in STEM subjects on a large scale to achieve long-lasting effects in everyday activity on the project partners and other European HEIs. By increasing such competences of educators, it gives them tools and knowledge to redesign their teaching and implement digital resources and activities (e.g. learning analytics, digital languaging, screencasts, visualizations and intelligent assessment) for different personalized learning scenarios.

The agenda for the modernization of Europe's higher education systems supports the project idea as it suggests the need to exploit new technologies and ICT to enrich teaching/learning experience and providing ubiquitous and personalized digital learning possibilities for students. Also, the Digital Education Action Plan set by the Commission has a priority to make better use of digital technology for teaching and learning. The project aims to enhance educators' technological and pedagogical competences by organizing different kind of pilot events and providing OERs and learning environment for competence development. By increasing such competencies of HEI educators (main target group), it gives them tools and knowledge to produce and implement digital resources for different personalized learning scenarios and resources that supports students' activation. Hence, the project aims to promote digital and pedagogical competence and skills of HEI educators nationally and transnationally in Europe. Simultaneously based on literature, this is expected to affect positively on HEI students' engagement and learning outcomes (secondary target group) but also support to recover from the Covid-19 pandemic consequences such as decrease of students' competence level.

IMPLEMENTATION

The main activities/results of the DigiSTEM project are:

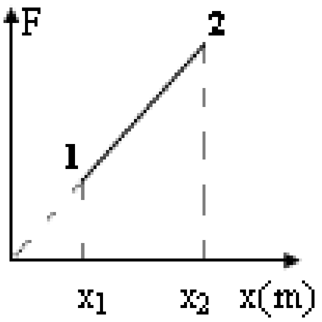
- developing DigiSTEM methodology that encapsulates innovative pedagogies, best practices and concrete examples for implementing digital learning/teaching of STEM and other similar subjects (PR1)
- building, maintaining and developing a digital platform for STEM subjects' digital teaching and learning to support educators' continuous professional development with high-quality resources (PR2)
- developing guidelines for European STEM educators to increase digital and pedagogical competence and implementing good practices and new methods smoothly into daily teaching activities and curricula (PR3)
- enhancing HEI educators' competence of such instructional design that improves students' active learning, self-regulated learning and learning engagement with the help of educational technology and learning analytics to provide more effective and personalized support of learners (PR1-PR3)
- to organize/participate 3 LTT (C1-C3) events and participate dissmination events (E1-E6) aimed at providing technological and pedagogical training/knowledge to STEM educators in the context of the project. Participants of training activities will be awarded with digital competence certificate.
- developing MOOC as a form of OER that will combine all the tangible results of the project to be able to promote and integrate developed good practices and innovative methods into daily activities of European HEIs. The MOOC is based on piloted PRs, which have been developed on the basis of feedback received during piloting. The project's pedagogical innovations and technological choices will be made as sustainable solutions that can be utilized after the project, for example 10 years after the end of the project.

Concrete examples for implementing digital learning/teaching of STEM

Based on analysis, the project team will make plans for resources to be included in DigiSTEM methodology. Resources include e.g. innovative pedagogies, suitable digital tools and examples of their usage, available digital resources, intelligent elements of digital assessment, computer-aided assessment in STEM subjects, exploitability of learning analytics etc.

In a cooperation, the project team will select and/or produce resources to be used as a part of DigiSTEM methodology and the continuous professional trainings in PR3.

Mathematical Analysis Applied in Sciences



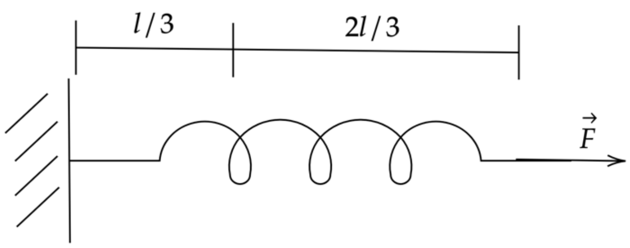
1) Find the mechanical work done by the force in Fig. 1 to move its point of application in its direction and sense from the coordinate point $x_1 = 1$ m to the coordinate point $x_2 = 5$ m, if in the coordinate point $x_1 = 1$ m the force value is $F_1 = 10$ N.

a) *-120J* b) 0 c) 120*J* d) 40*J*

Solution.

As the work of a force can be computed as the area of its subraph, we can solve this problem using elementary integral calculus. We will find the function $F(x)$, then the work done by the force is the result of the integral $\int_1^5 F(x)dx$.

As the graph of the function $F(x)$ passes through points $(0,0)$ and $(1,10)$, then using the equation of a straight line that passes through 2 points, we have: $F(x) = 10x$.



$$W = \int_1^5 F(x)dx = \int_1^5 10x dx = 10\int_1^5 x dx = 5x^2 |_1^5 = 5\left(5^2 - 1^2\right) = 120J$$

2) Find how many times the mechanical work done when elongating a spring on the first third of the elongation is smaller than the mechanical work done for the elongation with the remaining two thirds of the elongation.

a) 8 b) 4 c) 2 d) 0,5

Solution.

The tensile force F has the expression $F = kx$, where *k* is a constant known as the *rate* or *spring constant* .

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We will compute the work on the intervals of deformation $[0, l/3]$ and $[l/3, l]$.

$$W_1 = \int_0^{l/3} kx dx = k\int_0^{l/3} x dx = k\frac{x^2}{2}\Big|_0^{l/3} = \frac{k}{2}\frac{l^2}{9} = \frac{kl^2}{18}$$

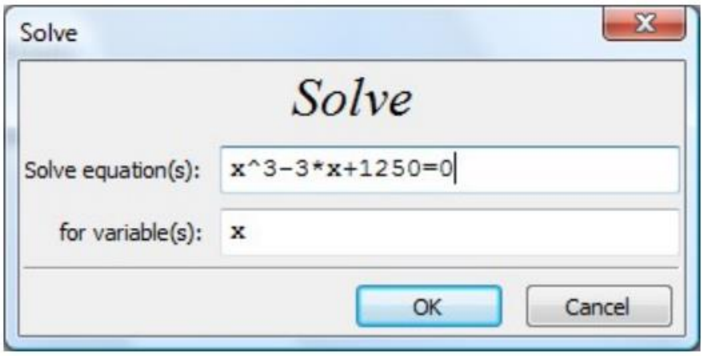
$$W_2 = \int_{l/3}^{l} kx dx = k\int_{l/3}^{l} x dx = k\frac{x^2}{2}\Big|_{l/3}^{l} = \frac{k}{2}\left(l^2 - \frac{l^2}{9}\right) = \frac{4kl^2}{9}$$

$$\frac{W_2}{W_1} = \frac{\frac{4kl^2}{9}}{\frac{kl^2}{18}} = 8 \Rightarrow 8 \text{ times}$$

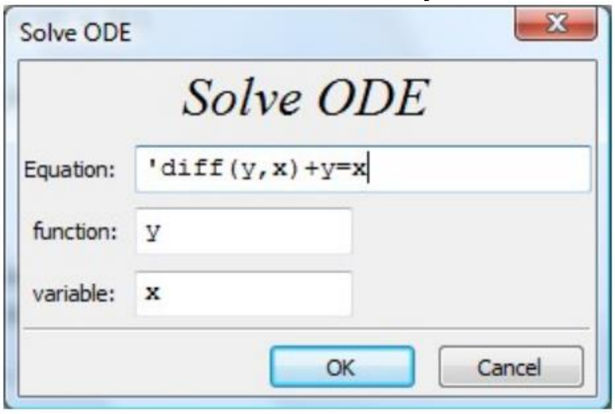
Maxima a symbolic-based mathematical software

Maxima is a symbolic-based mathematical software providing a number of functions for algebraic manipulation, calculus operations, matrix and linear algebra, and other mathematical calculations.

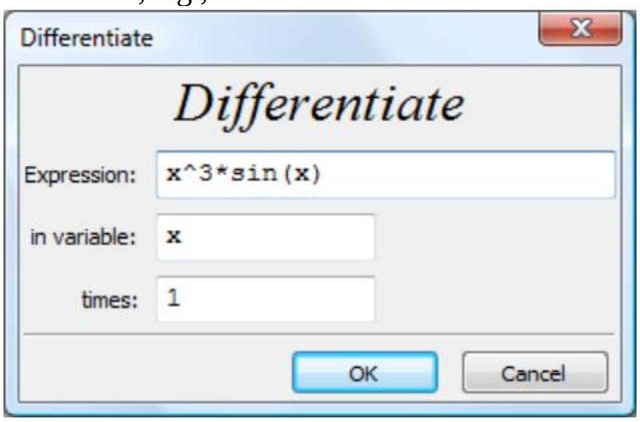
Solve: solves an equation, e.g.,



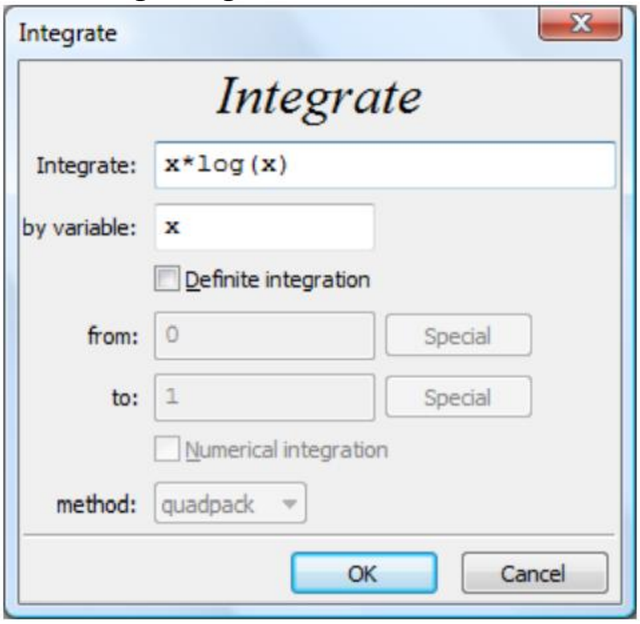
Solve ODE: solves a 1st order or 2nd order ordinary differential equation, e.g.,



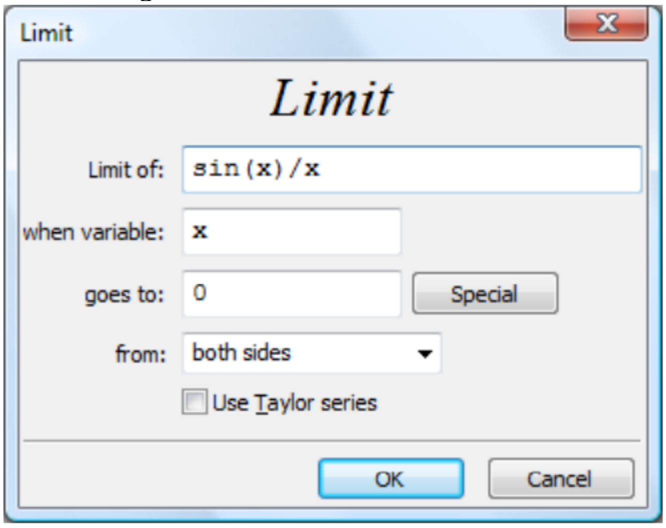
Diff: calculates a derivative, e.g.,



Integrate: calculates an integral, e.g.,



Limit: calculates a limit, e.g.,



GeoGebra a Dynamic Mathematics Software

Geogebra GeoGebra is a Dynamic Mathematics Software (DMS) for teaching and learning mathematics at all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package. GeoGebra is a rapidly expanding community of millions of users located in just about every country. GeoGebra has become the leading provider of dynamic mathematics software, supporting science, technology, engineering and mathematics (STEM) education and innovations in teaching and learning worldwide. It is as easy to use as Dynamic Geometry Software (DGS) but also provides basic features of Computer Algebra Systems (CAS) to bridge some gaps between geometry, algebra and calculus.

GeoGebra is open source software under the GNU General Public License and freely available at www.geogebra.org. There, you can either download installers for multiple platforms or launch the software directly from the Internet using GeoGebra Web Start.

Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student's learning.

GeoGebra was created to help students gain a better understanding of mathematics. You can use it for active and problem-oriented teaching, it fosters mathematical experiments and discoveries both in classroom and at home.

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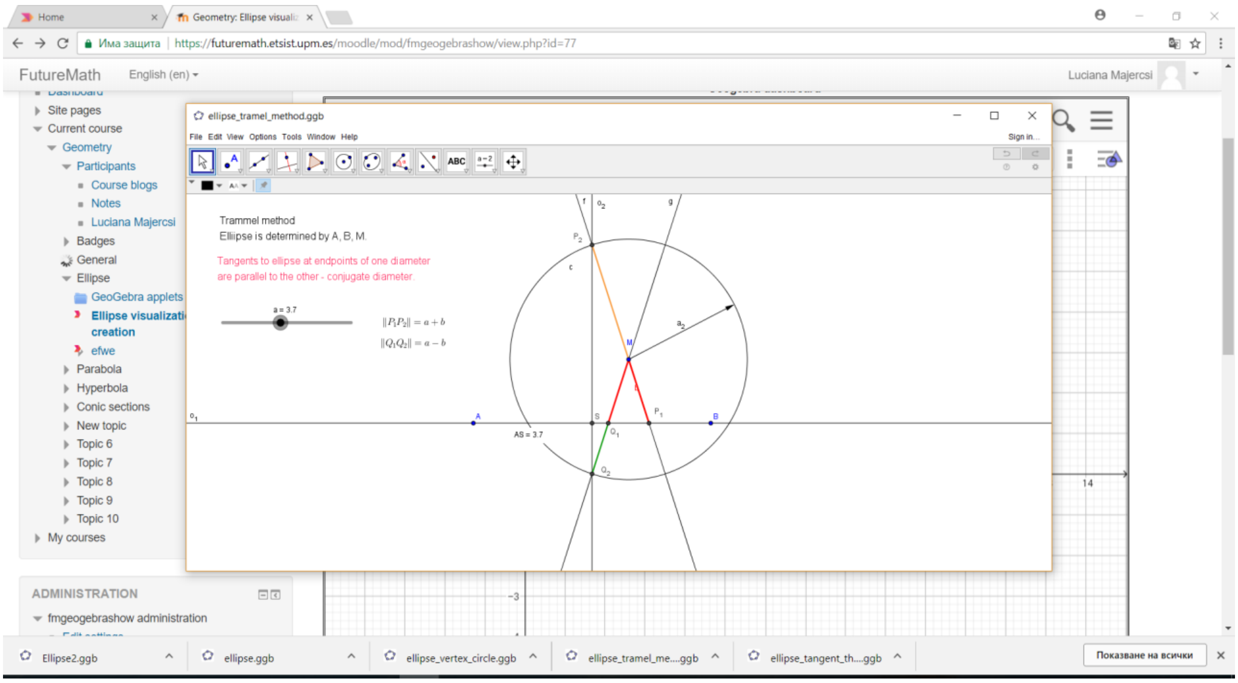
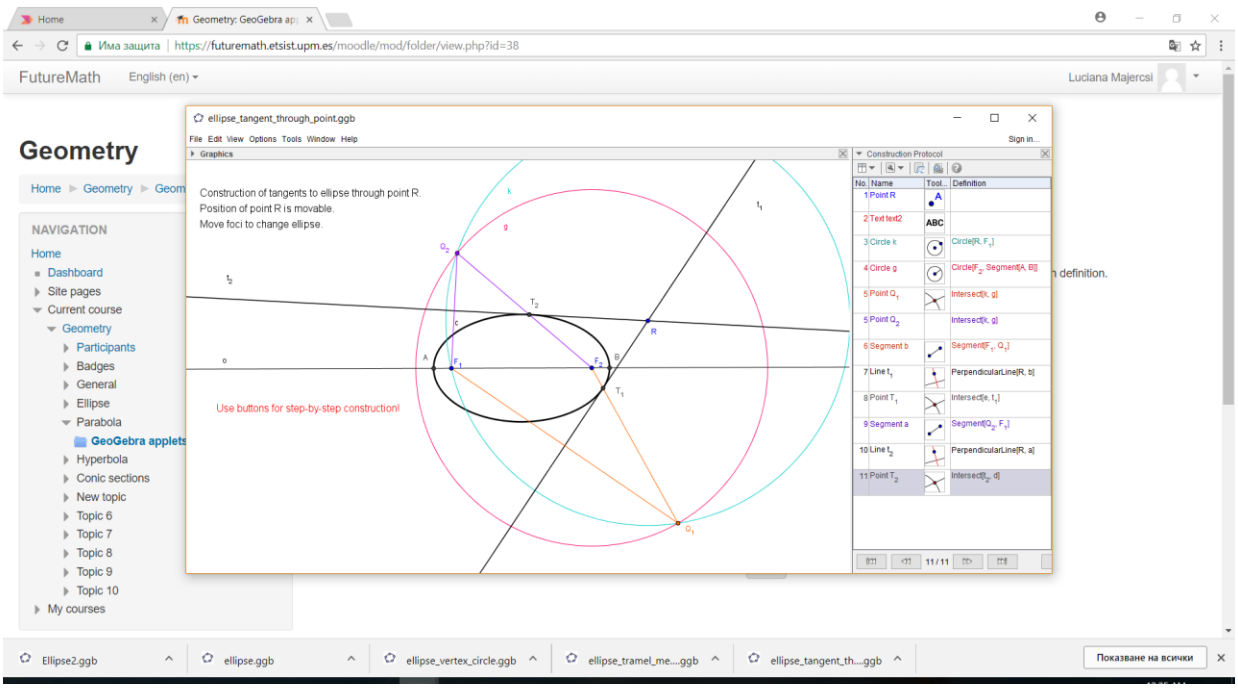
The methodology will be a comprehensive framework that does not previously exist. It will encapsulate innovative methodologies, best practices, pedagogies, resources and tools for teaching and learning of STEM and other similar subjects. By building such methodology, the project aims to respond to the recognized gap highlighted in educational research - educators have an inadequate competence





CONCLUSION

The objective is to build HEI educators' competence of such instructional design that improves students' active learning, self-regulated learning and learning engagement with the help of educational technology and learning analytics to provide more effective and personalised support of learners. In this way, it is possible to achieve the effectiveness of the project from the curriculum level to practice. The project is divided in three main Project Results (PR1-PR3). One of the partners is appointed as the coordinator of each output even though each output will be developed in close cooperation with all partners. The Project Results are described in previous section. As a consequence of the exploitation of Project's Results (PRs), it is expected to improve HEI students' motivation and to decrease dropouts (Kinnari-Korpela, 2019). Although the project focuses on HEI STEM subjects, the PRs can be applied to other disciplines with some adaptations. Hence, the project can contribute to improve educators' skills to apply modern methodologies, novel pedagogy and digital teaching/learning solutions on a large scale.

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