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RULES_MATH PROJECT - TEACHING AND LEARNING MATHEMATICS BASED ON COMPETENCIES

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Abstract: *Mathematics plays one of the most important roles in developments of our modern and technology-centered society. In fact, good mathematical skills are crucial for science and economy. Unfortunately, various studies have shown that mathematical competence in Europe has weakened in recent decades. The lack of mathematical proficiency is already causing problems in engineering mathematics' and other courses in European HEIs. In fact, this seems to be a global problem, and e.g. the learning outcomes of Eastern European countries have been weaker than expected, especially in mathematics, after they moved to the Western European model of education (e.g. SEFI 2002).*

As we all know, Mathematics is an essential part of any engineering degrees. Mathematics is a tool that engineers still use throughout his or her life. It is therefore important that this knowledge and competencies have to be properly seated. Thinking about this, we proposed the 'New Rules for assessing Mathematical Competencies' project to change the educational paradigm and to get a common European teaching and learning system based on competencies rather than contents.

Additionally, in recent years the study groups have been increasing and becoming even more heterogeneous. This naturally causes problems for organization of mathematics' teaching as for example the entry level of competence in mathematics (RulesMath project study this problem) varies greatly depending on the background studies. Under these circumstances, taking into account individual needs or organizing dynamic and creative activities becomes almost impossible during the classroom sessions. As a sum of many factors, it has been reported that the drop-out rates are high in the field of technology

In this paper, we will present how we can teach, how students can learn mathematics based on competences, how materials developed within this project are used by students in our universities and their positive influence in the process of teaching and learning mathematics.

Keywords: *Innovative teaching and learning Methods, Competences, Engineering Mathematics Education.*

INTRODUCTION

Mathematical skills are a prerequisite in technical studies and mathematics lay the basis for understanding different engineering disciplines. Thus, the students' poor skills in mathematics slow down or even prevent their studies. In principle, an engineer must be able to think analytically and to be capable of logical reasoning. In addition, an engineer needs to understand mathematics, which allows them to deal with and understand technical problems. Overall, mathematics penetrates deep into the engineering professional field, affecting the opportunities to absorb and learn engineering subjects. Thus, for example to be able to make new technological innovations, the understanding and skills of mathematics are crucial.

Unfortunately, the lack of basic skills and knowledge of mathematics among the European engineering students complicates and in the worst case, even prevents future technological

development in Europe. In order to maintain the competitiveness of Europe, the basic level of mathematical proficiency needs urgently to be increased on a large scale. Based on above described situation, the proposed project aims to improve the mathematical proficiency of European engineering students by developing methods and best practices to learn, teach and assess mathematics effectively. Since the objectives of the project are international, the best results can be achieved with transnational co-operation. Based on the results of a survey collected in our universites, students expect more digital learning possibilities and utilizations of ubiquitous technology in mathematics' studies. This is very natural as the whole of society is changing. Big data, open data, cloud services, digitalization, IoT etc. affect society and social activities on a large scale. As working life is constantly changing, its expectations and requirements have become more diverse. The 21st century skills, such as collective thinking, collaboration, creativity and shared problem solving skills are key components in modern working life and therefore the university teaching and learning should also train these skills.

TRENDS IN HIGHER EDUCATION

Chris Parr in his article "6 trends that will accelerate the adoption of technology in higher education" (Parr, 2014) takes a look at the six "key trends" picked out in the NMC Horizon Report: 2014 Higher Education Edition that are accelerating the adoption of technology in higher education. The report, aims to examine emerging technologies for their potential impact on and use in teaching and learning within higher education settings. It is divided by three trends' categories due to the temporal significance (Johnson, L., Adams Becker, S., Estrada, V., Freeman, A., 2014):

- fast trend - driving changes in higher education over the next one to two years;
- mid-range trend - driving changes in higher education within three to five years;
- long-range trend - driving changes in higher education in five or more years.

FAST TREND

"The top 25 social media platforms worldwide share 6.3 billion accounts among them," the Horizon report says. "Educators, students, alumni, and the general public routinely use social media to share news about scientific and other developments.

The impact of these changes in scholarly communication and on the credibility of information remains to be seen, but it is clear that social media has found significant traction in almost every education sector."

For educational institutions, social media enable "two way dialogues between students, prospective students, educators, and the institution that are less formal than with other media", it continues, adding that educators are using them "as professional communities of practice, as learning communities, and as a platform to share interesting stories about topics students are studying in class".

According to Horizon Report 2014 Higher Education Edition, "education paradigms are shifting to include more online learning, blended and hybrid learning, and collaborative models".

Institutions that "embrace face-to-face, online and hybrid learning models" have the potential to engage with students who "already spend much of their free time on the internet", learning and exchanging new information.

"An increasing number of universities are incorporating online environments into courses of all kinds, which is making the content more dynamic, flexible, and accessible to a larger number of students," the report says.

"To encourage collaboration and reinforce real world skills, universities are experimenting with policies that allow for more freedom in interactions between students when working on projects and assessments."

MID-RANGE TREND

"There is a growing interest in using new sources of data for personalizing the learning experience and for performance measurement," the Horizon report says. "As learners participate in online activities, they leave an increasingly clear trail of analytics data that can be mined for insights."

The report concludes that although students and educators are generating more and more data, especially in online environments, "higher education in general has yet to fully embrace these sorts of processes".

"There is a growing interest in developing tools and algorithms for revealing patterns inherent in those data and then applying them to the improvement of instructional systems," it says.

Pedagogical practice on university campuses all over the world is shifting, as students learn "by making and creating rather than from the simple consumption of content", Horizon Report: 2014 Higher Education Edition says.

"University departments in areas that have not traditionally had lab or hands-on components are shifting to incorporate hands-on learning experiences as an integral part of the curriculum. Courses and degree plans across all disciplines at institutions are in the process of changing to reflect the importance of media creation, design, and entrepreneurship."

New funding mechanisms have "put university students more in control of the development of their research than ever before", the report continues.

"Through the crowdfunding websites like Kickstarter or Indiegogo, student-led projects that might have stalled at the concept or model stage can now be brought to fruition. A student at Cornell University, for example, is using Kickstarter to develop Kicksat (Manchester, 2011), a project intended to launch a small spacecraft into low earth orbit." In another example, at Dartmouth College, researchers are exploring how student-generated video can be used to "further learning and evaluate a student's academic performance through the collection of various assignments housed on the Media Projects page (Simon, 2013) of the college's website".

LONG-RANGE TREND

According to the Horizon report, there is "a growing consensus among many higher education thought leaders".

Such models "use technology as a catalyst for promoting a culture of innovation in a more widespread, cost-effective manner", and pilots that are being developed for higher education institutions include the improvements of organizational structures to "more effectively nurture entrepreneurship among both students and faculty"

There has been a shift in the perception of online learning to the point where it is seen as a viable alternative to some forms of face-to-face learning", the Horizon Report says. "The value that online learning offers is now well understood, with flexibility, ease of access, and the integration of sophisticated multimedia and technologies chief among the list of appeals."

Developments in learning analytics and "a combination of cutting-edge asynchronous and synchronous tools" will continue to advance the state of online learning and keep it compelling, it continues, "though many of these are still the subjects of experiments and research by online learning providers and higher education institutions".

According to the 56-strong panel of experts that were consulted for the report, the advent of voice and video tools is "not only increasing the number of interactive activities between online instructors and students, but also greatly improving their quality", while audio tools "such as VoiceThread and SoundCloud, along with video creation tools such as iMovie and Dropcam, enable faculty to capture important human gestures, including voice, eye contact, and body language, which all foster an unspoken connection with learners."

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INNOVATIVE METHODS AND TECHNIQUES

The main objective of the RULES_MATH project is to develop assessment standards for a competencies-based teaching-learning system for mathematics in engineering education.

The aims of the project can be summarize as follows:

(1) To develop a collaborative, comprehensive and accessible competencies-based assessment model for mathematics in engineering context.

(2) To elaborate and collect the resources and materials needed to devise competencies-based assessment courses.

(3) To disseminate the model to European HEIs through the partner networks and also promote the dissemination all over Europe.

The institutions involved in RULES_MATH project have long experience in innovation and they have adapted their degrees to the Bologna Accord. Concerning the target groups to be addressed:

(1) The primary target group of the RULES_MATH project is the pool of mathematical university teachers, trainers, lecturers, and researchers from engineering undergraduate degrees, master degrees, or PhD level (including staff from project partners) who are interested in changing their teaching system in the mathematical teaching/learning field. Including who would like to enhance their mathematical competencies using the most advanced e-learning tools, digital assessment, study materials, and courses.

(2) Secondary target group is that of students from engineering undergraduate degrees, master degrees or PhD programmes. They will have access to the assessment materials (new competencies-based resources) that will improve their learning method making themselves the responsible of the acquisition of competencies and knowledge.

As the results of the RULES_MATH project will be available as OER, this can ensure the exchange of experiences and ideas, possibilities and resources for work development, research work, etc. Targeted sectors are research training organizations, university enterprise training partners, research centers and scientific institutes. Training organizations, schools and university training organizations could also be beneficiaries. Potential final users are also private individuals as home self-learners, interested in self education who, for personal reasons, may not normally engage with formal education, including disabled people and people perceiving discrimination due to social and gender stereotypes.

The RULES_MATH project will focus on mathematical competencies and not just on the mathematical contents which was the case in earlier times in other educational projects. Since mathematics lecturers are much more familiar with the content view (the mathematical structure) it is a major challenge for them to deal with competencies-oriented assessment goals. This project may provide material for supporting them in this respect. Furthermore, the development of a new mathematical approach is being demanded by engineering and science trainers to motivate students, and also for students to be motivated with mathematics learning.

NEED ANALYSIS

To collect information on existing mathematics education at European technical universities the needs analysis survey was done.

The needs analysis was made to clear up, what is the point of view of students about the future of mathematics.

The need analysis was done in all partner universities in RulesMath project and also in “Angel Kanchev” University of Ruse, Faculty of Natural Sciences and Education, Department of Mathematics.

And with the help of the needs analysis results and "A Competence-based Framework for Mathematics Curricula in European Engineering Education“ SEFI 2013 publication give us guidelines for the planning and implementation phases of the project.

The follow questioner was applied (online) to the students:

https://lomake.tamk.fi/v3/lomakkeet/19758/lomake.html

Background

Age

Gender: Female

University: TUCEB

Degree programme

Background studies: High school

I have a smartphone: Yes

I have a tablet: Yes

I have a computer: Yes

Teaching and learning methods in mathematics context

What do you think is meant by modern teaching and learning methods in mathematics' context?

Select which teaching method you perceive as modern (select all you agree)

- Teaching with transparencies and overhead projector
- Teaching with computer presentations using dataprojector
- Using short teaching videos/screencasts
- Writing on whiteboard
- Utilizing smartphones/tablets in learning purposes
- Utilizing symbolic calculator
- Operating in Moodle or other learning environment
- Making notes
- Teaching using dynamic mathematical software applets
- Working in groups
- Use of simulations/demos
- Use of virtual labs
- Other

If other, please specify.

Which teaching methods are being/have been used in your university mathematics' courses?

- Teaching with transparencies
- Teaching with slides and overhead projector
- Using short teaching videos/screencasts
- Writing on whiteboard/blackboard
- Utilizing smartphones/tablets in learning purposes
- Utilizing symbolic calculator
- Operating in Moodle or other learning environment
- Making notes
- Use of virtual labs
- Other

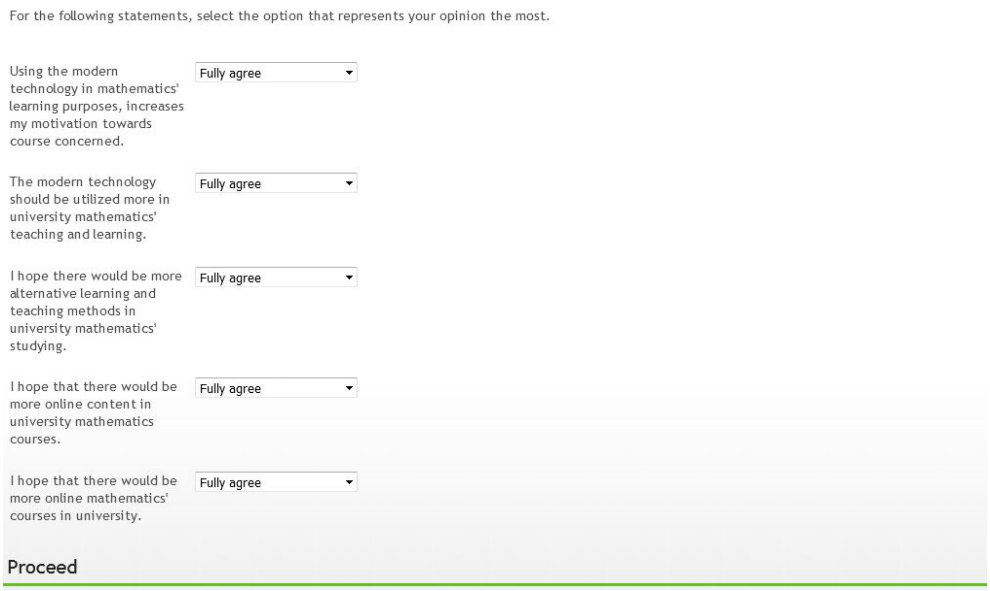
If other, please specify.

I have utilized short videos/screencasts in mathematics' learning.: Yes, my teacher provides short videos

If your replied that your teacher doesn't provide, but you have used videos, where did you find videos?

Select five methods, that are the most important for you in terms of learning. Mark down numbers 1-5. (1=the most important, 5=the fifth most important).

- Personal guidance of lecturer during classroom sessions
- Teaching with overhead projector
- Short video lectures / Screencast videos
- Teaching with whiteboard
- Utilizing symbolic calculator
- Making exercises during classroom sessions
- Learning theory on my own (outside classroom)
- Making exercises on my own (outside classroom)
- Checking model solutions for homework
- Using on-line instructional resources
- Using interactive dynamic applets



Looking at the answers we can see the what students expect from our project.

Which teaching methods are being/have been used in your university mathematics' courses?

- Writing on whiteboard/blackboard
- Making notes
- Teaching with transparencies
- Teaching with slides and overhead projector

Select which teaching method you perceive as modern (select all you agree)

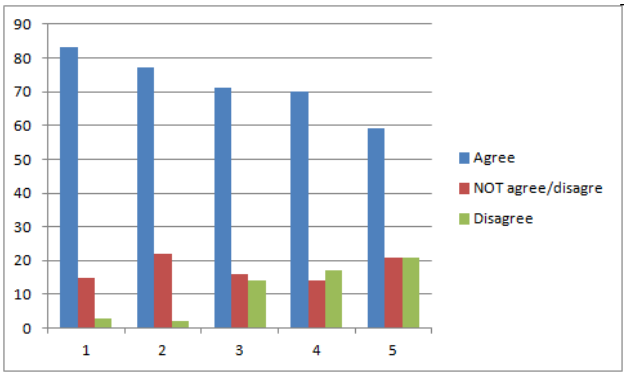
- Operating in Moodle or other learning environment
- Utilizing smartphones/tablets in learning purposes
- Teaching using dynamic mathematical software applets
- Working in groups
- Use of simulations/demos
- Use of virtual labs
- Utilizing symbolic calculator
- Teaching with transparencies and overhead projector
- Teaching with computer presentations using dataprojector
- Using short teaching videos/screencasts

Select five methods, that are the most important for you in terms of learning.

- Making exercises during classroom sessions
- Personal guidance of lecturer during classroom sessions
- Teaching with overhead projector
- Short video lectures / Screencast videos
- Utilizing symbolic calculator
- Using on-line instructional resources
- Using interactive dynamic applets
- Learning theory on my own (outside classroom)
- Making exercises on my own (outside classroom)
- Checking model solutions for homework

The most important ways of learning was very teacher centered as the top one was “Making exercises during classroom sessions” and followed by “Personal guidance of lecturer during classroom sessions” and “Teaching with whiteboard / Using on-line instructional resources”.

It appears that in a point of view of the students modern ways of teaching math bases on utilizing technology.



They were:

1. Using the modern technology in mathematic's learning purposes, increases my motivation towards coures concerned
2. The modern technology should be utilized more in university mathematic's teaching and learning.
3. I hope there would be more alternative learning and teaching methods in university mathematic's studying.
4. I hope that there would be more online content in university mathematics courses.
5. I hope that would be more online mathematic's courses in university.

Most important methods in terms of learning were very teacher centered whereas working alone outside the classroom was seen not important.

This is the problem we are facing in today's teaching – the contact lessons have been decreased.

RULES IN TEACHING AND LEARNING MATH BASED ON COMPETENCIES.

Mathematical Analysis is composed of two main parts: the Differential Calculus (for functions of several variables) and Integral Calculus. This chapter, entitled "Methods of Integration" is the key that opens the wide door of the Integral Calculus, the branch of Mathematical Analysis that can be associated with the top of the tree, where most people finally find the answer about Mathematics applicability in the real world. This means that almost all of the Mathematical notions (theorems etc.) studied in high-school or further have contributed to the base on which Integral Calculus will be modeled.

It would be better if we thought about the road between two destinations which people go through by train. Integral Calculus is exactly the final destination

Naturally, we question ourselves: "Why is Integral Calculus so important for our lives?".

The answer for this question is simple, but very suggestive, given by a famous mathematician R. Penrose: "The better we understand the laws of Physics and we approach deeper in the laws of nature, the more we will be led in the world of Mathematical concepts." Actually, Integral Calculus finds a Mathematical model for almost all phenomenons in the nature and this is reason for which an engineer must be familiarized with these concepts.

Their concrete applicability will presented in the next chapter, but now, let's concentrate on the introductive part of Integral Calculus, the first and most important condition which must be accomplished that we work with Integrals.

COMPETENCIES

After completing this chapter "Methods of Integration", the competencies that students must acquire are:

The notion of mathematical competence has been presented in all the PISA mathematics frameworks from the very beginning in the late 1990s. However, the actual role of mathematical

competencies in the PISA outcomes has been subject to considerable evolution across the five PISA surveys completed so far; that is, until 2013.

Recently, it has been adopted as a framework for the study of the mathematical competency. Mathematical competency can be considered as the sum of various competencies. The eight competencies considered that our student must acquire are:

C1. Thinking mathematically

This competency comprises a knowledge of the kind of questions that are dealt with in mathematics and the types of answers mathematics can and cannot provide, and the ability to pose such questions. It includes the recognition of mathematical concepts and an understanding of their scope and limitations as well as extending the scope by abstraction and generalisation of results. This also includes an understanding of the certainty mathematical considerations can provide.

C2. Reasoning mathematically

This competency includes on the one hand the ability to understand and assess an already existing mathematical argumentation (chain of logical arguments), in particular to understand the notion of proof and to recognise the central ideas in proofs. It also includes the knowledge and ability to distinguish between different kinds of mathematical statements (definition, if-then-statement, iff-statement etc.). On the other hand it includes the construction of chains of logical arguments and hence of transforming heuristic reasoning into own proofs (reasoning logically).

C3. Posing and solving mathematical problems

This competency comprises on the one hand the ability to identify and specify mathematical problems (be they pure or applied, open-ended or closed) and on the other hand the ability to solve mathematical problems (including knowledge of the adequate algorithms). What really constitutes a problem is not well defined and it depends on personal capabilities whether or not a question is considered as a problem. This has to be borne in mind, for example when identifying problems for a certain group of students.

C4. Modelling mathematically

This competency also has essentially two components: the ability to analyse and work in existing models (find properties, investigate range and validity, relate to modelled reality) and the ability to 'perform actve modelling' (structure the part of reality that is of interest, set up a mathematical model and transform the questions of interest into mathematical questions, answer the questions mathematically, interpret the results in reality and investigate the validity of the model, monitor and control the whole modelling process). This competency has been investigated in more detail in Blomhoj & Jensen (2003, 2007).

C5. Representing mathematical entities

This competency includes the ability to understand and use mathematical representations (be they symbolic, numeric, graphical and visual, verbal, material objects etc.) and to know their relations, advantages and limitations. It also includes the ability to choose and switch between representations based on this knowledge.

C6. Handling mathematical symbols and formalism

This competency includes the ability to understand symbolic and formal mathematical language and its relation to natural language as well as the translation between both. It also includes the rules of formal mathematical systems and the ability to use and manipulate symbolic statements and expressions according to the rules.

C7. Communicating in, with, and about mathematics

This competency includes on the one hand the ability to understand mathematical statements (oral, written or other) made by others and on the other hand the ability to express oneself mathematically in different ways.

C8. Making use of aids and tools

This competency includes knowledge about the aids and tools that are available as well as their potential and limitations. Additionally, it includes the ability to use them thoughtfully and efficiently.

These competencies are transversal to the different mathematical topics and can be mastered at different levels.

STUDENTS VS LEARNING MATHEMATICS BASED ON COMPETENCIES

The material was given directly to the students. All the students from are push to use the materials and to learn using the materials. In this way, we will test the materials from our MLP.

In the end of the course, we give to the students a questionnaire and in this way, they can provide feedback from the materials from our MLP.

In this way, at the question "select five methods, that are the most important for you in terms of learning. Mark down numbers 1-5. (1=the most important, 5=the fifth most important)".

- Personal guidance of lecturer during classroom sessions (Fig. 1).
- Teaching with overhead projector (Fig. 2)

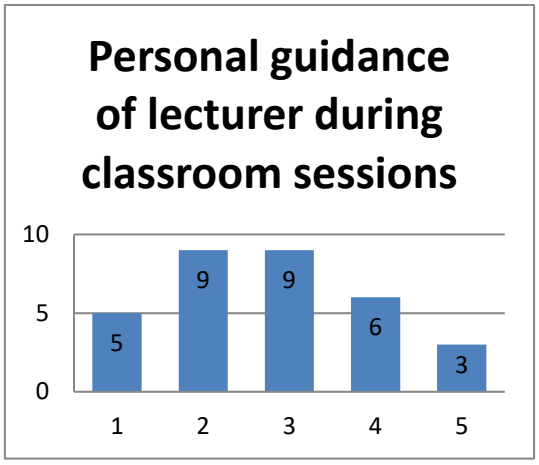


Figure 1

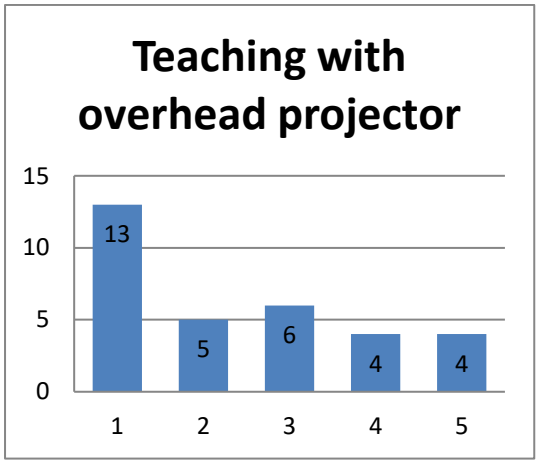


Figure 2

- Short video lectures / Screencast videos (Fig. 3)
- Teaching with whiteboard (Fig. 4)

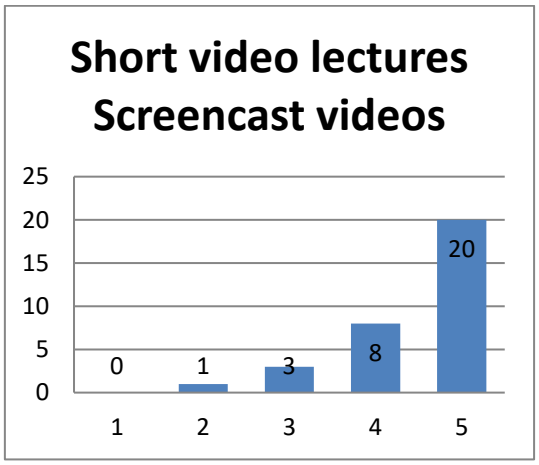


Figure 3

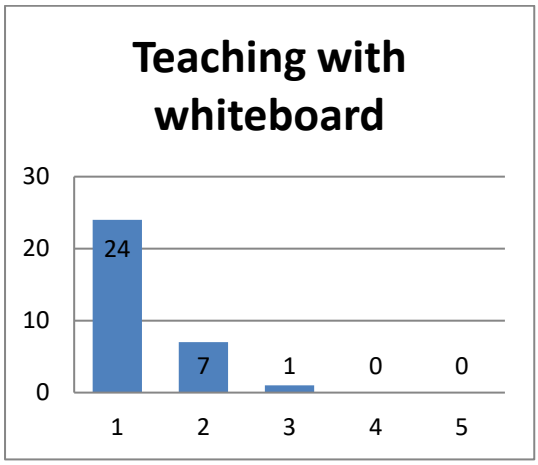


Figure 4

- Utilizing symbolic calculator (Fig. 5)
- Making exercises during classroom sessions (Fig. 6)

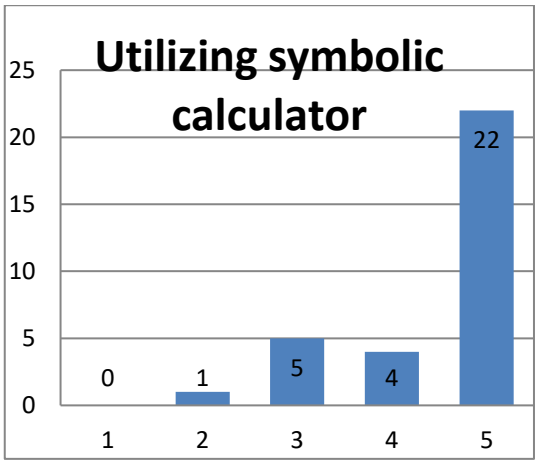


Figure 5

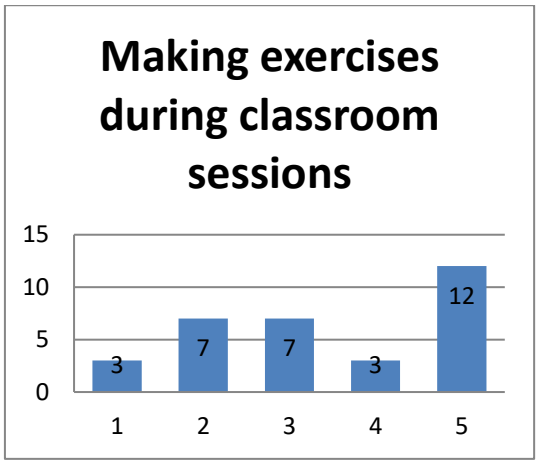


Figure 6

- Learning theory on my own (outside classroom) (Fig. 7)
- Making exercises on my own (outside classroom) (Fig. 8)

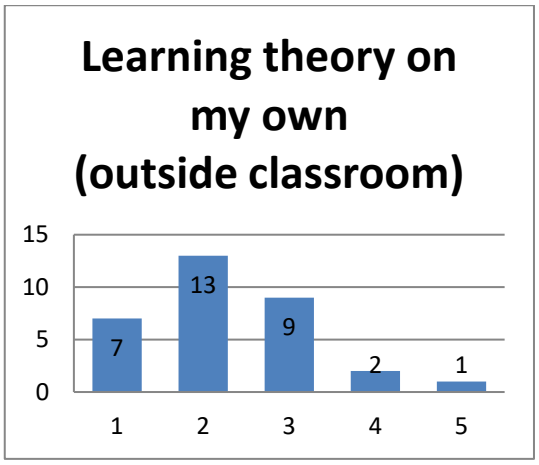


Figure 7

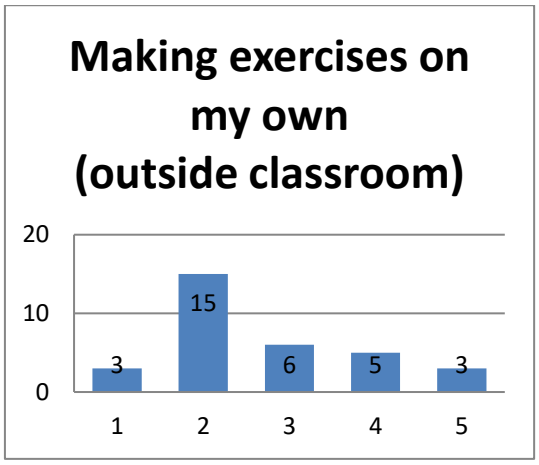


Figure 8

- Checking model solutions for homework (Fig. 9)
- Using on-line instructional resources (Fig. 10)

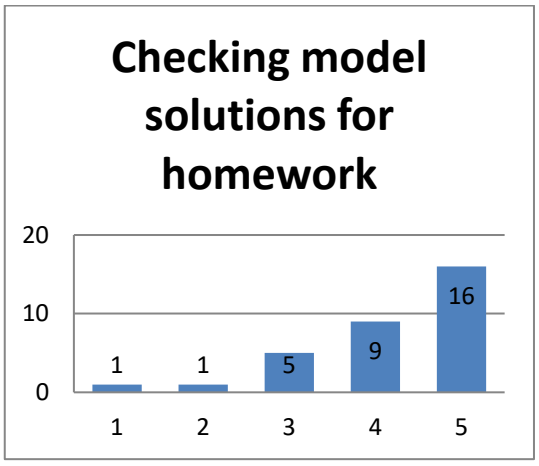


Figure 9

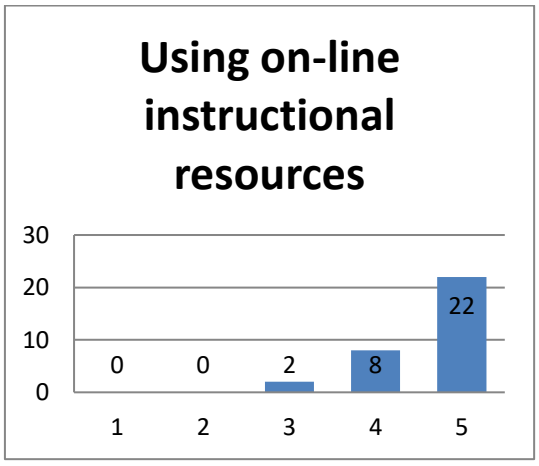


Figure 10

- Using interactive dynamic applets (Fig. 11)

Asking the students "For the following statements, select the option that represents your opinion the most" we obtain:

- Using the modern technology in mathematics' learning purposes, increases my motivation towards course concerned (Fig. 12).

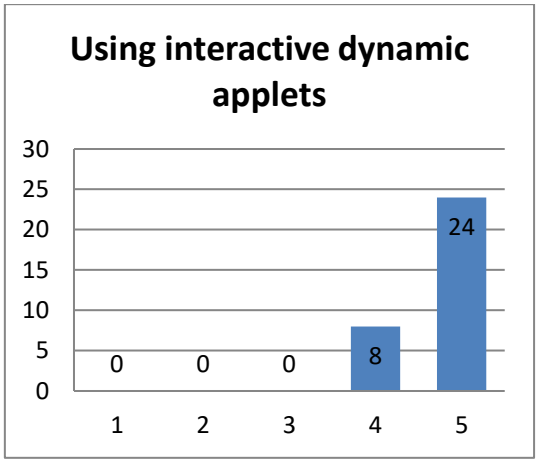
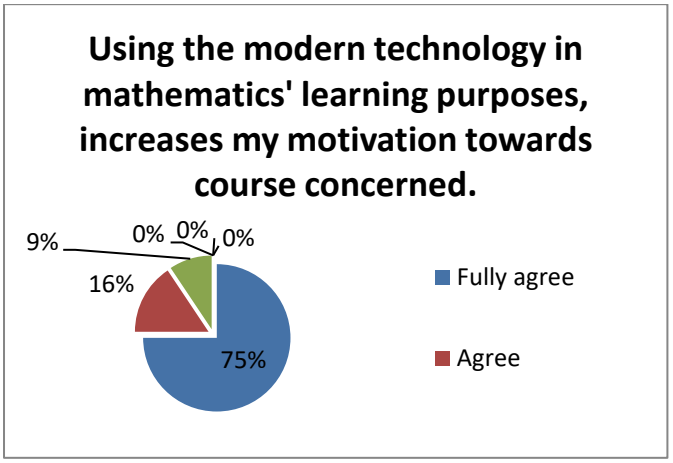
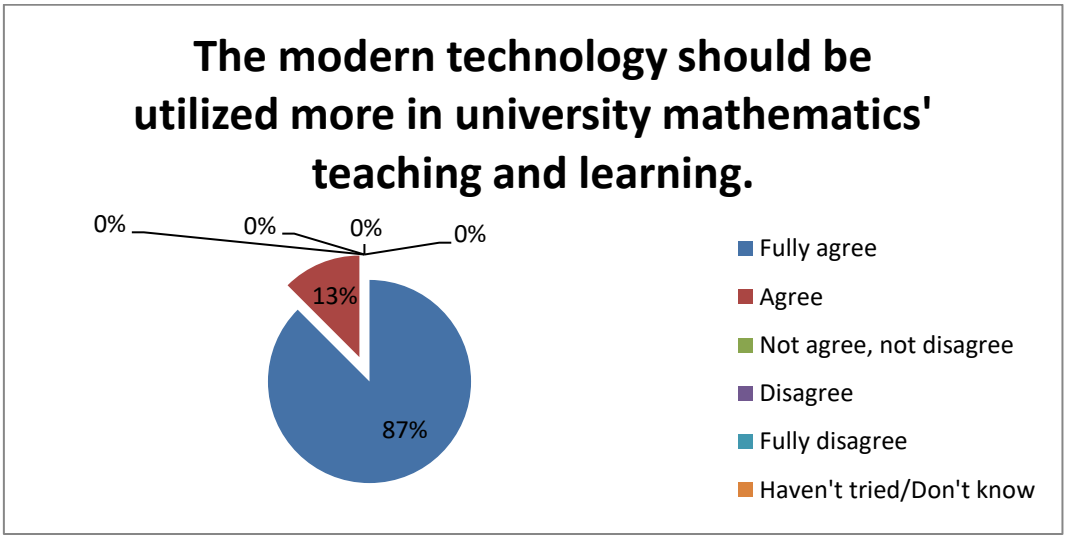


Figure 11



Fugire 12

- The modern technology should be utilized more in university mathematics' teaching and learning (Fig. 13).



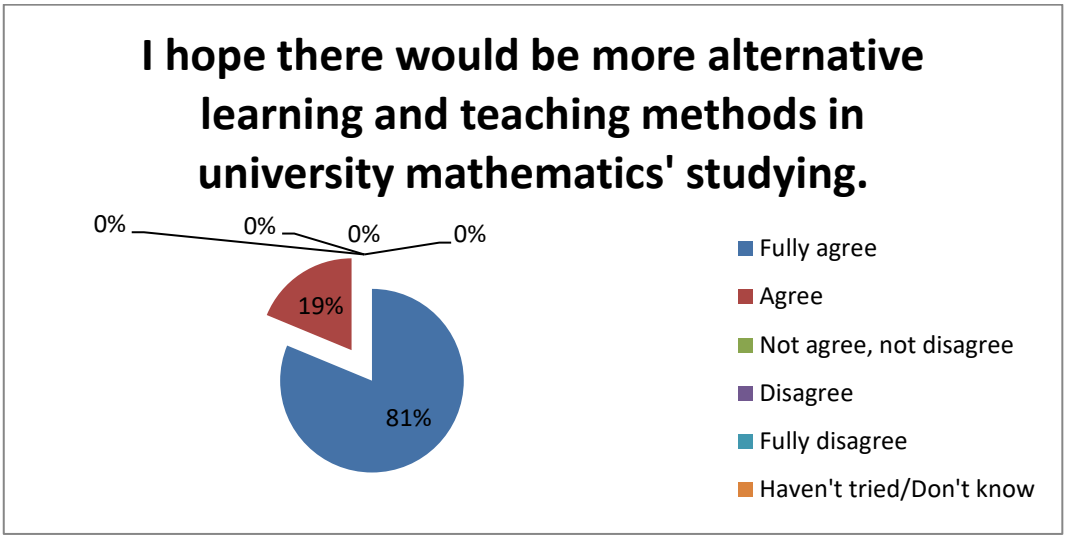
Fugure 13

- I hope there would be more alternative learning and teaching methods in university mathematics' studying (Fig. 14).
- I hope that there would be more online content in university mathematics courses (Fig.15).
- I hope that there would be more online mathematics' courses in university (Fig. 16).

CONCLUSION

The students from our universities think that learning and teaching math based on competences halp them to increes there interest in this subject.

We hope that our RULES_MATH project will be a good start for them and alos help them a lot!



Fugure 14

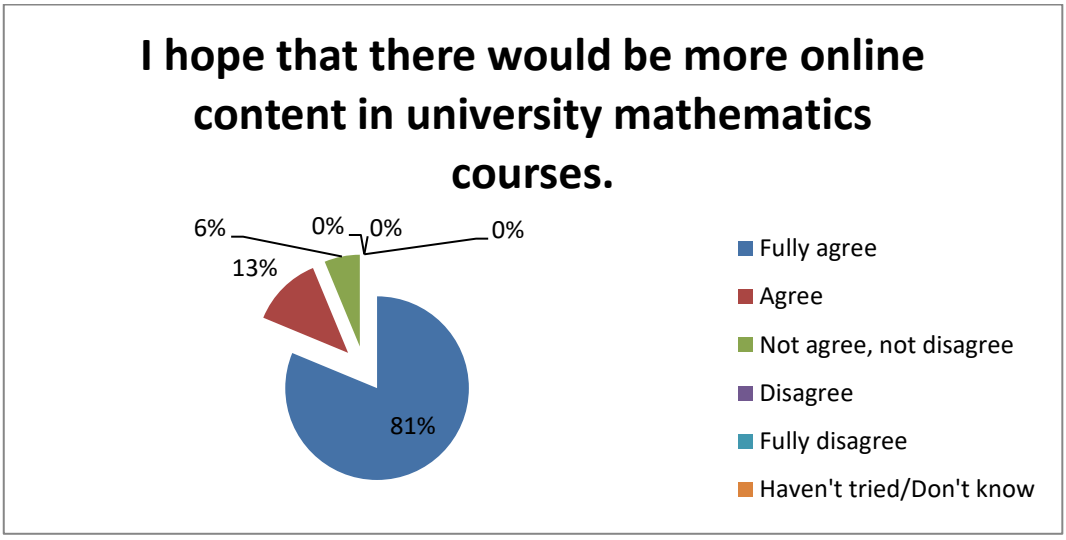


Figure 15

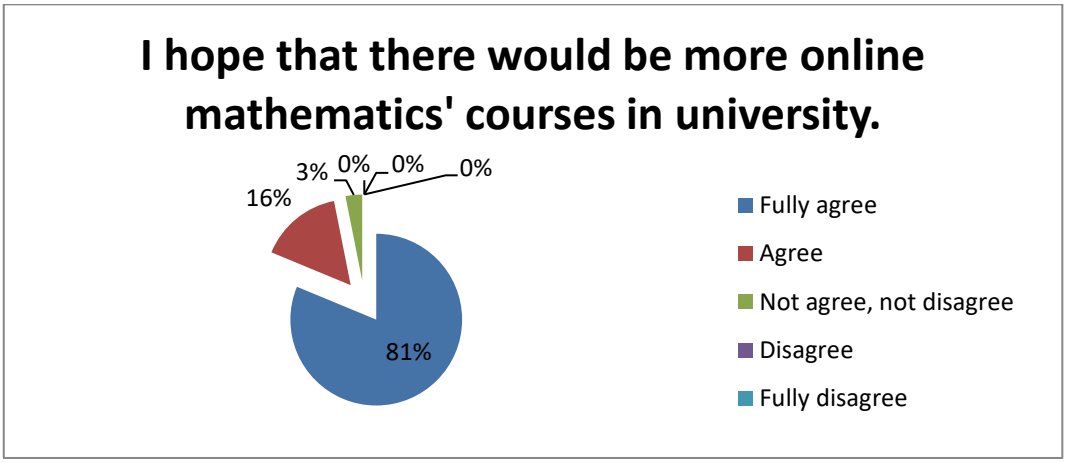


Figure 16

REFERENCES

European project *Rules Math – New Rules for Assesing Mathematical Competencies* URL: https://rules-math.com/ [viewed 09.09.2019]