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SOME EXAMPLES FOR TEACHING MATHEMATICS IN STEM CONTEXT

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ABSTRACT. STEM education is quite new way of teaching which emphasizes problem and project based learning, i.e. teaching Science, Technology, Engineering and Mathematics via solving certain real-life problems or problems related with the future carrier of the students. In this paper we will give some examples for teaching mathematics in STEM context.

1. INTRODUCTION

STEM as an approach in teaching Science, Technology, Engineering and Mathematics was initiated in 1990s by National Science Foundation [1]. STEM was introduced to describe the focus on developing curriculum to enhance learning in these four areas. STEM is an educational framework that brings reality into the classroom by connecting different subjects together in a way that they will relate to both the real and business world and to each other.

STEM approach in the education integrates the four areas which form the acronym, instead of teaching them separately and it emphasizes problem based and project based learning, in order to provide students with critical thinking skills and enable them to become creative problem solvers. That is why STEM education is becoming popular nowadays. According to [2], the rationale for targeting above mentioned four areas is that while Science and Math are important to

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achieve a basic understanding of the universe, Engineering and Technology are needed for people to interact with the universe. When we refer to STEM, we are referring to a real-world, inquiry-based exploration of the world around us, with the goal of breaking down artificial barriers between disciplines. Incorporating creative thinking and applying arts in real situations makes connection between STEM approach on one side and Art and Architecture on the other side, so very often STEM is extended to STEAM education.

The main objective of the innovative STEAM learning approach is to strengthen students' personal and social abilities in order to familiarize students with the new demands of the labor field and create better opportunities for their future carrier. STEM education research is a relatively young field with limited but growing empirical research available to inform interested parties [3]. Nowadays, science, technology, engineering and mathematics are essential for growth and stability of the global economy.

So-called 21st century skills, like problem-solving ability, communication skills, creativity, critical thinking and collaboration are considered to be essential for successful participants in the society. All of these competencies are prerequisite students' further studies in STEM areas, their taking up of related careers and ventures into entrepreneurship and inventions [4]. STEM-centered learning provides a powerful direction for building those skills.

STEM is important because science, technology, engineering and mathematics appear all around us, STEM reflects real life. Thus, implementing STEM approach in the education gives students opportunity to explore developments in the environment, which are usually interdisciplinary and to solve real problems which, as future careerists they will face up. Education should not be based on memorizing facts, but stimulate critical thinking and evaluate information. It should be based on ability to apply knowledge and skills to problem solving. Skills need to be taught in an applied way, as part of a greater whole, rather than the traditional approach of developing skills in each subject, separately. So this approach contributes in students' motivation and challenge for studying STEM focused fields. There are many benefits that have been connected with the use of integrated education, "using an interdisciplinary or integrated curriculum provides

opportunities for more relevant, less fragmented, and more stimulating experiences for learners" as it is cited in [5]. Integrated STEM curriculum models can contain STEM content learning objectives primarily focused on one subject, but contexts can come from other STEM subjects [6]. Because STEM reflects real life, and jobs in the real world are interdisciplinary, we need to educate students in how subjects integrate and work together.

2. STEM Curriculum

The thing which makes the difference between STEM education on one side and the traditional science and math education on the other side, is the blended learning environment and showing students how the scientific method can be applied to everyday life. STEM education teaches students how to integrate knowledge and focuses on the real-world applications of problem solving. A curriculum that is STEM-based is necessary to include real-life situations to help the students learn. The main characteristic of this learning approach is practical training, during which students learn and work in a real way through experimentation. Teachers should provide students with the necessary tools they need in order to make easier the use of their own knowledge in a profitable and enriching way, and to get closer to the solution of the considered problem. To carry out this methodology, digital competence, teamwork and decision-making processes need to be integrated into each subject's curriculum. In addition, an important concept within the STEM model is to combine learning concepts with game-like practices. STEM education focuses on innovation and the applied process of designing solutions to certain contextual problems using current tools and technologies.

A typical STEM lesson usually involves few basic steps: identifying a real-world problem (in order to put the students in specific real position when they must analyze and think deeply), which is more attractive and interesting for them - they will feel that they are studying something productive and useful; ask questions to explore the problem (and potentially solve the problem); develop solutions and explore a hands-on activity (teachers should provide additional materials for collaborative explorations in the groups where they can share the ideas, make decisions and find appropriate their solutions of the problem). STEM lesson

should provide multiple right answers and approaches created from the students in order to solve the appointed problem. Teachers should admit failures of the students. In that way students will have opportunity to learn what is wrong, why is wrong and to try again some other approach.

STEM pedagogy requires students to collaborate in order to solve challenges, so a teacher modeling the strength of a group approach is beneficial. In order to be effective, the curriculum must be flexible enough to be used with various ability levels and educational environments while still being focused on the engineering design process. Teachers have to be able to offer problems that meet student interests, talents and academic needs.

Making math and science both fun and interesting helps the student to do much more than just learn. STEM approach helps students to burn in them love for learning. STEM educators should combine knowledge of different subjects in order to make creative and successful lesson, to support students' learning, in order to reach STEM goals. STEM approach includes not only teaching strategies, but encouraging collaborative learning with students.

Mathematics serves as a language for studying science, technology and engineering. Mathematical courses have the main role in attracting students to STEM and reaching highly trained STEM professional, because students usually find Math as difficult subject which reject students to study technology and engineering. Thus, new methodology and approach was necessary to change the situation, so STEM approach is on the way to improve the attitude towards mathematics among students. In the STEM education, the teaching and learning mathematics is not taught conceptually but rather procedural tool to solve various disjointed applications.

The use of digital tools and different software is also useful in solving problems with the STEM approach. Until the recent years, many teachers claimed that deep understanding the process of solving given problem is the most important aspect of learning mathematics. They thought that while studying, the method and the procedure which are used for obtaining certain result are more useful and interesting then the final result itself. According to the teachers before the STEM approach to be introduced, when students are trying to solve a given problem they must think and do mental effort, which is actually the biggest advantage for the

students who learn mathematic, because the using of the mathematical software bring absence of the students' thinking. But, many research studies nowadays find out that most of the students have better results in mathematical exams if they use some mathematical software [7, 8]. Modern computer methods should not be avoid especially at the universities where the students who study science, technology and engineering usually face up with complex mathematical problems. Digital tools may be included as additional and helpful tool, for simplifying the complicated mathematical calculations. If math teacher wants to help his students not only to learn the theoretical basics of pure mathematics, but also to get pleasure from it, he has to make efforts to combine the traditional method and modern approach by using digital tools. So, students will get not only the knowledge and skills, but they also will get joy and satisfaction from studying. The expertise of educators, whether in classrooms or out of formal education, is a key factor in determining whether the integration of STEM can be done well.

3. Some Examples for Teaching Mathematics in STEM Context

STEM education typically focuses on problem-based and project-based learning in the classroom. The projects and activities incorporate technology to emphasize the application of math and science and prepare students for future classes. Teaching mathematics with the STEM approach, teacher starts with consideration of some real-life problem on the lesson, in order to show the students the importance of acquiring certain mathematical concept. Moreover, students will find out mathematics knowledge as essential for acquiring other subjects' knowledge. It is the role of the teacher to select those problems that arouse interest among the students, meet the set goals of the educational process and are within reach of the capabilities of the learners.

STEM education became very popular immediately after its introduction and many researchers and teachers are interested to develop and implement it. Real-life problems concerning mathematics for its solving can be rarely found in the math academic literature, not enough. Very often teachers find out hard to find

real life problem appropriate for math lessons, in order to introduce math concepts. Many researchers are now working to improve such situations. Teachers who participate in the Erasmus+ project "Mathematics of the Future: Understanding and Application of Mathematics with the Help of Technology" [9] have worked on developing method for teaching mathematics, which is STEM related. They have introduced different real life problems convenient mainly for calculus topics.

We will give in this paper some examples (real-life problems) for teaching mathematics in STEM context, which can be applied on math lessons on an university level.

Example 1. *A farmer in his orchard plants has 50 apple trees. Each tree produces approximately 900 apples in a season. The farmer wants to enlarge the orchard and plant more trees, but by his experience, he knows that for each additional tree planted in the orchard, the output per tree drops by 15 apples for each new tree. How many trees the farmer should add to the existing orchard in order to maximize the total output of the trees?*

It is not difficult for the students to determine the final solution heuristically, with this numbers, using different software, Excel for example. But, if the teacher change the numbers in the problem and give the next example:

Example 2. *A farmer in his orchard plants has 100 apple trees. Each tree produces approximately 1000 apples in a season. The farmer wants to enlarge the orchard and plant more trees, but by his experience, he knows that for each additional tree planted in the orchard, the output per tree drops by 5 apples for each new tree. How many trees the farmer should add to the existing orchard in order to maximize the total output of the trees?*

Students may find out difficult to determine the solution heuristically, in the same way. Thus, students will realize that math concepts, math procedures and formulas are necessary for direct calculation of the solution, i.e. for solving real-life problems. These two examples are convenient for introducing derivatives of a function with one real variable and for working on application of derivatives.

STEM approach can be implemented for introducing math concepts in almost all math topics. The importance of the differential equations as mathematical

models of the natural laws, can be explain via different practical problems in biology, chemistry, physics, etc. Malthus Law as a practical problem in biology, can be described with differential equations. The law of radioactivity in chemistry and the Newton's second law in the dynamics of the material point are also modeled with differential equations.

Example 3. *One body was heated to a temperature of* 80^0C *and it was left in an environment with a constant temperature of* 15^0C*. After 5 minutes, the temperature of the body will drop to* 70^0C*. Find the time t for which the body temperature will drop to* 60^0C*.*

The last problem is encountered as a physical problem, which is solved with the help of Newton's law of cooling, i.e. by solving a first-order differential equation.

Example 4. *We have to make a tin tank in a form of rectangular cuboid that will collect 125 liters liquid. Which dimensions of the tank will require the least amount of material for its construction?*

Example 5. *We have to make box which requires* $200cm^2$ *cardboard for its construction. Which dimensions should the box be in order its volume to be the largest possible?*

The Examples 4 and 5 are appropriate to use when introducing partial derivatives of function with two variables and their application.

Example 6. *A farmer needs a rectangular tin with an area of* $1000dm^2$*. The dimensions of the sides are not important, only the area. After the use in a certain season, the farmer have to roll it in a cylinder in order to use it for another purpose. Which dimensions the rectangular tin have to be, in order the farmer to reach the largest volume?*

The last example can also be used when introducing application of derivatives of a function in order to minimize or maximize certain size.

Example 7. *A children's playground has the shape of two circles which intersect, with equal radius R=8m and central distance d=8m. In the intersection of the two circles, there are children's requisites for playing, and outside the intersection, on both sides, there is a green-grass area for playing. In order to maintain the playground, it is necessary to know the area of the green-grass section and the area of the section with children's requisites. Try to calculate both of them.*

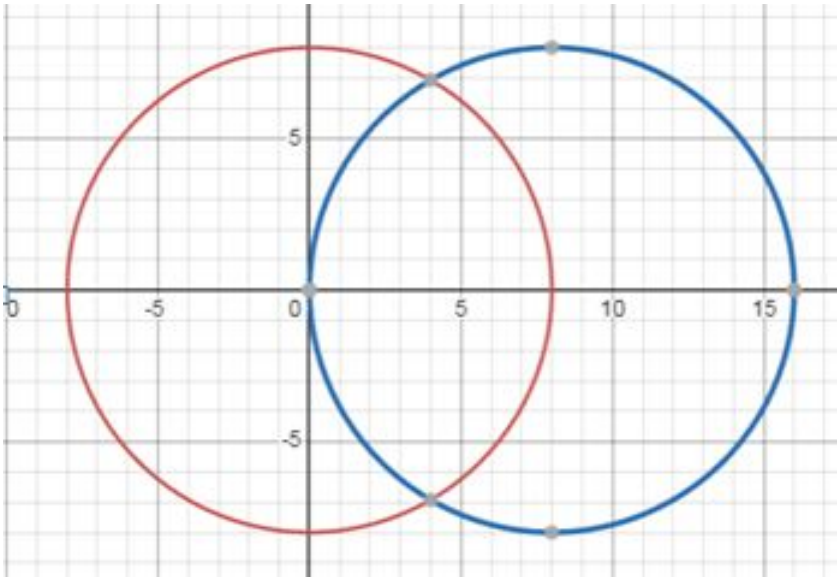

FIGURE 1. The shape of the children's playground in the Example 7

The Example 7 is convenient when introducing polar coordinates for calculating area using double integrals.

Example 8. *In a manufacture there are 4 departments with 60 employees who work 8 hours per day. The employees in the first department can finish certain work for 18 days. But, because of the high temperature outside in the summer months, they have to work 6 hours per day. The final user of their products is asking the work to be finished 3 days earlier, i.e. for 15 days. How many employees have to be engaged from other departments, in order the work to be finished for the time that the final user is asking?*

The problem in Example 8 can be solved using ratio and proportions.

4. CONCLUSION

STEM approach in teaching mathematics can contribute in arising interest among students for learning mathematics, and more over can burn love toward mathematics among students who are afraid of it. Students have to feel the need of mathematics in their carrier and in their life, thus STEM approach should be implemented in all levels of learning mathematics, starting from the primary school.

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