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THE IMPORTANCE OF THE MATHEMATICAL MODELING IN STEM EDUCATION

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ABSTRACT. The science, technology, engineering, and mathematics (STEM) education model is very popular and used method in the recent years in most of the countries in the world. With STEM education at primary, secondary and high level the students acquire important skills, creativity, innovation, and entrepreneurship. For STEM integration and training different teaching methods can be used. The mathematical modeling is one of the most important methods which can be used at all educational levels. Mathematical modeling will be considered as a bridge to STEM education. Mathematical modeling, is the process of analyzing real-life or realistic situation using mathematical methods in the most general sense. The mathematical modeling cycles should be used in STEM education at all levels from primary to tertiary education in order to increase the students' motivation towards learning mathematics for solving real-life problems.

1. INTRODUCTION

The 21st century, as a technology-based century, offers new job opportunities. But, all these new opportunities recquire new qualifications from the laborers. The computer techologies, information techologies and digitalizations offer many tools which are used in different fields like: science, arts, economy, engineering,

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medicine, agriculture, [1]. The main skills and qualifications required from workers are not only routine operations, but the ability for solving problems by understanding complex systems with describing, explaining, analyzing and predicting, is the most important, [2]. The world of work and communication is changing rapidly. The teachers need to prepare students in secondary and high schools with the 21st century skills they need to thrive in today's digital and globalized society. The seven essential 21st century skills are: critical thinking, communication, collaboration, creativity, cultural awarness, digital literacy and autonomy. One of the most important 21st century skills to teach the students is how to think critically. With so much information available online, it is crucial that young people analyze, question and challenge what they are being told. They should remain open-minded, evaluate situations and think outside the box when approaching tasks. Communication is the skill many students find challenging to acquire, especially in a second language, so it is essential to have possibilities for practice. Collaboration links with communication, as good collaborators work effectively with others to achieve a common goal. Learning how to take turns, respecting other people's opinions and being a good team player is vital for the success. Teamwork skills will also help students when they leave school and find jobs, as many of them will have to work with people from different backgrounds or cultures. Similar to critical thinking, students should be encouraged to be creative and to think of new and innovative ways to solve problems. Although the students have great understanding of the digital world it is important to use technology in the classes so that the students will be engaged and motivated to learn. The students do not know a life without Google, social media or smartphones, so this can be used at the classes for educational purposes.

The total society expects workers who have most of the 21st century skills. But, the students attend teacher-centered classes almost at all levels in education, [3]. So, because of the quility of teaching, the students in high percent have difficulties to transfer and apply the obtained knowledge at classes in their daily lives. Shifting the focus from teaching to learning and from the teacher to the learner is the core of the effective educational process, [4–6].

The science, technology, engineering, and mathematics (STEM) education model is very popular and used method in the recent years in most of the countries in

the world. By using of this method in primary, secondary and high education the students acquire important skills, creativity, innovation, and entrepreneurship. STEM Education was originally called Science, Mathematics, Engineering and Technology (SMET), [7], and was an initiative created by the National Science Foundation (NSF). This educational initiative was to provide all students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce. Although the idea of STEM education has been contemplated since the 1990s in the USA, few teachers seemed to know how to operationalize STEM education several decades later, [8]. STEM education can link scientific inquiry, by formulating questions answered through investigation to inform the student before they engage in the engineering design process to solve problems, [9]. Over the last few decades, STEM education was focused on improving science and mathematics as isolated disciplines [7,10] with little integration and attention given to technology or engineering, [11, 12]. The authors in [13], operationalized STEM education key concepts and blend learning theories to build an integrated STEM education framework for further researching integrated STEM education. An integrated approach to STEM education envisions removing the walls between each of the STEM content areas and teaching them as one subject, [10]. Integration is distinct from embedding in that it evaluates and assesses specified standards or objectives from each curriculum area that has been incorporated within the lesson, [7]. In order to ensure integrated approach in STEM education, it is neede to be chosen appropriate teaching methods. The most used methods in STEM education are problem-based learning, project based learning, inquiry-based learning. Project-/Problem-Based Learning (PBL) creates dynamic learning environments, incorporates various stimuli, allows learners to gain valuable experiences that extend to real-world applicability, and should be considered as a primary delivery method in STEM classes, [14,15]. But for using of these methods in STEM education it is necessary mathematics and its application for solving of real-life problems. One of the most important tools for transition to STEM education is mathematical modeling, [16,17].

2. MATHEMATICAL MODELING IN STEM

As mathematics is a basis for the other sciences, the mathematical model is simply a representation of the real-life phenomenon by mathematical equations. That means that one can predict the result of a physical or chemical process without going to laboratory. Just understanding the phenomenon and mathematics is enough for mathematical modeling. Mathematical modeling involves a complex process in which a problem state encountered in real life is formulated mathematically and solved with the help of mathematical models, and the solution is interpreted and evaluated in the real world, [18]. So, for a good appreciation of mathematics, mathematical modeling should be a core course in all high school and faculties all over the world. The students will appreciate the importance of mathematics for the major chosen, [19].

In [20], the two main arguments for teaching mathematical modelling as an integrated element in mathematics in general education especially at secondary and tertiary level, are the following:

(1) Mathematical modelling bridges the gap between students' real-life experiences and mathematics. It motivates the students' learning of mathematics, gives direct cognitive support for the students' conceptions, and it places mathematics in the culture as a means for describing and understanding real life situations.
(2) In the development of highly technological societies, competences for setting up, analyzing, and criticizing mathematical models are of crucial importance. This is the case both from an individual perspective in relation to opportunities and challenges in education and work-life, and from a societal perspective in relation to the need for an adequately educated workforce. Mathematical models of different kinds and complexity are playing important roles in the functioning and forming of societies based on high technologies.

The mathematical modeling is seen as a creative process to interpret the results and make changes to the model in order to define, control, or optimize the situation in order to make the real-life situation meaningful, [21].

One of the first schemes presented as an approach to mathematical modeling is given in [22]. The mathematical modeling cycle consists of the real situation and

the real world, the mathematical model, and the results in two parallel sections, 2. In the loop, problem-solving is often perceived as a guide for the real situation, [17].

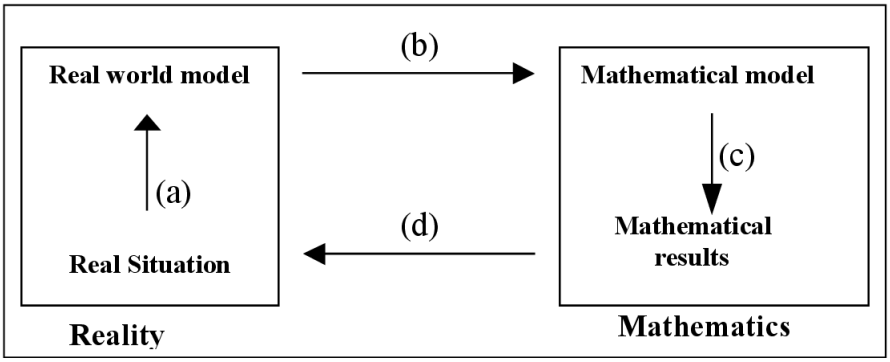

FIGURE 1. Mathematical modeling cycle, [22].

In the literature, many alternative representations of modeling can be found. About teaching mathematical modeling it is agreed that the modeling process is a sort of cycle that starts and ends with a problem situation in real life or in a non-mathematical discipline, and that there is a translation of the problem into mathematical terms and a mathematical solution. It can find a lot of modifications, extensions and improvements regarding this cycle, [23]. More detailed representation including the phases in mathematical modeling: 1) Understanding, Constructing; 2) Symplifying, Structuring; 3) Mathematising; 4) Working mathematically; 5) Interpreting; 6) Validating; 7) Exposing; is given in [24].

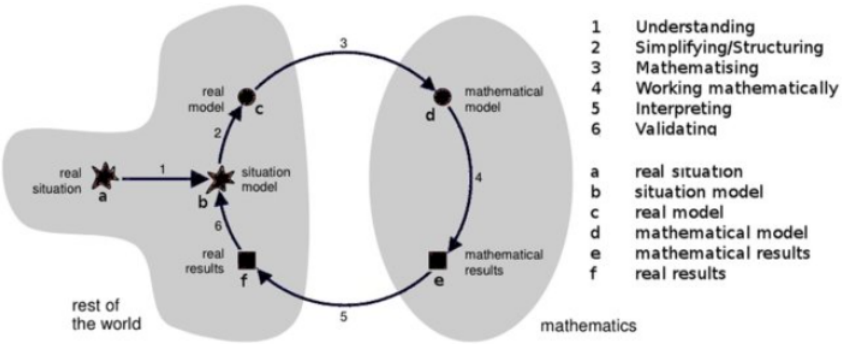

FIGURE 2. Mathematical modeling cycle, [24].

Important element in the modeling cycle is questioning. The main and necessary questions should be asked for obtaining the right direction in the analysis which is doing for solving the posed problem. The more detailed modeling cycle is given by authors in [23]. They made a study and found extra aspects in the modeling process:

(1) Problem Analysis: Determination what is the problem?
(2) Worlds, Models, and Knowledge: The modeller does not work in the mathematical world only: problems come from other domains with relevant non-mathematical knowledge and relevant non-mathematical models.
(3) Verification: Testing of the obtained solution and mathematical model in mathematical logic and consistency.
(4) Validation: Testing of the obtained solution and mathematical model in practice.
(5) Communication: Interection with the teacher or client.
(6) Iteration: Going through modeling cycle more than once.
(7) Reflection: Questioning about the used models, possibilities for improvements.

The modeling cycle of Perrenet and Zwaneveld is given at the following figure:

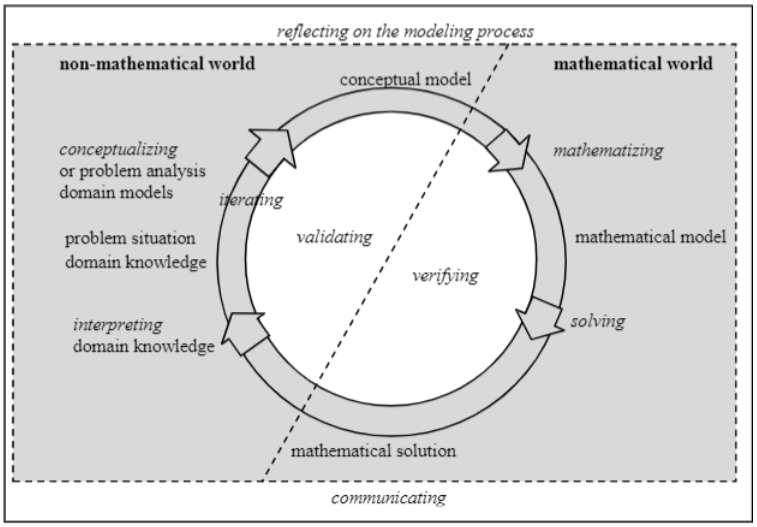

FIGURE 3. Mathematical modeling cycle, [23].

Mathematical modeling can solved real-life problems from different areas. Because of that, mathematical modeling is considered as an effective and powerfull tool in STEM education, [25, 26]. Mathematical modeling can be applied in different sciences, so it is known as interdisciplinary mathematical modeling. It connects mathematics and science. The starting point of the mathematical modeling is understanding of the real-life problem, enters in STEM. In [27] theoretical framework of STEM integration, has been shown as three Venn diagram using mathematical modeling applications. The first circle represents the elements of metacognitive theory (metacognitive knowledge, processes, skills, and strategies), the second circle includes social development theory (social mediated interaction—promoting communication). The third circle consists of the teaching elements which are considered as basic for education, [17].

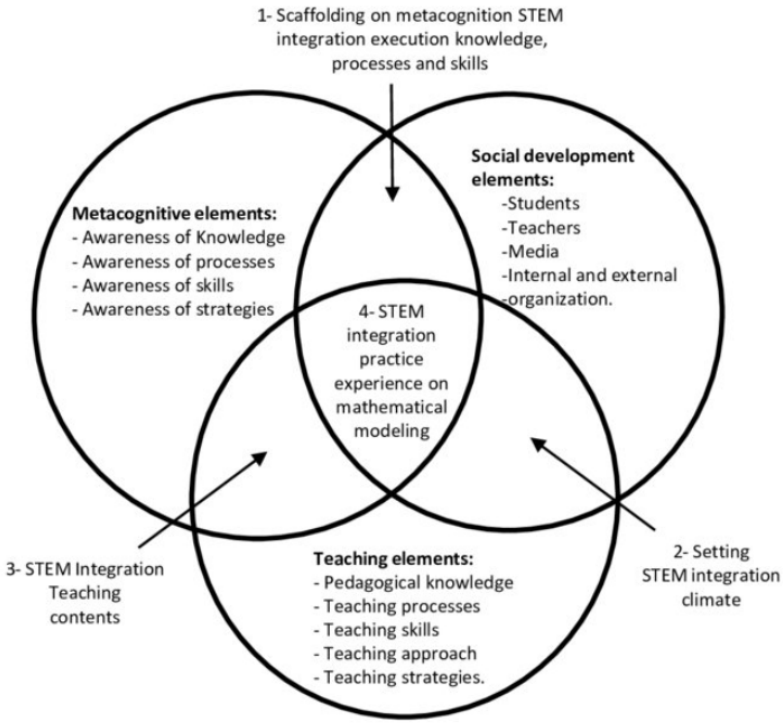

FIGURE 4. Mathematical modeling cycle, [27].

Mathematical models can predict the behaviour of the quantification methods, new designs, and new situations. In [28] it is shown that the application of mathematical modeling is of particular importance in STEM education.

3. CONCLUSION

One of the most important tools for transition to STEM education is mathematical modeling. As mathematical modeling involves activities such as describing natural phenomena or designing a component or a system by writing mathematical equation was mentioned as a component to interconnecting STEM's discipline. The ability to solve a problem in mathematical modeling is closely related to the cognitive activities that are applied while they are facing a problem-solving task. Therefore, good cognitive skills will lead a person to be more analytically minded while facing mathematical modeling problem solving. Consequently, a lot of mathematical modeling activities should focus on cognitive aspects, and this could help students' exposure indirectly to STEM-related careers in real life. Mathematical modeling is considered a challenging task and it involves high-level problem-solving abilities and it is proved as an enjoyable task for students to develop their cognitive abilities. Therefore, implementing this task, could lead students to be more analytical as required in STEM careers industry.

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