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Mathematical modeling language/tool with disciplinary as a solution strategy in the study of worldwide subjects

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Abstract

In recent decades, many governments throughout the globe have made boosting mathematics, biology, and chemistry (MBC) education a major priority of their educational policies to better educate students for a scientific and technological future. Study of mathematics transdisciplinary is not confined to the "STE," (Science, Technology and Engineering) but should extend to every subject area. Using mathematical modeling as a model for promoting both modeling and interdisciplinary mathematics education (IdME) in the classroom is a great example of how to implement both concepts in the classroom. As a way of creating ideas, mathematical modeling fosters all of the following: Students can put this plan into effect since they have solved the applicable challenges. The study of mathematics provides a chance to investigate a variety of environmental concerns.

Keywords: Mathematics modeling, solution strategy, transdisciplinary learning, interdisciplinary mathematics.

Introduction

Models are a way for us to express our ideas about how the world works. Mathematical modeling is the process of expressing such views in mathematical terms (R. Ferri & Mousoulides, 2017). For one thing, it is a simple and well-defined language that holds all of the facts that mathematicians have proved over decades and computers can subsequently be utilized to run numerical simulations. Math is also a highly precise language that assists businesses in identifying underlying assumptions (R. Ferri & Mousoulides, 2017). When it comes to mathematical modeling, there is usually some room for compromise. The vast majority of complex real-world systems are impossible to represent in their totality because they are just too intricate. As a result, identifying the system's most critical components is the first step in reaching a compromise. The remainder will not be considered for inclusion in the model (Rocha, 2018). The second degree of compromise is deciding how much mathematical manipulation is worth it. However, despite mathematics' ability to show generalizations, these conclusions are very dependent on the equations themselves (Widjaja *et al.*, 2019). Even minor changes to an equation's structure might need a significant overhaul of the underlying mathematics. Model equations handled by computers may not provide beautiful solutions, but they are far more resistant to change (Roth, 2020; Tangkawsakul *et al.*, 2020).

We believe that A. Uyomov's definition of a model as it is used, which he describes as a whole whose investigation is a method of gaining knowledge about another system, is an adequate way to characterize the notion of mathematical modeling (Tezer, 2019). The other systems in Uyomov's concept are the mathematical ideas and qualities that describe environmental occurrences in our case. Students begin utilizing mathematical modeling methods and tools in elementary school, but a full description based on and only in the ninth grade, during a unit on the topic, is a scientific conceptual framework offered following the school's Algebra curriculum (Williams & Roth, 2019). For example, students who have studied chemistry or biology may be familiar with environmental phenomena that may be modeled mathematically as a way of learning about environmental phenomena as a result of their studies in those fields (Ekici & Plyley, 2019; Tezer, 2019).

A teacher should prepare to provide models (illustrations, schemes, table) to students while working on the mathematics curriculum to symbolically transfer characteristics of modeling entities to pupils, particularly their structure and connections (Tytler, 2016). Students may learn about numerous figurative and mathematical models (such as drawings, schemes, and tables containing concise expressions of conditions) while working through text-based challenges (Sunee, 2015). Pupils learn how to use various models to solve applicable issues in general and environmental challenges in particular (Consortium, 2016; Sunee, 2015).

For example, pupils may be required to design something unique model to show the links between different words in a subject or unit while categorizing mathematical concepts (algebra, geometry). Teachers may use a problem's content to assist motivate students, For example, you can learn about volume in general and the volume of a pyramid in particular. Students may get a greater knowledge of ideas and their attributes by observing properties, articulating theorems, and solving problems utilizing the information they learn about various material (real) models. In addition, as part of their homework, students may utilize mathematical modeling to participate in active cognitive activities both in class and at home (Consortium, 2016).

Students learn formulae for determining the areas of flat figures, the surfaces of spatial objects, and the volumes of such things by using mathematical modeling as a technique of cognition. Practical issues, particularly those with an environmental focus, are a primary tool for this. Solving problems involving geometric figures, theorems, properties, and definitions is one way to lay the groundwork for environmental education by cultivating students' spatial imagination and understanding of the links among various mathematical conceptions (Sullivan & Yang, 2013). When it comes to issuing solving, drawings serve as the most effective modeling tools. Using the geometric shape pyramid as an example, let us see how we might solve an applied issue of environmental content. Using mathematical modeling and interdisciplinary mathematics education as a theoretical lens, this research aims to determine how mathematical modeling may help advance interdisciplinary mathematics education (Ärlebäck & Albarracín, 2019).

Discussions

Organic waste is a byproduct of human life and activity (de Camargo *et al.*, 2014). Polluting the air and water near major cities is the result of massive landfills. For example, the volume of the Great pyramid has been exceeded by municipal waste outside of New York. A square with a 227-meter side seems to exist at the foot of a Great Pyramid, and the Pyramid's height is around 147 meters. The answer in this example is 63123025 m^3. The graphic displays a computer-assisted solution to the problem of estimating the volume of the Great Pyramid (Andresen, 2009).

Learners of 'volume of a pyramid' will benefit from a variety of approaches to teaching this issue. The following will aid in the development of the geometric concept:

Students must be able to solve the challenge to graduate, they first need to understand the issue at hand; next they need to understand the concept of volume and the formula for calculating it; and last they need a picture of a pyramid, which mimics the scenario mentioned above (Гриб'юк, 2014).

When it comes to teaching geometry, we use models of geometric shapes, but in geography, we use cartographic projections to show the earth's surface as a flat plane. Students 'research' the earth's surface using auxiliary projections, such as a cylindrical, plane, and cone (Oleksandrivna, 2014).

In elementary school and the fifth and sixth grades, students are introduced to a variety of models for expressing the circumstances of practical issues. Students in the 5th grade, for example, learn about three distinct problem-solving methods while working on an applied issue. There aren't enough environmental issues addressed in the current crop of school textbooks (Olena Hrybiuk, 2019a). Our research has focused on determining the consistency of the conceptual framework that underpins particular environmental phenomena, as well as students' level of understanding in these fields, by examining the course materials in these disciplines. The application of science, botany, zoology, biology and the principles of ecology shapes students' knowledge of environmental occurrences and the types of mathematical models utilized in math classrooms. Consequently, Within the framework of the topic under investigation, the interdisciplinarity of the disciplines is shown in a diagram (Franchuk; Tigrov *et al.*, 2021). Pupils' mastery of theoretical material's structural components helps them acquire new mathematical models that are essential for the efficient application of the technique of mathematical modeling in mathematics and biology and chemistry classes (Hrybiuk, 2021).

We may apply the conceptual approach developed by O. Pogorelov2 to learn and practice utilizing the technique of mathematical modeling (MMM), which is analogous to proof by contradiction in geometry (O Hrybiuk, 2019). The key to this strategy is to first study the fundamentals of the technique in question, and then to develop the necessary abilities to put that knowledge to use. While the preceding technique is provided in a basic way by solving problems, it is further explained in a second stage via a conceptual framework and a comprehension of its essence and reference principles (Olena Hrybiuk, 2019a).

Mathematical modeling may only be researched and used in this scenario if the following requirements are met:

- An applied issue must be addressed to gain knowledge about the phenomenon under investigation
- Mathematical models that are appropriate for addressing a particular kind of applied issue with environmental content.
- Mathematical models that are appropriate for addressing a particular kind of applied issue with environmental content.

Definitions at a high level and in broad terms Mathematical modeling is widely accepted as being an activity involving a back and forth from reality and mathematical, but interdisciplinary mathematics education has a far more nebulous meaning. A group of researchers from several professions, including both of the authors of this study, recently produced the book "Interdisciplinary Mathematics Education - State of the Art" (Williams et al., 2019).In the absence of further discussion, it became evident that the term "discipline" is considerably simpler to define than "multi-, inter-, trans-, or meta-disciplines." Describe the meaning of multidisciplinary (OO Hrybiuk, 2019). Nikitina (2006) published an intriguing study in which she identified three different integrative methods to teaching science and mathematics that varied from one another in terms of both form and intent. There are three main approaches to teaching math and science, notably conceptualizing, contextualizing, and problem centering. According to the authors' empirical investigation, instructors may benefit from knowing the advantages and disadvantages of each of these tactics to choose the best manner to offer their multidisciplinary content. While (Roth, 2020) offers a concise and pragmatic definition, he says: "Interdisciplinarity signifies the existence of two or more academic areas or bodies of knowledge." The conventional borders between academic fields tend to be crossed in interdisciplinary work" (p. 417). It serves as the theoretical framework for this paper's discussion of IdME. By comparing (Roth, 2020) concept with mathematical modeling, the following ideas emerge: Mathematical modeling activities are impossible unless there is a real-world issue to represent (Olena Hrybiuk, 2019b).

Cycle perspective and individual modeling routes

Modeling cycles of any kind have recently been shown to be critical in classrooms for the education - learning of mathematical modeling (R. B. Ferri, 2006). Meta-cognitive modeling competence may be considered as an important learning aim in addition to general modeling sub-competencies. Modeling is not a linear process for individuals, according to studies of students' cognitive processes while doing it. Individual modeling techniques best represent students' back and forth hopping during the cycle. A cycle perspective, modeling and integrative mathematics have led to the construction of two main concepts, where (b) is dependent on (a).

(a) Mathematics itself is at the center of the modeling cycles that applied mathematicians and math educators have constructed in recent decades (Gilbert, 2004). The cross-disciplinary perspective is not immediately obvious. The words "simplifying" and "working mathematically," which are often employed in modeling cycles, do not imply the involvement of other disciplines. When just considering the cycles, this demonstrates exclusivity and a lack of overlap. Even in the modeling cycles of science, the same phenomenon can be seen because the disciplines focus on their own, but mathematics is only an afterthought.

(b) Since the inter-disciplinary view is not expressly visible in existing models, this means it can only occur when appropriate modeling problems are addressed. Reading the issue requires the person to understand the inclusion of various disciplines and realities in the dilemma. A person's experiences are not the sole source of extra-mathematical knowledge, but also the knowledge of other fields, such as physics or information technology (Blum & Ferri, 2009; R. B. Ferri, 2006). The better a student's modeling process is, the more "discipline knowledge" and "mathematical knowledge" he or she has. When students comprehend the numerous disciplines involved in the modeling problems, the separate modeling paths seem to be on a multi-dimensional level, to speak abstractly. If we look at it this way, mathematics modeling and transdisciplinary education have a lot in common (Doerr & English, 2003).

The viewpoint of teachers and the technique of cross-linking

In light of the previous section, we will now consider the situation from the perspective of educators. Our teachers have to be experts in all four STEM (Science, Technology, Engineering, and Mathematics) domains to teach interdisciplinary mathematics. We took the present discussion in STEM education as a starting point for our theoretical conception to address this problem. B. Ferri and her colleagues (2017) distinguish between single-field teaching strategies and cross-link field teaching methods. For example, an engineering educational environment is an example of a single-discipline method. This setting does not essentially involve the other disciplines. At least two disciplines must be promoted at once to cross-link the disciplines. In classroom study for the "Leonardo-da-Vinci Project" (B. Ferri et al., 2017) explicitly combined mathematics, physics, engineering, and art in one learning environment. Students in grade 9 (14 years old) utilized an inquiry-based learning environment to build and duplicate the Leonardo bridge (Vagliardo, 2006). Reflection on cross-linking the disciplines was the primary purpose of the lesson unit. The following definition of "cross-link" is based on empirical evidence and theoretical considerations: The term "cross-linking" refers to the practice of incorporating at least two (scientific) fields within a single lesson or whole lesson unit and allowing pupils to reflect on their metacognitive processes. Again, the primary focus is on making numerous disciplines clear (R. Ferri & Mousoulides, 2017). However, it is also conceivable for a teacher to examine the Leonardo Bridge just from a mathematical standpoint, disregarding all other disciplines. Students used a range of disciplines to their knowledge and modeling of the bridge (Mata et al., 2012).

Interdisciplinary activities and students' work

The creation of activities and teaching resources has been the subject of a large number of research investigations. Focusing on educational processes that have embraced a modeling viewpoint is the emphasis of this research. For example, these kinds of exercises take place in real-world settings and allow for a variety of interpretations by students. Activities like this allow children to participate in essential mathematical processes, including describing, analyzing, building and reasoning. Using a modeling viewpoint, researchers have identified six design principles that may be used to create these kinds of learning experiences (Prosser & Trigwell, 2006). Lesh and Doerr have improved the work of instructors and researchers to produce these design ideas (2003). According to the "Model Construction Principle," each mathematically relevant circumstance demands a clear description, explanation, or technique. To fulfill the 'Reality Principle,' students must be able to analyze the activity from their level of mathematical skill and prior knowledge. The 'Self-Assessment Principle' ensures that the course content includes criteria that students may discover and apply to examine and update their thinking processes. Additionally, students must be able to evaluate the effectiveness of their ideas and choose when and how to make necessary improvements, all of which should be included in the modeling process. As part of the 'Model Documentation Principle,' the students are expected to record how they understand the issue scenario and their solutions throughout the modeling exercise. Construct Share-ability and Reusability Principle, the fifth principle demands students to develop solutions that can be shared and reused by others outside of the local circumstance (Nasser, 2005; Prosser & Trigwell, 2006).

Although mathematically important, effective prototype principles guarantee that the modeling activity is as easy as possible while yet being accurate. Students are expected to come up with answers that may be used as models for understanding other circumstances that are structurally similar. Following the aforementioned guidelines, Mousoulides and colleagues have created a variety of student-focused, cross-disciplinary modeling exercises. They have been tested at a variety of schools around the globe, including the United States.

Recognize the connection between mathematical modeling and interdisciplinary mathematics

After summarizing the theoretical studies presented, it becomes clear that mathematical modeling and IdME have major practical and methodological commonalities. It is teachers who must first make interdisciplinary activities more clear to students and then actively link them via their instruction in the real world of modeling issues, as shown in the preceding section (Miller). It is possible that in some respects, mathematical modeling serves as an example of interdisciplinarity in mathematics education. Mathematical modeling and IdME's interaction is a difficulty that we would want to think about more and create an acceptable depiction of. "problem understanding," "validation," and other terms/concepts/processes such as "theory(-ies) of modeling" are all part of this theory (Cai *et al.*, 2014; Michelsen, 2015). As a mathematical modeler, you might regard this as the theoretical element, based on decades of theoretical and empirical study. This makes it very difficult to disentangle mathematical modeling from IdME because, although IdME includes mathematical modeling, we may also see mathematical modeling as a whole area of study in and of itself. Students might use this modeling-oriented method to focus on finding/proposing a system for balancing calorie consumption for the "nutrition and exercise" case study (Asempapa, 2015). Students may be pushed to come up with numerous models for different people when it comes to balancing diet and exercise (e.g. classmates; professional athletes; instructors; parents). In this way, the activity's focus would shift from mathematics and biology to modeling. If the (interdisciplinary) work does not meet the requirements of the modeling, difficulties, such as when you have a "word problem," IdME may be placed in its area. Modeling problems aren't inherent to every multidisciplinary endeavor that includes (some) mathematics (Anhalt *et al.*, 2018; Torres & Santos, 2015).

There are several ways to approach IdME that don't include modeling, thus one may use math and biology in a work but concentrate on math when dealing with the issue at the end (Asempapa, 2015). We are talking about "pure crossing disciplines" here. The link between modeling and IdME is shown via real-world questions includes in a real-world modeling problem. Questions of a modeling task, students understand the questions, identify all of the disciplines involved, and use or learn about extra-mathematical knowledge. For example, students in the Nutrition-Exercise case study could use this strategy to develop algebraic formulae for the count of calories in different diets and/or sports activities. Students would have to deal with both scientific and mathematical concepts, but the emphasis in resolving their given subject would be on either mathematical or biological principles (Torres & Santos, 2015).

Recommendations and Conclusions

If the prerequisites are met, then mathematical modeling is a useful tool for developing concepts (functions and equation systems; different forms of polyhedrons; solids of rotation). These models (material and ideal) can be used for both the formation of certain mathematical concepts and the study of the models that would be used at later stages when applied problems to environmental content are expected to be solved using the method of computer modeling, which is appropriate for this purpose. As a result, mathematical modeling includes both coordinate or vector approaches (Anhalt *et al.*, 2018).

Pupils in grades 7 through 9 are initially introduced to the MMM framework through addressing practical issues, particularly those with environmental significance. While studying themes of mathematics, biology, and chemistry, this step may be achieved by taking into account the inter-subject relationships between these areas, which are specified in tables.

The purpose of the first lesson on "Mathematical modeling" is to convey the approach's basic concept, learn its content, and create its reference rule (Anhalt et al., 2018; Dym, 2004). The third level of conscious application of the mathematical modeling (MMM) approach, which should be continued in high school, include addressing practical challenges, not only environmental ones. We can also see how the method is used to undertake ecological and biodiversity studies on the scale of a city, town, street, school, or house, and how the results are presented graphically.

Mathematical models in high school are becoming more diverse, allowing the MMM to be used in more ways. Anatomy, zoology, and botany are just a few examples of fields where MMM utilization is required. When researching the MMM, it is appropriate to use an algorithmic technique. The deductive technique is used in the second stage of applied problem solving, as the inductive method was used in the previous step (Erbas *et al.*, 2014).

Each of these three phases (preliminary, systematic, and conscious use) of the method of mathematical modeling (MMM) may be characterized by the learning activities of students.

In the beginning, it's a good idea to teach students how to address practical problems and environmental issues using the same method, which will serve as the basis for the MMM's content and reference rule (Kertil & Gurel, 2016). Due to practical problems, students can effectively implement every position in the scheme of the technique of mathematical modeling (White *et al.*, 2021).

For example, Students in fourth through ninth grades participate in the following mental activities: Algebra: solving problems using the equation approach; Geometry: solving issues using the test of equality and similarity of triangles, trigonometry, and techniques of coordinates and vectors) (White et al., 2021).

We address direct and inverse issues to make these two mental activities, which are at the foundation of the mathematical modeling approach, conceivable.

By applying imaginative solutions to mathematical issues, the modeling method aims to improve students' interest in the subject matter and their ability to think critically and creatively, as well as their ability to do research (Diefes-Dux *et al.*, 2012).

Largely, this is true for both steps one and two, which are about choosing to observe or develop an informal model. Using these procedures, it is possible to distinguish between the two processes: modeling and mathematical modeling. Math and biology or chemistry may be taught together by two instructors in an integrated session, where students can participate in such an activity (Abrams, 2001).

An integrated lesson combines information from many disciplines to build a broad picture of what we are learning; in this case, we are merging material from the mathematical and biological sciences with chemistry. Students have a greater knowledge of course material, discover connections between disciplines, increase their cognitive and creative talents, and learn about the environment because of taking these courses. Symmetry and proportion are ideas that are used in math, physics, biology, and chemistry. Both the coordinate and vector approaches are used in mathematical modeling. In high school, students should be able to utilize the MMM to address both applied and environmental issues, as well as modeling as a process of research of a species that relies on the location that may not be offered in the form of a specific inquiry. Pupils are ready to apply the first three steps of the modeling process and the fifth stage (Abrams, 2001; Banerjee, 2021; Hritonenko & Yatsenko, 1999).

The MMM is used to assist students to learn the structure of arguments in the early stages of addressing applicable issues. When studying 'Mathematical modeling' in the 9th grade, students get an in-depth look at how to use mathematical models like algebraic equations to solve issues in environmental science based on what they've learned in zoology, botany, and other science classes (Gainsburg, 2006; Hritonenko & Yatsenko, 1999).

Mathematical modeling is an important topic, and this first lesson on the subject gives an excellent opportunity for students to learn about the theoretical model of this topic as well as how to use the MMM to solve applied problems, which is also an excellent way to educate students about environmental issues. There must be a lesson that is generalizing and systematizing in nature. When it comes to knowledge expansion, the first step is to introduce concepts like "model," "mathematical model," and "mathematical modeling." Mathematical modeling should be taught in high school after students have studied chemistry, biology, and the basics of ecology in textbooks, and it is appropriate to have them perform graphic calculations but also study natural phenomena at this stage after pointing out the mathematical notions that were used to describe these topics. As a result, a teacher engages students in cross-curricular linkages. Using this method, students may research a variety of environmental issues while they are learning mathematics (Gainsburg, 2006; González-Parra *et al.*, 2018; Ludwig *et al.*, 2018).

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