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Interrelation of Mathematics within the STEM

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Abstract
Methodically inspecting mathematics in STEM educational programs participates with a percentage of twenty five percent. Interaction of mathematics in science, technology, and engineering is inevitable. Science, technology, and engineering acquire tools of mathematics to observe, describe and predict natural phenomena. Science pays a huge attention to natural phenomena that surrounds us; in addition, mathematics comes up with the structures and logical relationships to its scope. Technology uses mathematics extensively; in general, mathematics is a powerful tool to find any solution in technology. Engineering is based on scientific concepts to sketch, plan, or design a construction. Engineering uses mathematics throughout any workflow in its domain. Application of mathematics in real world situations does not require the necessary use of engineering, science, or technology. Mathematics is less dependent on other subjects, as a result, mathematics participates in STEM educational programs with a greater percentage than twenty five percent. Nevertheless, combining four subjects on analyzing a natural phenomena generates high quality results with a higher accuracy.

Key Words: Science, technology, engineering, mathematics, mathematical science, interaction, project.

Introduction

Mathematics is in a close relationship with Technology, Engineering, and Science. Technology does not involve elements of mathematics considerably like science; however, mathematical modeling of technology has a great influence with programing computer languages. Engineering models technical drawings, schema, projects, plans, with the services of mathematics. Engineers use mathematical tools steadily, but they do not need extremely high accuracy. As a result, engineers round their results to the point that it does not affect the practical work. Mathematics is the language of science. All scientific observations, predictions, experiments, and analysis need validation. Mathematics verifies any value of a scientific work by using its modeling strategies in harmony with the specific sample. Three academic subject recon on mathematics.

Technology and mathematics follow an interactive process; mathematics applies several fields in programming computers, and technology influences teaching and learning mathematics in education. The article, What Kind of Math is used in Computer Programming, says" There are five major types of math used in computer programming" (n.d). The most important mathematical field in programming includes: binary mathematics, college algebra, statistics, calculus and discrete mathematics. On the other hand, technology enhances teaching and learning strategies greatly. For instance, teaching geometry with figures in the exact scale, graphing functions accurately, computing examples with huge numbers or numbers with long decimal numbers extremely fast and precisely, verifying complex derivatives and antiderivatives results, etc. Integrated technology in mathematics emerges from elementary to higher education. Technology prompts mathematics and mathematics sophisticate technology.

Engineering utilizes mathematics as a tool to explore its application inside its scope. Mathematics relies heavily on precision measurements, while engineering rounds measurements to a certain degree of accuracy. However, engineers use mathematics as a powerful tool throughout their work. The article, The Role of Mathematics in Engineering Practice and in the Formation of Engineers, claims, "Engineers' use of mathematics is considered in three parts: curriculum mathematics, mathematical thinking, and engaging with mathematics" (Goold,2012). Engineering education curriculum incorporates mathematics from middle school up to higher education. In higher education the curriculum contains mostly courses of applied mathematics. Every field makes logical sense in their methods or datas, especially technical and natural sciences that operate mathematically in their entire domain. Engineers engage mathematics when they draft a project, predict data, finalize the project, verifying their findings, etc. Mathematics affiliates with all branches of engineering.

Science predicts, explains, verifies evidence through mathematics; moreover, mathematics enhances teaching science to a great degree. Any scientific fact that cannot be explained mathematically, science does not accept as truth. Science verifies all facts with numbers or logically. Even teaching science demands mathematical application. The article, The

Mathematics and Science Integration Argument: A stand for Teacher Education, says “There is optimism for improving science teaching through integration with mathematics” (Furner and Kumar, 2007). Science is an exact field that requires lots of deep and strategic learning. The huge domain of science with the focus on various academic subjects makes it a complex field. Nonetheless, mathematics supplements teaching science with practical simplification; consequently, math connects science with logic. Integration of mathematics with the science or mathematical science anticipates, checks, and verifies scientific truth in any field of the science.

Mathematical science engages in a large variety of disciplines such as: pure mathematics, applied mathematics, statistics, computer science, biology, physics, engineering, etc. Also, communication as a part of social studies and humanities engages mathematical science utterly. The number of the disciplines that apply mathematical science increases with respect to progress of science, technology, and engineering. Mathematics is a constituent part of science, technology and engineering, and imparts a vigorous clarity of data to us.

Method

Mathematics as a most influential subject with science in cognitive elements of the STEM, transmits a great power to four subjects on studying their domains with full capacity. For instance, analyzing a natural phenomena requires several steps such as: translating verbal information into a mathematical model. The next step, constructing the model that is in consonance with empirical strategies. Another important tool in analyzing natural phenomena incorporates assorted STEM abilities. These abilities include mathematical reasoning, inductive reasoning, deductive reasoning, controlling precision...Most of STEM abilities and skills belong into mathematical scope; therefore, science, technology, and engineering, apply mathematics massively throughout their activities. Evry subject has to justify and validate their findings, nonetheless, only one subject is equipped with the instrument that measures results correctly and effectively. Mathematics is flexible to adjust in the STEM and collaborates friendly and expands effectiveness throughout any plan of action.

Standards for mathematical content in mathematics in the US demands to teach students about the connections of mathematics and real world situations. For example, standards in algebra 2 for most of the chapters contain modeling the real world cases. As an illustration, let's take a look one standard at the interpretation of function in terms of the real world situation and modeling according to Envision - Algebra 2 book - **HSF - LE.5** Interpret the parameter in a linear or exponential function in terms of a context (envision algebra, 2018). Inspecting the teacher’s education book is evident that mathematical modeling describes all mathematical strategies. The article, Real World Connections in High School Mathematics Curriculum and Teaching, says “Realistic Mathematics Education upon using realistic contexts in school mathematics at all times (Gorkhan and Cengiz, 2015). In general, all real examples can be described into verbal description, and the verbal text can be translated into mathematical statements. Consequently, bridging the verbal text with real situations influences education to involve massively the connection of mathematics and real-world examples.

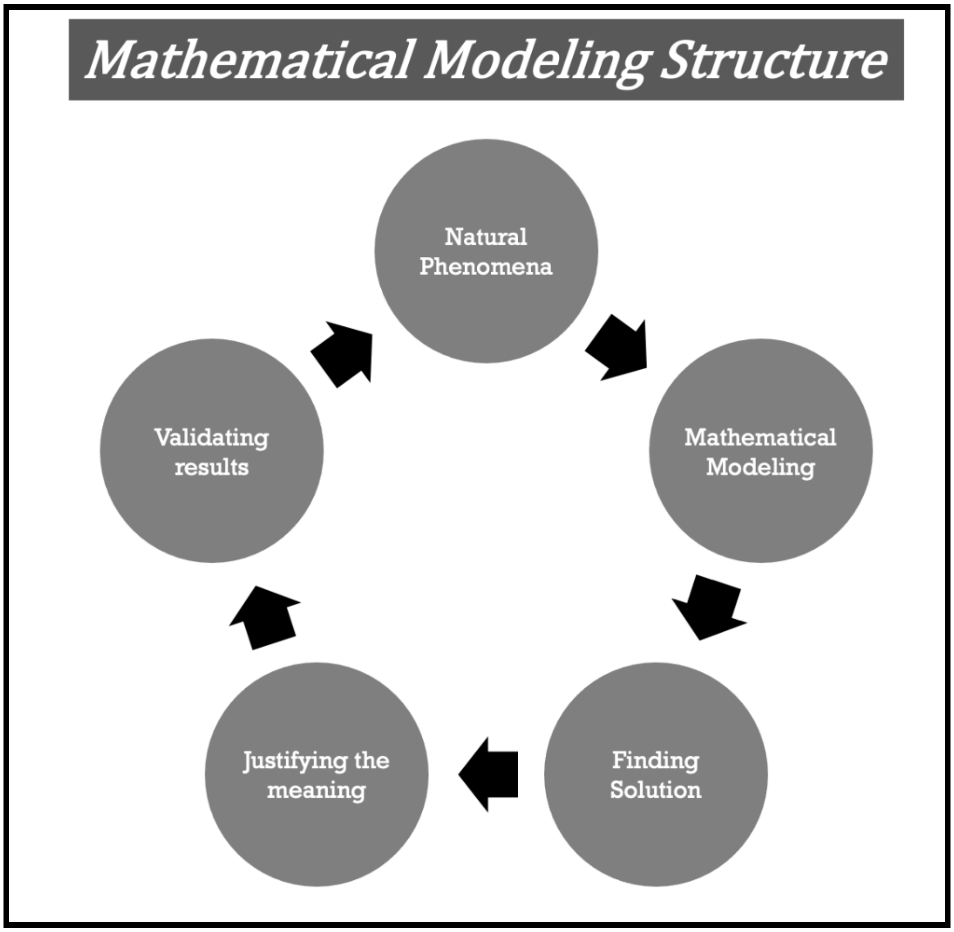

Fig 1. Analyzing natural phenomena from the perspective of mathematics described in five major steps.

Translating natural phenomena into mathematical modeling might occur directly without relying on other academic subjects. Definition of modeling is relative that might be understood differently to different people. The book, An Introduction to Mathematical Modeling claims, “Can a model provide explanation? This is a somewhat philosophical question and different people have different notions of what constitutes an explanation (Bender, 1978).” Nonetheless, modeling is in general an acceptable concept to almost everyone. Therefore, let's describe the mathematical model in Fig 1. According to the figure Natural Phenomena can be translated into mathematical modeling. The model provides mathematical statements followed by a desired result. The outcome may make sense or not, but it should be justified logically and empirically. In the end , all results should be verified with two or more methods to check for any accidental error. In case, different methods do not contradict each other with the results, it means the results are valid. The whole cycle completes its pathway solely based on application of mathematical tools.Scientific models might change from one field to another, but in general they follow several similar steps. For instance Chemistry, Biology, Physics, Geology, Mining, Architecture differ one from another, therefore, requires a different approach or different modeling structure to analyze any element on their domain. In general, they follow several universal steps that classify them as scientific fields. The Conceptual Physics text-book describes the scientific method in five steps:

1. Recognize a question.
2. Hypothesis - make an educated guess.
3. Predict consequences of the hypothesis.
4. Make calculation to the test or prediction
5. Formulate the simplest general rule that organizes three main ingredients:
   a) hypothesis, b) predicted effects, and c) experimental findings.

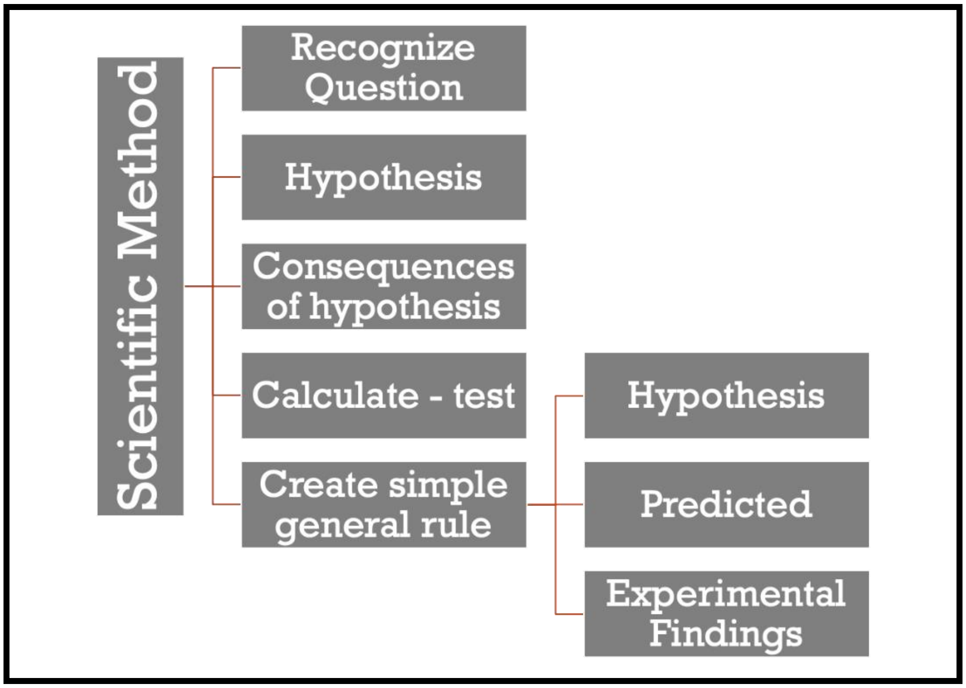

Fig 2. Scientific Method based on the conceptual physics text-book (Hewitt, 2015).

In figure 2 is a modification of the scientific method taken from the Conceptual Physics text-book. These steps narret the general modeling structure of the scientific method that deals with the research in any field of science such as chemistry, biology, physics, etc.

The model in figure 2 shows a close relationship with mathematics in all steps, especially, calculating or testing hypotheses and experimental findings. In general, calculating or testing hypotheses proceeds through mathematical screening. Numerical values give complete meaning to measurements, as a result, scientists can compare or contrast their outcomes with the estimated hypothesis. Creating a simple rule corresponds with interpreting the hypothesis through mathematical statements that communicate its complete and clear meaning without ambiguity. Mathematics enables hypotheses to express itself with simple equations like laws (Newtonian laws, Thermodynamic laws, Hooke's law, etc). Science tempts simplicity because the simple explanation is a powerful tool to reach a greater audience and provide them with clear outcomes. Mathematics keeps simplicity vigorous by converting a huge verbal text into a short simple formula with a complete formulated definition.

Modeling in technology respectively modeling structure of computer processing unit (the brain of the computer) in a simple form is demonstrated in figure 3. As we see in the figure, one of the important parts is arithmetic and logical units. The article Basic Structure of Computer system says," The work of arithmetic and logical unit is responsible to perform mathematical instruction (subtract, add, multiply, and divide) and logical instruction (greater than, less than, or equal to, and, or, not) on the information that is in form of binary code; the control unit and on performing the set of instruction the results are return to control unit" (ExploringBits, 2020). Application of mathematics clearly is applied in the arithmetic and logical unit, also input and output is in a close relationship with the functions. The basic property of the function is input and output or dependent variable and independent variable. Mathematics plays a crucial role in dividing these various functions in the computer processing unit.

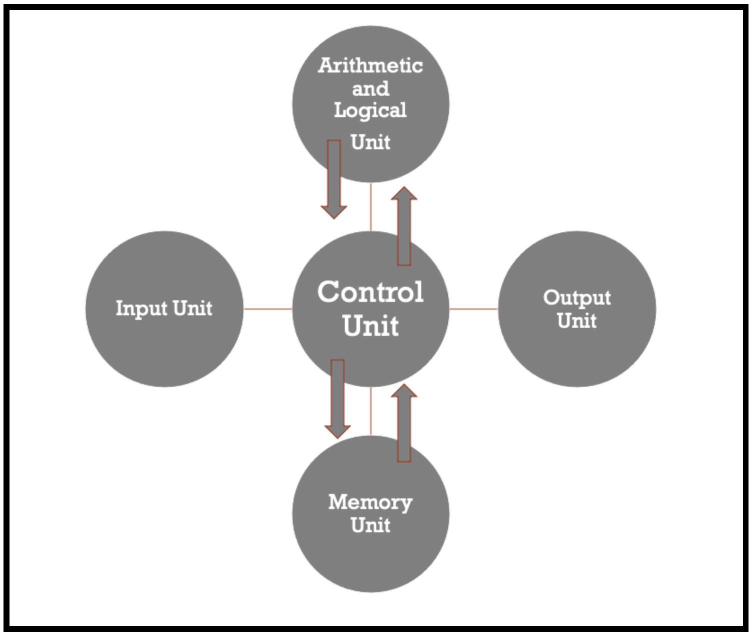

Fig 3. The modeling structure based on the computer processing unit - ExploringBits 2020.

Engineering uses mathematical tools massively in finding optimal solutions in its domain. In order to analyze the interconnection of mathematics within engineering scope, let observe an engineering model. Before we analyze the model, let's take a look at the definition of the model. "A model is a simplification of a system built with an intended goal in mind. The model should be able to answer questions in place of the actual system" (J. Bézivin & O. Gerbe , 2001).

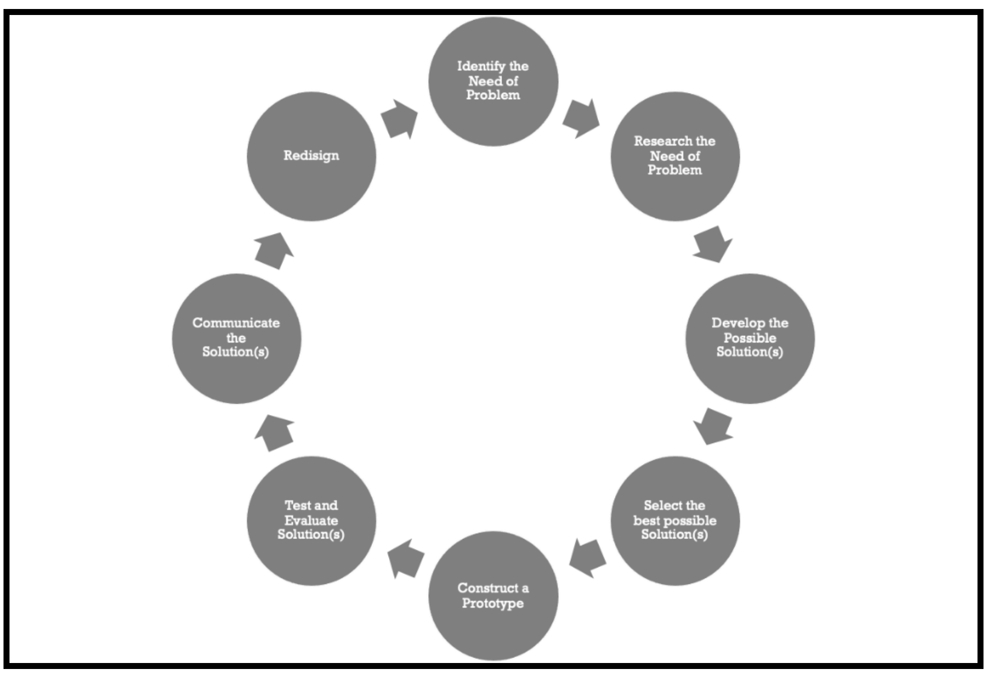

Fig 4. Modification of the Engineering Model that was created by the Massachusetts Department of Education. The model of the Engineering model design process includes eight steps in a repeating loop (LinkEngineringn, nd).

A simple engineering model might be described through three steps. The first step identifies the need of a problem that relates to the engineering realm. The second step deals with finding a solution to the problem.

The third step tests the solution. Practically, all steps require tools of mathematics in finding a right answer to the given problem. Mathematical tools operate actively and precisely in findings, testing and justifying the right solutions of any model including the simple engineering - three step - model.

Modification of the Engineering Model that was created by the Massachusetts Department of Education shown in fig 4, describes a process that follows eight steps and demands the similar tools within the simple three step model. When we are talking here about the tool, we are referring to mathematics as a tool. Before we make any other step, let's define the tool. “A tool (T) is an instrument that, when applied to a particular method can enhance the efficiency of the task…” (Estefan, 2008). The tool enhances the process, which deals with WHAT, and methods that deals with HOW. Literally engineers consider it as a tool ‘computer’, nonetheless, my focus is on abstract tools - mathematical tools. The model in the fig 4, repeats the word problem in two loops while the solution in four loops. The tool for finding the solutions in the four cases is mathematics. In addition, what to do with the problem, and what to redesign or design as a final product varies exclusively from the solutions.

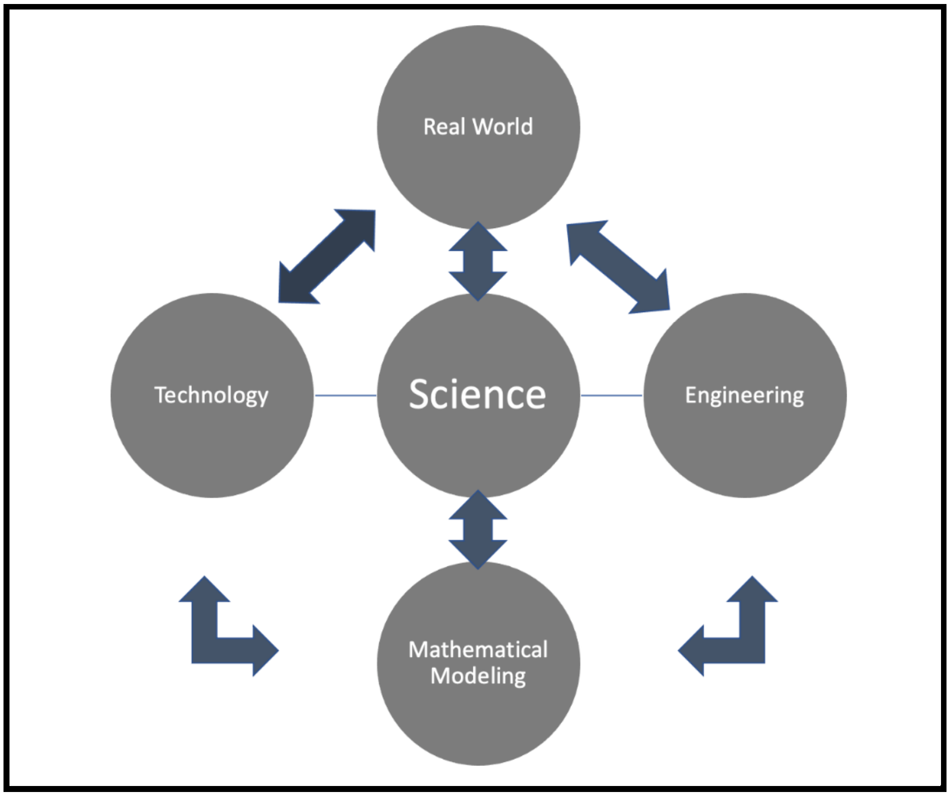

Fig 5. Analyzing a real world situation from the perspective of combining several fields - STEM.

Studying any real example from the perspective of science, technology, and engineering needs simplifying the case of research into mathematical models. In principle, a mathematical model identifies the real example or problem (according to Fig. 1), and then “recognize and use connection among mathematics ideas” Kirthi & Premadas, 2013). Moreover, translating the real example into a mathematical statement (mathematical modeling) determines the strategies on finding a solution. Inspect the solution with different methods and make sense of it (justify the meaning). Verifying each mathematical statement represents the system and its solution, completely. If the solution does not have any contradiction within the mathematical processes then it might be accepted as a valid one. This process describes thick lines of any model in the STEM.

Mathematical modeling plays a huge part in solving a STEM problem; nevertheless, combining elements of four subjects together provides the best and fast solution. Science contributes to identifying and analyzing behaviors of the problem. Engineering contributes to creating and structuring the mathematical model. Technology contributes to calculating faster equations or expressions of mathematical statements. “Usually, mathematical strategies on solving problems are based on step by step logical actions” (Pllana, 2021). Mathematics contributes to structuring the whole process of finding the solution, and selecting the optimal solution. Based on Fig 5, mathematical modeling contributes more than other subjects in finding the optimal solution to a real world problem, nonetheless, combining all four subjects in any case study yields the best outcome.

Discussions

Defining mathematical science with a few words does not encompass the entire meaning of the subject, nonetheless, let's try to find the relationship between mathematics and STEM inside the definition. According to the article, one of the definitions of the mathematical sciences is as follows, “The mathematical sciences are disciplines in themselves, with their own internal vitality and need for nourishment. But they also serve as the fundamental tools and language for science, engineering, industry, management, and finance” (The Mathematical Sciences, n.d.). The simple definition of mathematical science is a combination of pure and applied mathematics with other subjects that are associated with science, but they are not subfields of mathematics. When we inspect (Fig 6 and Fig 7) the simple definition and the other formal definition, it is obvious there is a combination of mathematics with STEM. The focus of the paper is to shed light on the connection of mathematical science and STEM, even though there are other subjects that need to verify their truth through mathematical language, too.

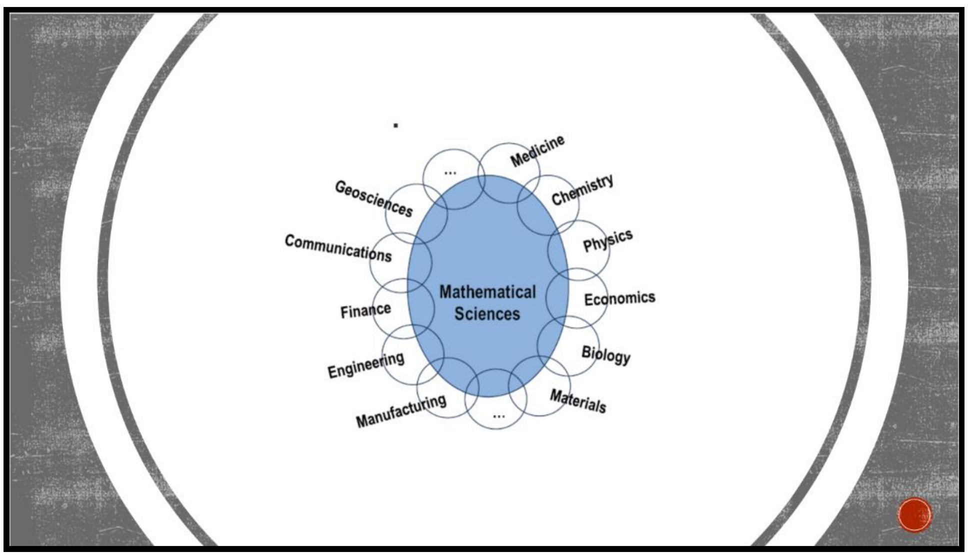

Fig 6. The mathematical science and their interfaces. SOURCE: Adopted from National Science Foundation, 1998, *Report of the Senior Assessment Panel for the International Assessment of the U.S. Mathematical Science, NSF, Arlington, VA (National Research Council).*

Inspecting fig 6, delineate the connection of mathematical science with eleven academic subjects displayed in a mixed arrangement with social and technical sciences. On the left side is portrayed Engineering, manufacturing and material portrayed Technology, and other subjects portrayed Science. Mathematical science found a greater application with passing time; in fig 7 describes a greater application of mathematical science in other academic subjects. Number of sciences that use mathematical tools expanded (from 1998 to 2013) from11 academic subjects into 21 academic subjects. In the fig 7, social sciences are rearranged on the left side, technical sciences on the right side, and technological subjects are on both sides (left and right).

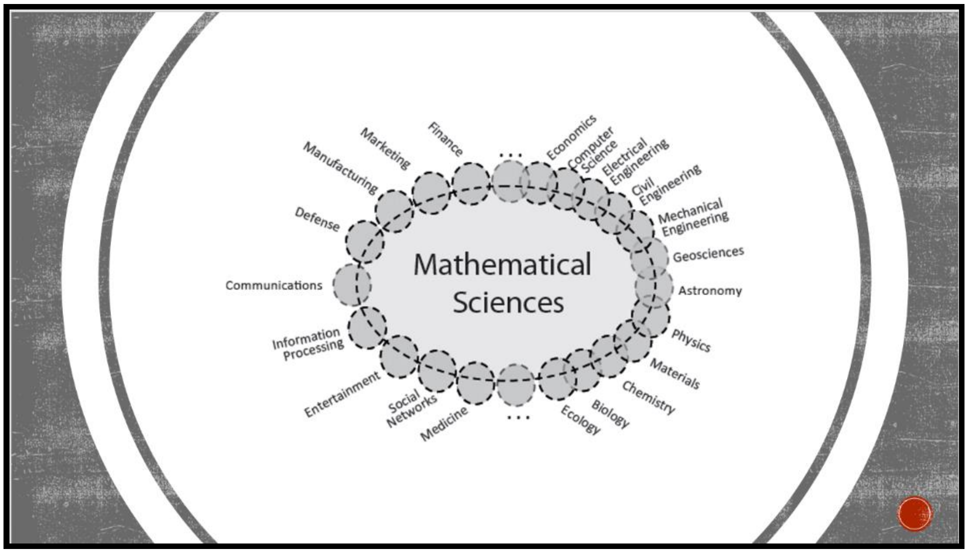

Fig 7. The Mathematical sciences and their interfaces in 2013. The number of interfaces has increased since the time of figure 6 in 1998 *(National Research Council).*

Mathematics is a tool to verify the truth. Mathematical science in essence is pure mathematics and applied mathematics; in addition, assists other sciences to verify their empirical results. The article, Math is like science, Only with Proof, states, " Math is not science. Science seeks to understand some aspect of phenomena, and is based on empirical observations, while math seeks to use logic to understand and often prove relationships between quantities and objects which may relate to no real phenomena" Beth Malsgok, 2017). Mathematics may be is not science, but it is the queen of science. In general, mathematical science models natural phenomena and proves their relationships of given patterns from the perspective of any scientific or engineering field.

Mathematical science behaves as a communication tool for STEM, respectively other academic subjects, its work is under the shadow of other fields. Consequently, the credit goes in the name of the science, technology, engineering, or another academic subject. "Within the academy, the mathematical sciences are playing a more integrative and foundational role, While within a society more broadly their impacts affect all of us - although that is often unappreciated because it is behind the scenes (National Research Council)." Even though mathematical sciences do not get deserved credit, it is capable of modeling real world situations and solving real world examples on its own.

Results

Mathematics can explore some phenomena by modeling real world or imaginative situations without relying on other subjects at all. There are cases when mathematics completes a project from the start to the end based exclusively on mathematical tools and processes. The best way to prove it is elaborating a simple project because simplicity explains anything thoughtfully. The article, Explaining Away; A Model of Affective Adaptation, states "People analyze incoming information with two questions in mind: ''Is it important to me?'' and, ''Do I understand it sufficiently "(Wilson and Gilbert)? If we look at laws of physics (Newton Laws, Bayle's laws, Kepler's law, etc.), most laws are defined with a simple short equation. The short equation with few variables corresponds to a simple explanation. In order to explain how mathematics can study natural phenomena solely, I will take a project (Key Features of Functions) of high school algebra.

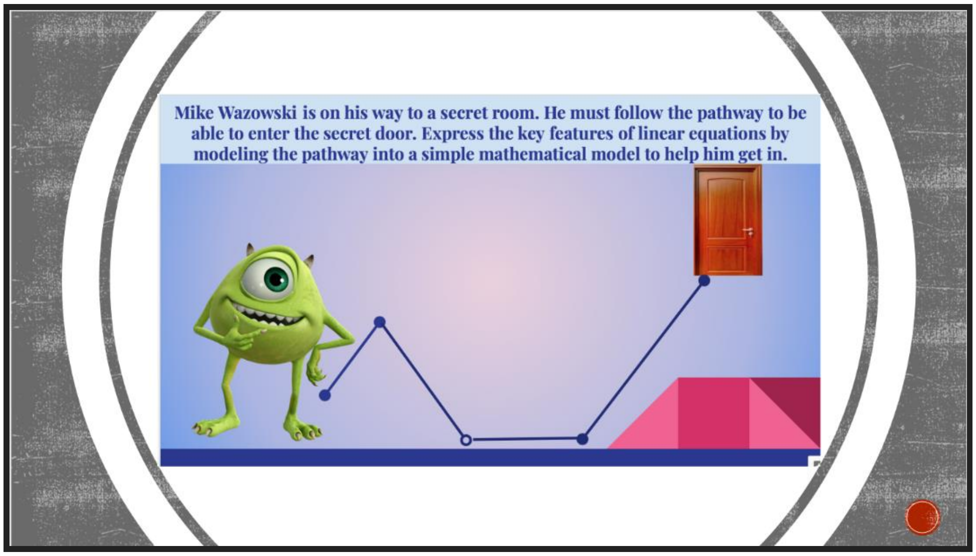

Fig 8. Students modified the original project that is given in **Fig 9.** The student's modification proves the given project might be altered in a variety of forms, and still we can use merely mathematical strategies to find satisfactory solutions without relying on other academic subjects.

Imagine a real situation in terms of a cartoon when Mickey Mouse takes a walk from one room to another to grab a piece of cheesecake. The pathway is described in fig 8 with lines; in cartoon situations steep lines (slopes) signify stairs. Practically, Mickey Mouse walks from the first floor to the second floor by using stairs; in the second floor walks horizontally for a certain distance; walks downstairs in the form of steep line (slope) to the basement; and walks upstairs in the form of steep line (slope) to the first-floor picks up the cheesecake. The pathway is described by the lines from the initial position to its destination. The Fig 9, shows distances are not on scale within given intervals to the cheesecake on the table (destination).

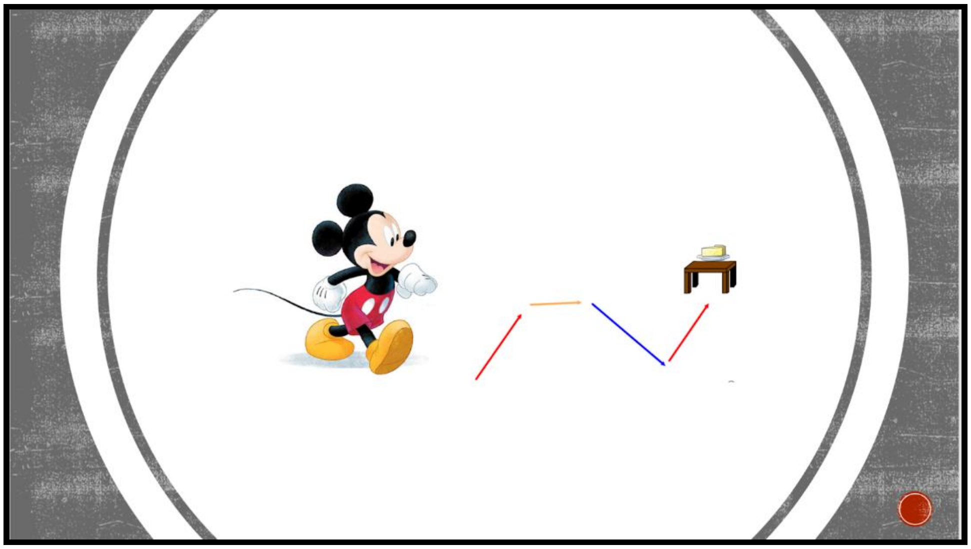

Fig 9. Mickey Mouse has to follow the pathway in order to get the cheesecake. Express the Key features of linear equations by modeling the pathway into a simple mathematical model (ClipArt).

The word problem that narrates the story of the imagined scenario might be translated into mathematical statements; the whole process provides us with lots of information, but the intention of the project is to focus on key features of the linear functions, and restricts the exercise of several strategies. Find each key feature (Fig 10), and describe them in the real world example:

a. Domain
b. Range
c. x-intercept(s)
d. y-intercept(s)
e. Interval `where the graph is positive
f. Interval `where the graph is negative
g. Interval where the graph is increasing
h. Interval where the graph is decreasing
i. Rate of change in interval [0, 5]
j. Rate of change in interval [6, 8]
k. Find a piecewise function of the given pathway

Fig 10 and Fig 11 presents just a few answers of the project that satisfies to prove mathematics can solve an example independently from other academic subjects. The project is described in several (8 slides) powerpoint slides, and each slide presents one or two key elements followed with creative pictures.

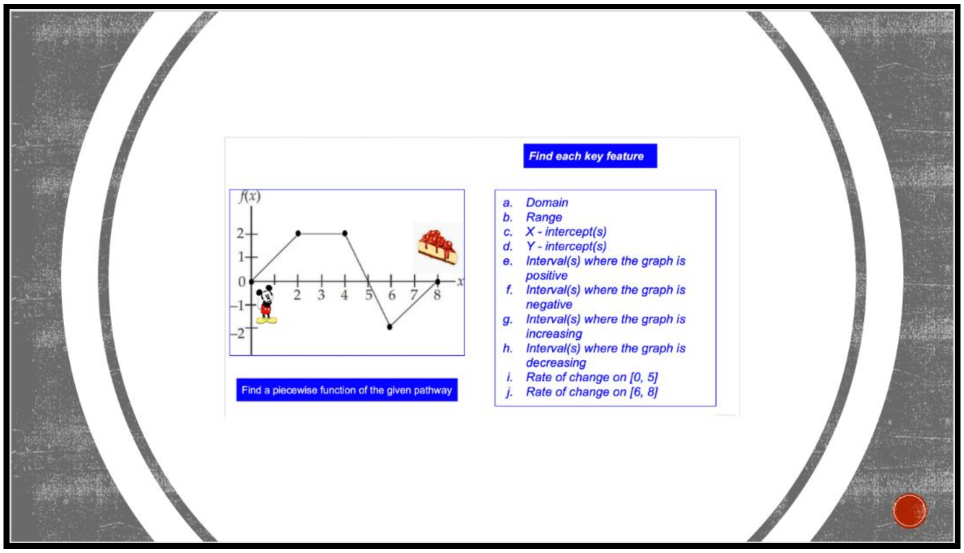

Fig 10. The outline of the task on the project that students need to complete the work. Questions are based on the key features of functions. The mini-project is given to algebra students of JMSA in Union City Nj. The purpose of the project is practicing with application of key features of function in the real world.

The purpose of the project has multiple dimensions such as: working with multiple steps, applying mathematical strategies in the real world, modeling a real world or imagined scenario, applying elements of creativity, etc. The imagined scenario project is based on a cartoon story. According to the article, Explore a Real Cartoon Example, claims “The project is a reflection of a real-world example on a description of a cartoon story that incorporates several questions related to geometric figures and mathematical questions” (Pllana, 21). Despite the fact the project has multiple intentions, we are interested to view this work from the perspective of exploring and solving an example utterly through lenses of mathematics.

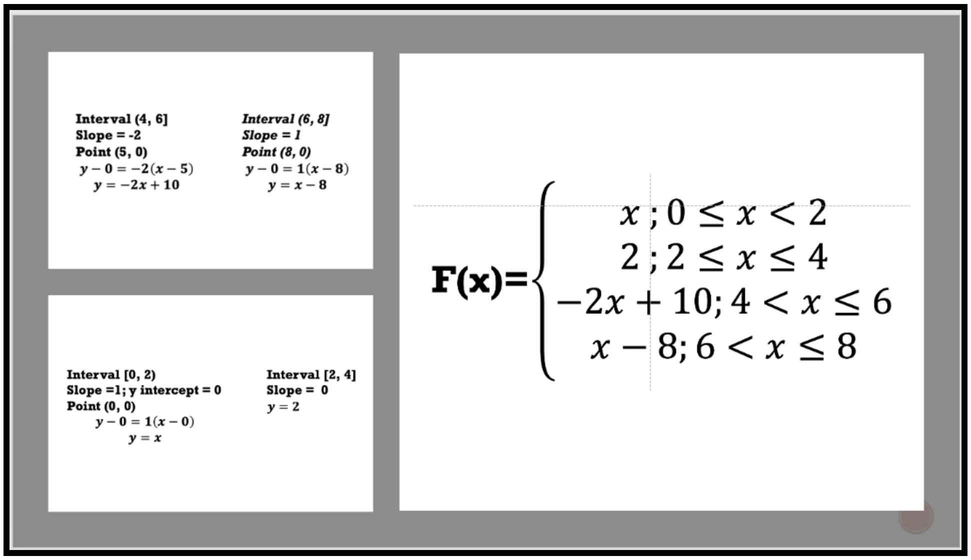

Fig 11. Piecewise functions that describe Mickey Mouse's Pathway. Four linear equations express the whole pathway from initial position to terminal destination.

The given example sums up with piecewise functions because the linear pathway has different directions. "Sometimes an equation can't be described by a single equation, and instead we have to describe it using a combination"(Piecewise Defined Functions). Because there are four restricted pathways with different directions, we can write four linear equations and solve them with a comfortable method. Three equations were found by using point slope form and the other one was found by using slope intercept form. Additionally, the combination of four linear equations in a single piecewise equation.

Mathematics can model any real world example. This project can easily involve calculating velocity of the mickey mouse, and how much time he needs to reach the destination. Mathematics can observe an example from the lenses of physics. "Mathematics are equations of Physics" (Apostol, 2018). Involving vectors in the project would give the flavors of the science, but still the work stays in the boundaries of mathematics (vectors and scalars are part of the mathematical field - Linear Algebra, Advanced Calculus, etc). The simple project proves that the project may be modified and does not change the nature of work; Also, The simple project represents infinitely many other natural phenomena.

Conclusion

Mathematics is a vital academic subject in keeping STEM virgous, and in other subjects that utilizes mathematical science. Math has a special place in STEM. According to Branches of Science, science is divided into four main branches. They are as follows:.Natural Sciences, Social Sciences, Formal Sciences, Applied Sciences (Dileepa, 2021) (Dileepa, 2021). Natural sciences contain physics, chemistry, biology, earth science, etc. Applied sciences contain computer sciences, engineering, applied physics, applied chemistry, applied biology, etc. Formal sciences contain mathematics, statistics, logic, and decisions. As we see from the selection of branches of science STEM is SCIENCE, nonetheless, the main tool on keeping science overpowering is mathematics.

The definition, what is mathematics, does not encompass the whole domain of mathematics because it has a broad scope. When Richard Courant could not define mathematics he said, "Mathematics is mathematics." Mathematics can study any real example independently from other STEM subjects, but physics, chemistry, biology, computer science, engineering cannot work without math. Hence, mathematics is interconnected within the STEM, and participates directly or indirectly with a greater percentage than other academic subjects. Even though the definition of mathematics states an incomplete domain of mathematics, math completes the domain of science, engineering and technology.

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