Reviving the role of mathematics in science through STEM

Akhmad Jazuli
Mathematics Education Department, Universitas Muhammadiyah Purwokerto, Jl. K. H. Ahmad Dahlan, Kembaran, Banyumas 53182 Indonesia

E-mail: akhmadjazuli@ump.ac.id

Abstract. The STEM learning presented here is designed to facilitate the students to possess skills of imagination, collaboration, problem-solving, as well as critical and creative thinking which highly needed in this rapidly changing era. STEM learning aims to combine science, technology, engineering and mathematics by means of connections between subjects and real-world problems. In the empirical facts, however, STEM has only been practiced in natural science, and has not yet been applied to social science. This literature review analyzes the role of mathematics in developing science, both natural science and social science. In conclusion, mathematics can be played as a role in the development of science, both natural science and social science with various conditions.

1. Introduction

The gap between the knowledge generated in the education system and the skills or competencies demanded by the business world is widening. Overcoming these limitations requires new thinking in science, technology, engineering and mathematics (STEM), including the development of skills that the business world needs. Future career development will also greatly depend on the degree to which we have mastered "21st century skills", who are able to think critically, creatively, to solve problems, and to work in team.

Over time, education is required to be able to produce graduates who are competent in their fields. We hope that vocational high school graduates are ready to enter the industrial world. Therefore, graduates need to be equipped with strong, practical, and connected knowledge. STEM learning is the hope of learning that will be able to answer the needs of the times. This approach has been tested and developed in many countries. STEM, originating from America, is now expanding to Europe, Australia, and Asia.

Beside the high demand that high school graduates are required to have adequate competence, the difficulties of implementing STEM always exist. Over time the STEM approach was developed continuously to improve its quality, one of which was developing into STEAM (Science, Technology, Engineering, Art, Mathematics). On the other hand, integrated STEM has also been developed [1], of course this approach will continue to be developed in line with the needs of the times. There are those who develop in literacy [2], some develop in the perceptions of their teachers [3], some are developing in the collaboration of their teachers [4].

In connection with this STEM, various problems arise in its implementation. Can this approach be used in all levels of education, from elementary school to university? Does science in this approach apply to all sciences, or only natural sciences such as physics, chemistry and biology? This means that it does not apply to social sciences such as history or economics. Is mathematics in this approach the
form of mathematical content such as algebra, geometry, and calculus? Can mathematics in this approach be the ability to think mathematically, such as reasoning or logic? Is this STEM sufficient to be taught by a teacher or many teachers (team of teachers)? Then, what about learning mathematics itself, how to teach it? Therefore, STEM or STEAM-based education will be increasingly attractive to invite education experts to develop it.

Mathematics has two sides known as "Mathematics is a king and he is also a servant". Mathematics is king as well as his assistant. This means that mathematics can develop on its own with its characteristics. But on the other hand mathematics plays a very important role in the development of other sciences. This second characteristic is part of STEM learning. Yakman’s study states that STEAM is a theory that explains the interpretation of science and technology through engineering and art which is based on mathematics [5].

Process standards in mathematics learning include problem solving, reasoning and proofing, communication, connection, and representation abilities [6]. If these five process standards are met, students will have the ability that is needed in today's era, namely accustomed to thinking before acting. In every problem faced, students will find their own solutions based on their observations and critical analysis.

Mathematics is a tool for presenting ideas or problems that appear in the form of mathematical modeling to make it easier to understand, solve, and find solutions. There are five covers of mathematics material taught in schools, namely numbers and operations, algebra, geometry, measurement, data analysis, statistics, and probability [7]. Of course, the weight of this coverage will vary according to the level of education.

2. Method
This research is a literature review of a number of lesson plans prepared by teachers using STEM learning. The lesson plans consisted of 60% natural science subject teachers and 40% social science subject teachers. The teachers are 50% vocational high school teachers and 50% are general secondary school teachers in Indonesia. The analysis is focused on the application of mathematics to science.

3. Result and discussion
The result of the research is that teachers who teach natural science using STEM learning are generally able to plan well. Especially in integrating mathematics into science. Meanwhile, teachers who teach social science using the STEM approach are generally unable to integrate mathematics into social science. Even some teachers still misunderstand STEM learning.

3.1. The role of mathematics in science
Mathematics has an important role in the development of science. Therefore, it is necessary to explore mathematics so that it is related to science [8]. Some examples of the role of mathematics in various fields of science.

3.1.1. Mathematics in physics
In physics, there are many uses of calculus, especially differentials, including (1) determining the average velocity with its instantaneous velocity, (2) determining the spring force, and (3) the electric circuit [9].

3.1.2. Mathematics in chemistry
In chemistry, the use of calculus, especially differentials is found, among others, in determining the instantaneous rate of reactions. The function of reactants can be developed by considering various factors [9].
3.1.3. Mathematics in biology
Calculus material, especially differentials, is also commonly found in the field of biology, among others, in determining population growth [10].

3.1.4. Mathematics in economics
Several mathematical materials related to economic matters include: (1) determining the cost function, changing in average cost and the marginal cost, (2) determines compound interest (3) determines depreciation, (4) calculating tax, for example \( f(x) = 10.162 + 0.25(x = 73.800) \) for \( 73.800 < x \leq 148.850 \), and (6) determining Break Even Point (BEP) [9].

3.1.5. Mathematics in history
Mathematical material can also play a role in historical material. When explaining pyramids in Egypt, students can be invited to determine the area of the pyramid, the volume of the pyramid, and the high slope of the pyramid. Furthermore, students are invited to be able to make artificial pyramids like the one in the Louvre, which is composed of a number of shapes made of glass and shaped like triangles and rhombuses [11].

3.1.6. Mathematics in construction
Mathematics, especially geometry, is widely used in building construction, among others: (1) The White House in Washington DC. This building is a building full of geometric shapes. Based on this information, the ellipse equation can be found, together with its focus and eccentricity. The center of the ellipse has a big meaning, so it can be designed as needed. Within the capitol building was what was known as the whispering gallery, which was called the Statuary Hall. The ellipse equation can be developed, together with the locations of the two focuses; (2) build bridges. Mathematics plays a role in building bridges. The lower part of the bridge is parabolic, which functions to keep the bridge from breaking [11]. For example, the lowest point is 10 feet above the ground. If the center of the bridge is considered to be the point of origin, then the three points of the parabola are \((0, 10), (-2100, 500), \) and \((2100, 500)\). This information is sufficient to construct the parabola equation, using the parabolic form, \( y = a(x - h)^2 + k \). Based on this equation the student can further develop the form of the parabolic.

3.1.7. Mathematics in the automotive engineering
Mathematics has an important role in designing car headlights. The shape of an elliptical parabola has the property that the energy radiating from one focus converges on the other. The parabola can be used in either direction, i.e. the incoming energy is collected at the focus, and the energy emitted from the focus is reflected from the parabola, sent out. Its function is to emit light towards the front by placing the light source in the focus of the parabola. The light from the bulb hitting the surface of the parabola will be reflected forward in the form of a parallel line, which is depicted on the spotlight [11]. Car headlights work the same way. Headlights are typically "high beam" or "low beam". This effect can be achieved in a number of ways.

3.2. STEM learning
STEM learning is an approach. STEM is currently becoming an important issue in the world of education. The STEM approach basically integrates four components, namely science, technology, engineering and mathematics into the learning process. If in the past the four components were understood as different and separate things, now these components are integrated as one interrelated unit to create an active and applicable learning system based on problem solving [12].

Before becoming popular in Indonesia, the STEM approach has been implemented in advance by several countries. The United States as a pioneer of this approach is the first country to apply the STEM approach in teaching and learning activities in schools. Believed to be successful and to have a positive impact on learning, STEM was later adopted by a number of countries in Asia and Europe, for example
in Taiwan, Malaysia, China, Finland and Australia. For approximately 3 years, STEM has been developed by these countries and has become more significant in recent years.

As a trend that is being promoted in the world of education, STEM is an approach to solving problems in the real world by guiding the mindset of students like engineers and scientists think. Through this STEM, students are led to become problem solvers, inventors, innovators. In addition, students can also build independence/confidence, think logically, are technology literate, and be able to connect the results of STEM education with the world of work [13]. STEM education applies problem-solving based learning, which places scientific inquiry and the application of mathematics in the context of designing technology as a form of problem solving. Scientific inquiry is rare in technology education and technology design activities are rare in science classes. But in everyday life, scientific design and investigation are routinely applied simultaneously as solutions to real-world problems [14]. With STEM, students have the confidence to develop their creativity [15].

One of the characteristics of STEM Education is that it integrates science, technology, engineering and mathematics in solving real problems. However, there are a variety of ways it is used in practice to integrate STEM disciplines, and patterns. The integration should still refer to the initial STEM concept [16]. The degree of integration depends on many factors [17].

4. Conclusion
The STEM learning used today is designed to produce students who are able to imagine, collaborate, solve problems, have critical and creative power and have the skills needed in a rapidly changing era. STEM education aims to combine science, technology, engineering, and mathematics by means of connections between subjects and real-world problems. Mathematics plays a role in developing science so that it produces something needed in the real world. STEM learning needs to be designed for all fields of science, both natural science and social science. In the application of mathematics, of course there are many limitations that must be made. This is done so that mathematics as a tool for interpreting data can be developed.

Acknowledgment
We appreciate and fully thank you for the members of students who has participatee to this completing the article.

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