# STEM in Science Learning in the Era of the Industrial Revolution 4.0

**Sri Melinda** ✉[1], **Udin Syaefudin Sa'ud**[2]

[1,2] Pendidikan Dasar, Universtias Pendidikan Indonesia , Bandung, Indonesia
✉ srimelindanasution@upi.edu

**Abstract.** The Industrial Revolution 4.0 related to technology and information brought changes to human lifestyles. This change immediately demands the world of education, especially students, to have more massive competencies. Some of these competencies include science, technology, critical thinking, creativity, and innovation, working together, communicating well, and having self-confidence. Not only students but also teachers are required to be creative and innovative, especially in teaching students in the school environment. The approach that can be used in teaching students according to the demands of the 4.0 era is the Science, Technology, Engineering, and Mathematics (STEM) approach. The purpose of this study is to explain more broadly about STEM to science learning in the 4.0 era. This study uses a literature review study of relevant research results in the form of journals and articles related to STEM in science learning. This literature review will contribute as a reference and increase the insight of researchers and readers. In addition, this study is expected to open up new ideas for deeper research on STEM.

**Keywords:** Science Learning, STEM, Industrial Revolution 4.0

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**INTRODUCTION** ~ The Industrial Revolution is the most important history in the development of human life in the last few centuries as sustainable development of life (Stearns, 2013). Industry observers have the concept that industrial development around the world has reached the wave of industrial revolution 4.0 or Industry 4.0. When an industrial activity has reached the 21st century which is experiencing the digital revolution, it is used as a result of the continuous development of the existing industrial revolution. This history begins with the Industrial Revolution 1.0 applying steam power in the production process because the steam engine was invented, the Industrial Revolution 2.0 began to apply electrical energy in creating large-scale production, and the Industrial Revolution 3.0 began to develop computerized information technology to automate production (Hussin, 2018). The 4th industrial era or better known as industry 4.0 is the result of a combination of existing and renewable inventions. This resulted in very significant changes such as; social change, industrial-organizational governance, macroeconomics, and the technology used (JONES, 1984). The changing world is now entering the era of the industrial revolution 4.0 or the fourth world industrial revolution where information technology has become the basis of human life (Kemristekdikti, 2018a).

Industrial revolution 4.0 also has an impact on the world of education, especially science education. The real impact of the industrial revolution 4.0 in science education, there is a shift in educational patterns and goals, currently, science learning focuses on the use of technology to meet future needs. Science Education has a role in producing human resources who are creative, innovative, and have superior competencies, both soft skills, and hard skills so that they can

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face various global issues (Suwito). and being able to compete globally and master technological developments is important for everyone and important for the future of a country (Subekti, H., et al, 2018).

In this 4.0 era, the STEM (Science, Technology, Engineering, and Mathematical) approach in science learning is one alternative, to train students in applying their knowledge in making problem-solving designs through the use of technology. STEM (Science, Technology, Engineering, and Mathematical) education, which provides the integration of disciplines of science, technology, engineering, and mathematics, is an innovative approach and supports the upbringing of science and technology literate individuals (Erdogan, I & Ciftci, A., 2017). Some of the benefits of STEM education are that it makes students problem solvers, inventors, innovators, able to be independent, logical thinkers, technology literate, able to connect culture with history with education, and able to connect STEM education with the world of work (Morrison, 2006).

## METHOD

This article uses a literature review as a research method. The literature study carried out covers several aspects such as identifying, analyzing and synthesizing previous research. Previous research for this study was in the form of national and international journals, thesis reports, books, and other document sources relevant to the research theme.

## RESULTS AND DISCUSSION

### STEM (Science, Technology, Engineering, and Mathematical) approach

STEM is an acronym for Science, Technology, Engineering, and Mathematics. The term was first launched by the National Science Foundation (NSF) of the United States (US) in the 1990s as the theme of the education reform movement to grow the workforce in STEM fields, as well as develop STEM literate citizens, and increase United States global competitiveness in science and technology innovation (Hanover Research, 2011). In the learning process, STEM is a learning approach in which there is integration between the four subjects that focus on solving problems in real everyday life and professional life.

STEM was designed by the National Science Foundation (NSF) (DeCoito, 2014), which is a combination of Science (study of the natural world), Technology (study of products made to meet human wants or needs), Engineering (design processes used to solve problems). problems), and Mathematics (the language of shapes, numbers, and quantities). STEM is not just a grouping of fields of study but is a "combination" and holistic approach to problem-solving.

Through STEM learning if applied properly and designed in the right learning, students are better able to solve real-world problems (Buckner & Boyd, 2015). The engineering design process, in which students define a problem, conduct research, develop some ideas which they design prototypes. Students can then test prototypes, reflect on and evaluate designs, and redesign to make improvements. Through this process, students can also learn to carry out open exploration and hands-on inquiry, making this a natural part of their learning, and most importantly, they can engage in deeper learning, to develop a mindset to

always thrive where "failure" is seen as positive steps towards improvement and better solutions.

Integrating STEM subjects can contribute to various competencies and learning outcomes (among others: problem-solving, critical thinking, making real-world connections) but this can often be a problem for educators (DeCoito, 2014). Educators may have constraints in terms of sufficient knowledge of each subject's content, conceptual relationships between given knowledge domains, understanding of science processes, and difficulties in how to integrate effective STEM-based learning. Changes are needed in a variety of ways including professional development for teachers, mentoring opportunities for teachers and students, external partnerships (to bridge the gap between academic knowledge and concrete application), and school or district approaches (Elrod & Kezar, 2015)

**Table 1.** Definition of STEM Literacy (Asmuniv, 2015)

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|---|---|
| **Science** | Scientific Literacy: The ability to use scientific knowledge and processes to understand the world and nature and the ability to participate in making decisions to influence them. |
| **Technology** | Technological Literacy: Knowledge of how to use new technologies, understand how new technologies are developed, and can analyze how new technologies affect individuals, communities, nations, and the world. |
| **Engineering** | Design Literacy: An understanding of how technology, can be developed through the engineering/design process using project-based learning themes by integrating several different subjects (interdisciplinary) |
| **Mathematics** | Mathematical Literacy: A collection of analyzing, reasoning, and communicating ideas effectively and from how to behave, formulate, solve and interpret solutions to mathematical problems in applying different situations. |

**Industrial Revolution 4.0**

The first generation of industrial revolution occurred in Great Britain at the end of the 17th century which occurred spontaneously without any encouragement from the government and was the generation that changed the most in the series of generations of the industrial revolution; from conventional to technology-based (Savic, 2018). Previously in 1760, the industrial system was still in the form of a home industry with a special characteristic, namely combining agriculture and industrial activities by employing and training one or several workers. The birth of the invention of the steam engine and electric loom became the starting point of Industry 1.0 which was the age of the first industrial machine (Hartwell, 2017; Peters, 2017).

Industrial revolution 2.0 is the result of an upgrade from industrial revolution 1.0 where the factory production system has applied electromagnetic and mass-produced using an assembly line system (Zhou, Zhou, & Liu, 2015). Industrial revolution 2.0 was stimulated by two theories, namely the theory of Maxwell

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and Faraday which combined magnetic and electric forces. These two theories gave birth to electric motors and power plants so that they play an important role in large-scale assembly lines (Ravasoo, 2014).

Although there are significant differences between the characteristics of industry 1.0 and industry 2.0, there are similarities between these two eras of the industrial revolution, namely the discovery of new technologies that change the way of production systems in many factories. Thus, in the industrial era 3.0 where the internet is an innovation developed with advanced technology that makes it easier for companies to communicate with each other through hardware, computer software networks, and telecommunication systems (Chung & Kim, 2016)

Industrial revolution 4.0, which is currently taking place, refers to the advancement of modern technology in which the internet and supporting technologies (such as embedded systems) act as the center for the operation of production system integration. Concepts such as the Internet of Things (IoT), industrial internet, cloud computing (Cloud-based Manufacturing), and Smart Manufacturing are important aspects of the visionary concept of the fourth industrial revolution (Schumacher, Erol, & Sihn, 2016).

Industry 4.0 terminology was first published in 2011 at an exhibition in Hannover Germany (Chung & Kim, 2016). Even the idea of industry 5.0 has started to appear in several publications that emphasize the implications of biological materials as a sustainable resource (Sachsenmeier, 2016). The concept of the industrial revolution 4.0 is based on complex technologies, such as cyber-physical systems, the internet for everything (IoT), cloud computing, big data, and advanced analytics technology (Zhou, Zhou, & Liu, 2015).

**Science Learning**

Science is defined as the building of knowledge and processes Bybee, Carlson-Powell, & Trowbridge (2014: 65). n that Science has three major elements: attitudes, processes or methods, and products. Attitudes are certain beliefs, values, opinions, for example, suspending judgment until enough data has been collected relative to the problem. Constantly endeavoring to be objective. Process or methods are certain ways of investigating problems, for example, making hypotheses, designing and carrying out experiments, evaluating data, and measuring. Products are facts, principles, laws, theories, for example, the scientific principle: metals when heated expands Sund & Carin (2010: 2). Science (IPA) is a special type of knowledge, which relates one way to another by conducting observations, experiments, conclusions, and theoretical preparations (Jasin, 2012: 58). Science is a way to systematically explore the natural environment so that it does not only master the systematic accumulation, mastering the collection of knowledge but also the discovery process (Sulistyorini, Tjandrakirana & Soetjipto, 2016). Science is the study of events that occur in nature (Iskandar, 2016). Two interrelated things cannot be separated from science, namely science in the form of conceptual knowledge

as a product, and science as a process, namely the scientific method (Maghfirah

& Herowati, 2017). Meanwhile, the nature of science itself is a scientific process, product, and scientific attitude (Wicaksono, 2017). Science is a way to develop thinking skills, how to investigate a problem, a collection of all knowledge, and its relation to technology and society (Koballa and Chiappetta, 2010: 105). Science is a difficult subject for students to complete, so learning is needed that can correlate science concepts with their contexts in everyday life so that the learning process becomes more meaningful and efficient for students (Indriati & Riskiyah, 2017). Science learning is a process that can help students learn more meaningfully through process skills so that they can master scientific knowledge and natural laws and apply it in real-life contexts. Science learning should be able to connect situations directly and real conditions, because science has a focus on studying everything that exists in nature (Gita, Annisa, & Nanna, 2018).

## CONCLUSION

STEM is one of the learning approaches that can be applied in schools to deal with rapid changes in all fields in the era of the industrial revolution 4.0. STEM is very suitable to be applied in science learning to produce superior human resources, both in soft skills and hard skills, and easy to adapt. Students who are already familiar with STEM are faster at solving problems that arise in everyday life.

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