

STEM Education in Japan, the United States, and China

Fengyuan Liu*

Department of Mathematics and Information Technology, The Educational University of Hong Kong, Hong Kong, China

* Corresponding Author Email: s1131781@s.eduhk.hk

Abstract. STEM education is designed for students to improve their skills so that they can handle the challenge in the 21st century. STEM skills are needed in nowadays' job market, so it is essential for a country to develop STEM education so that the next generation can adapt to the future society. This paper analyses the development of STEM education in Japan, China and the United States to provide suggestions to solve the existing problems in these three countries. This paper found that there are three main problems which are the gender gap problem, the uneven quality of STEM teachers and students' low interest in learning STEM. To solve these three problems, governments should build a qualified STEM teacher training system. Schools should pay more attention to the educational background of the teachers rather than other irrelevant factors. Teachers are encouraged to correct the negative stereotypes about STEM and give clear instructions on the future career choices of students. In this way, students' interest in learning STEM and self-efficacy can be improved.

Keywords: STEM education, gender gap, STEM.

1. Introduction

Science, Technology, Engineering, Mathematics (STEM) education was developed to allow students to adopt the challenge that appeared in the 21st century. It required students to master multiple skills and be ready to work in the field they were interested in. According to Widya, Rifandi and Laila Rahmi's paper, STEM education can encourage students to develop problem-solving skills, innovation skills and cooperation skills [1]. They also mentioned that STEM education focuses on the ability to apply knowledge in real life and hands-on experience. They put forward that the knowledge given by teachers is only information, but STEM education allows students and learn to use problem-solving-based methods so that they do not easily forget the knowledge.

Widya, Rifandi and Laila Rahmi indicate that STEM is widely used during the development of technology such as the invention of the telephone and the light bulb. In order to deal with this situation, Russia began to develop STEM education in 1957. Moreover, the research on STEM education in the United States began in 1969, and its application began in the early 1990s. After 2000, the quality of STEM improved because of the fund from different companies. Since then, some non-western countries like Korea, Malaysia and Saudi Arabia have applied STEM education in their countries [1].

Nowadays, STEM education is drawing more and more attention. However, there is limited research comparing different questions that happened in different countries and putting forward the solutions to them. Therefore, this paper will analyse the problems that happened in Japan, China and America and give some solutions.

This paper is going to discuss the situation of STEM education in different countries and put forward some existing problems in the system first. Then the paper will talk about whether STEM education can bring benefits to local students. Furthermore, it is going to discuss how to solve the difficulties during the implementation of STEM education.

2. STEM Education in Different Countries

2.1. STEM Education in Japan

2.1.1 Current situation

Before 2016, Japanese citizens did not understand the importance of STEM education and the movement done by the government. The first reason is that the meaning of technology and engineering is considered close. The only difference between these two terms is that technology is for “education”, and engineering is the research done at the university level [2]. In addition, in the early 2000s, only a few studies about STEM education were funded in Japan. However, when the United States developed the framework of K-12 science education in 2011, the research about STEM education grew rapidly. In 2016 the Japanese government published the Science and Technology Basic Plan, which wanted to integrate cyberspace and physical space to solve social problems. After that, research on STEM education receives increasing funding [2]. This further promotes the development of STEM education in Japan.

According to Kumano’s research, after the implementation of the Science and Technology Basic Plan, most secondary schools and elementary schools received computers for every student in the schools [2]. What is more, during the COVID-19 pandemic, some teachers were worried about whether they could control the class through iPad. Some support and instruction were offered to the teachers by local boards of education. Furthermore, the Japanese government has announced that they are planning to build Future Classroom to help students to conduct STEM learning in schools. This new type of classroom has three aims. The first one is to help students learn knowledge about STEM inside the school. The second aim is to develop individualised learning so that students can focus on the area they are interested in. In this way, students can be more motivated. The last purpose is to introduce schools to school business process reengineering (BPR) and develop learning environments by focusing on Information and Communication Technology. It seems that the Japanese government put much effort into developing STEM education in order to allow the next generation to adapt to the future society [2].

2.1.2 Problems appear in Japan’s STEM education

However, STEM education in Japan still has potential problems. In Matsuura and Nakamura’s paper, they found that Japanese students have less interest in STEM compared to other regions in Asia [3]. According to the survey, there is a trend for students in East Asian countries/regions like Japan, Singapore, Korea and Hong Kong. They become more willing to participate in science-related jobs in their future careers. Moreover, more and more students believe they need to do well in science to get into the university they prefer [3]. Despite this trend, the proportion of Japanese students who are willing to participate in science-related jobs in the future is the lowest in the above-mentioned regions. In addition, the proportion of Japanese students who believe they need to do well in science to be admitted into the university they prefer is also the lowest. However, Japan has the second-highest Science Score among these four countries/regions [3]. As a result, the Japanese government needs to boost students' interest in science. Otherwise, even with the best equipment, the results will not be satisfactory.

2.2. STEM Education in the United States

2.2.1 Current situation

Stebbins and Goris state that there was a trend in more jobs needing STEM-related backgrounds in the United States. STEM degree graduates are highly sought after and typically earn higher salaries than non-STEM degree graduates. This situation brings pressure on local schools, and the need for STEM learning packages also increases [4].

Kocabas, Ozfidan and Burlbaw indicate that in the 21st century, more studies about STEM were conducted. Also, the government decided to spend more budget on STEM education so that their students can have higher scores and be prepared for the future market and society [5].

2.2.2 Problems appear in United States' STEM education

In recent years, Americans started to be worried about American STEM education because some American citizens thought that they might not have enough qualified teachers in the STEM fields. Also, they began to question whether their children could adapt to the competitive society. Are American students competitive enough in the world?

In fact, American students still perform above average in the world range. However, compared to some Asian countries/regions like Singapore, Hong Kong and Japan. American students' performance was not outstanding in the mathematics and science fields [5]. Thus, American students still fall behind the world's top in math and science. By widely conducting STEM education in American schools, American students can have better performance in both science and mathematics.

People in the United started to concern about the current dominant economic position because of the mediocrity of American education [5]. According to the survey, around 90% of American teachers possess regular or standard professional state certification. At the same time, 1.3% of American teachers do not have any teaching certification. What is worth mentioning is that teachers who have certification in teaching mathematics or science are the least among all the subjects. They also state that nearly half of science and mathematics teachers do not have corresponding degrees [5]. It is evident that the United States needs more trained teachers in the field of mathematics or science.

The gender gap in the STEM field cannot be ignored. Half of the women who work in the STEM field choose to resign in their mid or late-thirties. This situation can bring barriers to recruitment [6]. According to the survey, this gender gap begins to be shown in middle school. In Hong Kong, 62.7% of the boys said that they would like a job that involves science. On the contrary, 47.7% of the girls want a job involving science in their future careers. The same phenomenon appears in other countries/regions except for the United States. Around 60% of both genders are willing to work in the STEM field in the future [3].

2.3. STEM education in China

2.3.1 Current situation

With the rise of STEM education, China also started to pay attention to it. The Ministry of Education still claimed that a new education model named interdisciplinary learning needed to be developed in 2016. This new model has similarities to STEM education [7]. In 2017, STEM education was officially included in K-12 curriculum standards, and many provinces started to publish guidelines for the establishment of the STEM curriculum. Despite the fact that there are no unified curriculum standards for STEM education, STEM education is gradually integrated into the curriculum through educational reform [8]. In the China STEM Education 2029 Action Plan, a platform for STEM research and evaluation is provided, and multiple STEM schools will be built in the future [9]. STEM education may have a positive influence on China's rural education. Students in rural areas have limited chances to access the Internet or computers. By developing STEM education, marginalized groups from rural areas will get to know a platform to communicate with others so that their voice can be heard [10].

With the development of STEM education in China, China started to train STEM with the cooperation of universities. Both Beijing Normal University and Shanghai Normal University set up STEM courses for science and science-related teacher training [11]. However, there are still problems with the STEM teacher training system in China. So et al. state that teacher education mainly focuses on one subject rather than STEM. What is more, a systematic STEM teacher training mechanism has not yet been formed [11]. This can result in a qualitative and quantitative deficit of professional STEM teachers. The authors also suggest that a STEM teacher admission system needs to be built in order to ensure the quality of STEM teachers. Some difficulties may appear during the implementation of STEM education in China because most Chinese teachers used to teach at a theoretical level. As a result, teachers may encounter trouble in transforming written words into actual classroom practices.

Meng et al. illustrate that although Chinese students have an excellent understanding of scientific knowledge, scholars still question the effectiveness of science education in elementary and secondary

schools [8]. Moreover, Chinese students show a lack of creativity and low interest in science in Programme for International Student Assessment (PISA). This result shows that Chinese students may encounter more difficulties in STEM learning. What is more, the gender gap problem also appears in China. They found that peer collaboration can improve boys' programming self-efficacy. However, girls' performance is shown in another way [8].

2.3.2 Problems appear in China's STEM education

As the paper has already mentioned, Chinese students seem to have low creativity and low interest in science. As a result, compared to foreign students, Chinese students can have more problems or poor outcomes after the implementation of STEM education. Moreover, So et al. point out that the lack of systematic STEM teachers' training mechanisms can lead to a low qualitative and quantitative deficit of professional STEM teachers [11].

3. Analyzing the Current Situation of STEM Education in Three Different Countries

By analyzing the current situation of STEM education in three different countries, some questions about STEM education appear. The first problem is the gender gap that appears in the process of STEM education and future career choice. Kuschel et al. suggest that some early recruitment of women into STEM entrepreneurship needs to be encouraged so that research about what characteristics of women lead to the gender gap [5]. Through research, people can minimize the impact of these characteristics during the learning process. The second problem is the students' low interest in STEM. The study shows that students' stereotypes about STEM can affect their interest in STEM via self-efficacy and outcome expectations. To solve this problem, teachers should put more effort into dispelling stereotypes and turning them into a comprehensive understanding of STEM [12]. The third problem is the uneven quality of STEM teachers. So et al. put forward that some international programs for teacher education can be established so that they can promote communication among global educational communities and bring advanced international recourses [11]. In addition, a platform for teachers to share their experiences with each other is also necessary.

4. Suggestions on Developing STEM Education

4.1. The Country's Dimension

The paper mentions that the problems of the STEM teacher training system appear in both China and the United States. As a result, the governments should put more attention on the establishment of the training system. The governments should encourage universities to set up programmes that aim to train STEM teachers. They need to publish some policies to attract more college students to attend the programs. In addition, they should assist schools in building environments that are suitable for conducting STEM education, like the Japanese government.

4.2. The School's Dimensions

When schools recruit teachers who teach STEM, they should consider teachers with STEM-related educational backgrounds. For example, they should view whether the interviewees have corresponding degrees as an important criterion. These problems appear in the United States because half of science and mathematics teachers do not have corresponding degrees [5]. Schools should also establish a platform for teachers to communicate their experience in teaching STEM. In this way, teachers can solve the problems they meet more effectively.

4.3. The Teacher's Dimensions

The lack of interest in STEM is an issue that appears in both China and Japan, so it is vital for teachers to motivate students to put more effort into STEM. According to Luo et al.'s paper, students

often have negative stereotypes of STEM. These negative stereotypes lower the interest and self-efficacy in learning STEM [12]. Therefore, teachers need to eliminate negative stereotypes during teaching. For instance, they can design more interesting teaching activities and emphasize the importance of STEM in today's job market. The gender gap issue is found in various countries as well. Teachers are suggested to solve this problem by focusing on their career interests and giving them proper instruction so that they can have a more objective judgment on the choice of STEM careers.

5. Conclusion

STEM education requires students to master multiple skills, including science, technology, engineering, and mathematics. In addition, STEM education in the 21st century is to encourage students to put knowledge into practice so that they can adapt to the highly competitive society. Unlike traditional teaching, students learn knowledge from books. STEM education encourages students to conduct project-based learning. In this way, students gain knowledge from reality, and they will have a deep impression of what they have learned.

This paper also discusses the development of STEM education in three different countries. Also, the paper talks about the outstanding points and shortages from different. Japanese government quickly publish several policies to promote the development of STEM education. In contrast, Japanese students seem to have a low interest in learning STEM. It will lead to low employment rates in the STEM field. Most United States teachers have a certification, but nearly half of them do not have certification in teaching science or mathematics. So, the United States needs more trained teachers in the field of mathematics or science to improve the quality of STEM education. On the other hand, over half of female and male students in America are willing to work in the STEM field. In other countries, there is a significant gap in career choices between gender. China also needs to improve the quality of STEM teachers. In order to accomplish this goal, a systematic STEM teacher training mechanism needs to be established. However, China already had a clear plan for the development of STEM education even in the initial stage of STEM education.

The paper also mentions some solutions to solve the issues from different countries. For instance, society needs to do some research about what characteristics of women lead to the gender gap. It can help educators to minimize the influence of these factors during the learning process. Other than that, teachers are encouraged to eliminate students' stereotypes about STEM, which may have a negative impact on their interest in STEM. Finally, some international programs that provide international recourses need to be conducted. At the same, teachers should communicate their experience through a fixed platform so that educators can gain views from different perspectives.

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