Research on STEM Education Policy in Germany

Yizhen Li

School of Finance and Public Administration, Yunnan University of Finance and Economics, Wuhua District, Kunming City, Yunnan Province, China, 650000,

Liyizhen888@163.com

Abstract. STEM education provides strong support for scientific and technological innovation in Germany, where the manufacturing industry is highly developed. Based on existing literature and data, this paper examines STEM education policy in Germany and analyzes the implications for other countries. The result shows that in the process of developing higher education institutions, German state has increased its policies and measures for STEM training to promote the sustainability of STEM education in Germany and to continuously improve the quality of STEM education. Other countries, represented by China, can develop STEM education in a comprehensive manner by training STEM professionals, playing an active role in disciplinary competitions, and strengthening project-based learning in various disciplines of STEM education.

Keywords: Germany, STEM Education, Education Policy, Policy Insights, China.

1 Introduction

In recognition of the current economic superpowers all throughout the worldwide, STEM education is also being promoted in Germany as a crucial strategy to develop creative talent and boost global competitiveness. There are also some research scholars in academia who have studied German STEM education policies and German STEM education models. For example, Yuan Lei and Jin Qun's Toward the Future in STEM Education: STEM Education Policy and Enlightenment in Germany analyses the STEM education policies and enlightenment in Germany [1]. Sun Wei and Ma Yonghong's 'Research on STEM Education Promotion Policies and Implications in Europe' further elaborates and analyses the STEM education promotion policies and project implementation in Germany [2]. This paper builds on data from other scholars' studies and the original literature to arrive at a specific analysis of STEM education policy in Germany. The study of STEM education policy in Germany is of great importance. Firstly, this study will effectively promote STEM education worldwide, stimulate students' interest in STEM and encourage public participation in STEM project learning. It provides some reflective reference for STEM education reform in other countries to promote the development of STEM education in other countries.

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2 Background of the Implementation of STEM Education in Germany

STEM, which stands for Science, Technology, Engineering and Mathematics, is not a separate discipline or a simple addition or subtraction of knowledge from many disciplines, but rather an application of knowledge from multiple disciplines to real-world problems. It focuses on enhancing students' creativity, problem-solving skills, and communication skills. The concept of 'Industry 4.0' was just acquired in 2013, ushering in humanity's 'fourth industrial revolution'[3]. However, the advent of Industry 4.0 requires a large number of technical skills. In Germany, where technological innovation is driving the zeitgeist and the dramatic changes of the times require a large supply of talent, German government is faced with the crucial question of how to train innovative and highly qualified technical personnel in the field of science and technology. A previous report by the German Centre for Economic Research said that Germany is experiencing a record shortage of professional occupations in the field of science and technology. At the end of October 2018, there were 496,000 jobs in the MINT sector in Germany, an increase of 5.9 per cent compared to the same period in 2017. The shortage rose to almost 338, 000 jobs, or more than 68% of the total number of jobs [4]. Germany is therefore promoting STEM education because of a growing shortage of high-quality skilled personnel. At the same time, the employment situation in STEM fields is not promising. The employment gap, the under-representation of women and the lack of coordination of resources all need to be addressed [1].

German government is therefore constantly taking new measures to improve STEM education and is constantly proposing new STEM education policies to promote STEM education in Germany. For example, since 2008, the German Ministry of Education and Research has launched a series of measures to encourage women to enter MINT/STEM fields, such as "Come to MINT" and "Successful MINT — New Opportunities for Women", which are specifically targeted at women [5]. In 2008, the Conference of German Ministers of Education and Culture issued a "Recommendation on Strengthening Mathematics, Natural Sciences and Technology", which proposed a range of measures from preschool to higher education to promote STEM-related research. in 2009, the Conference of German Ministers of Education and Culture issued the "Recommendation on strengthening mathematics-natural science-technology education", which proposed a series of measures to promote STEM-related research from preschool to higher education [6]. These STEM education decisions and educational initiatives have led to the continued development of STEM education in Germany, while enabling STEM education to achieve highly significant educational outcomes.

3 Analysis of the policy

Germany has a well-developed STEM education mechanism, the most representative of which is the STEM education chain (STEM Bildungskette), the core of STEM education in Germany. It is an educational ecosystem in which students, teachers, schools and society can effectively participate and achieve a virtuous circle [5]. The

STEM education chain consists mainly of government mechanisms, teacher training, school education, and the social participation of students. The government mechanism provides policies and programs for teacher training and school education, while teacher training provides teacher output for school education. School education promotes the talent output of social participation, social participation promotes school education, and social participation provides practical activities for teacher training.

3.1 Analysis of the Implementation Strategy of STEM Education in Germany

The Education Summit was held in Dresden in October 2008 with the participation of the German Chancellor and the Governors of the Länder. The meeting discussed the future policy directions for the reform and development of education in Germany, recognizing the importance of MINT education as a key objective for educational development. The Dresden resolution entitled "Progress through education — the German Qualification Scheme" was issued showing the importance that the German government attaches to STEM education [7].

Germany has long been renowned for its well-developed professional teaching system, with the training of STEM personnel being its main objective, and it is therefore important to focus on its approach to STEM teaching. STEM teaching in Germany is referred to as MINT (Mathematics, Informatics, Natural Sciences and Technology). Germany has implemented a number of policy initiatives to ensure the success of MINT teaching. It has also made bold changes in talent development by incorporating off-campus and on-campus experimental projects into the curriculum and evaluating and assessing them in a way that is comparable. 1)Political aspects. Its main responses have been: the integration of excellence in science and teaching; special training courses; special schools for outstanding students; special courses for outstanding trainees; support for outstanding students; the creation of public funds and funding agencies; private institutions for the training of outstanding students and young people; the organization of national and international MINT competitions; the creation of a German academic institute, etc. 2) The aspects of training personnel: The core of the MINT is the "school laboratory", which is based on "off-campus" training. For example, the DRL University Laboratory, founded in 2000 and run by the German Space Research Agency, has nine outdoor research laboratories and 13 experimental projects for students aged 9-12 by the end of 2012. There are two types of off-campus placements: a daily category and a special category. From 2003 to 2012, more than 18,000 people participated and worked in groups of 4-5, led by undergraduates, without teacher intervention. It is created especially for those with high talent. It starts with the space center's scientific research programme and has a professional supervisor, leaving the participants to undertake their own specific work and goals. At the end of the course, one of the students will present their research results to the public. There is no formal assessment of the school's off-campus laboratory in Germany, only a few individual studies. To fill the gaps in the school curriculum, Germany attaches great importance to the development of extra-curricular programs in STEM fields, where students develop an interest in careers in STEM fields through participation in university experimental projects and experiential learning in companies as they solve concrete problems [8].

3.2 STEM Education in Schools

To attract more students to work in STEM fields, the German Federation has developed a strong interest in STEM from kindergarten onwards. With funding from the German Institute for Education, “small research institutes” help schools and teachers through continuing education, project advice, expert advice, and academic certificates to turn school buildings into child-friendly research activities. Students have a strong interest in learning about STEM. School laboratories combined with socialization give greater prominence to the development and future of the subject. In Germany, students have the option of entering general high schools or vocational schools after completing their lower secondary education. Specialist teaching in STEM teaching starts in the upper grades, depending on the content of their courses. Closely linked to employment, almost 40% of graduates are sent to vocational schools. After completing higher education, they can choose to continue their studies at universities or engineering universities, such as universities of application or engineering universities, training to become professional technicians and researchers. STEM education at the primary level focuses on three subjects — mathematics, liberal studies, and craft design — as well as interdisciplinary areas of education to help children develop a basic interest in mathematics, natural science and technology. At the secondary level, grades 5 to 10 further develop students’ scientific concepts through courses in mathematics, physics and chemistry, as well as integrated courses in natural science or technology [9]. The Upper Secondary School of Arts and Sciences aims to provide students with a broad and in-depth liberal arts education in which students can choose the subjects to focus on from among the courses offered by the school according to their talents and interests, provided that they include a natural science course or a computer science course [10].

3.3 Staffing of Teachers

German government has very strict requirements for the training process of STEM teachers, which are reflected in long study periods, difficult examinations, and low admission rates. STEM teachers are trained at universities, including comprehensive universities and other academic institutions of higher learning [8]. Good teachers are a prerequisite for the implementation of STEM teaching, and the German federal government and the Länder work together to promote education. fight for teachers’ teaching. Firstly, there is increased financial support for funding teacher training programs. For example, with the support of German education and research institutions, an inter agency research network consisting of 300 national primary and secondary school principals and teachers has been established, and a research group has been set up. Its task is to jointly formulate strategies to promote stem work, develop curricula and teaching materials, and strengthen the education and analysis skills of stem teachers. Secondly, German nationals have replaced regular training with continuous professional development. The STEM Forum Working Group on Teacher Training recommends that continued professional development exhibitions should be an integral part of a STEM teacher's working life. The third is to strengthen the integration of theory and practice in teaching and to make the most of the advantages of teaching. In recent years, the German federal authorities have established their own teaching and practice system in Bochum. At the same time, the subject specialization schools of comprehensive universities such as Ruhr University and Humboldt University Berlin have carried out practical studies in subject pedagogy and teaching disciplines as well as other teacher training to make the most of the role of the university in the professional development of teachers.

4 Implications of STEM Education Policy in Germany for Other Countries

STEM education is practiced in many important countries around the world, but is most representative of China, the largest developing country in the world. In recent years, STEM has been developing rapidly in China, but there is a lack of relevant theoretical discussions; educational practices are more scattered and cannot form a complementary and continuous educational system. The various measures taken by Germany in promoting STEM teaching in primary and secondary schools have certain implications for China's development. Overall, the biggest gain of STEM education policy in Germany for other countries, represented by China, is the establishment of a well-developed STEM education ecosystem. STEM education in Germany has formed a chain of government mechanisms, teacher training, school education, and social linkages.

The specific insights can be divided into two points. The first point is to bring into play the positive role of discipline competitions. At present, there is a general negative perception of subject competitions in our country, due to the fact that they are to some extent utilitarian in nature. However, subject competitions in Germany cover a wide range of aspects such as mathematics, science and technology and are a widespread sport for all. The education sector in China should regulate competitions for primary and secondary school students, so that subject competitions can be completely detached from the purpose of further education and return to the essence of competition, retaining those students who are talented in science and technology education, increasing their enthusiasm for scientific research, improving their problem-solving skills, organizational coordination and competitive stamina, and providing highly qualified technical innovators for the country's scientific development.

The second point is that China needs to strengthen project-based learning in all disciplines of STEM education. STEM teaching and learning values interdisciplinary integration, and when taught locally, some teachers overemphasize the cross-cutting nature of STEM teaching and learning, as if no course is STEM. This study found that single STEM teaching and learning is easier to implement than achieving overall STEM quality. Interdisciplinary approaches break down disciplinary boundaries and emphasize the use of interconnected knowledge across disciplines to solve real-world problems, but can lead to weak learning if the disciplinary foundation is lost[8]. Therefore, the current STEM teaching in China is not yet ideal, and a transitional model between a single model and a cross-cutting model can be adopted to ensure both the existing curriculum and the teaching cycle of each major; explore the relationship between majors and develop subject-based interdisciplinary teaching to develop students' practical problems and critical thinking skills. To implement stem teaching that is in line with its own characteristics, it is necessary to improve teacher training and social participation, and organically link them to promote the sustainable development of stem teaching. To establish a STEM education ecology, China should first play the role of policy leadership and guidance. Under the leadership of policy, the government, schools, enterprises, social organizations and other parties need to work together to establish a sound long-term cooperation mechanism, mobilize the active participation of social forces, exchange and collaborate, and provide a broader learning platform for learners [10].

5 Conclusion

In Germany, where manufacturing is at a very high level, STEM education is an important guarantee of technological innovation. The education policy for STEM education is practical and has been continuously improved and modified to give a strong impetus to the implementation of STEM education in Germany. STEM education policy has improved the education chain consisting of teacher training, school education and social employment, and focuses on specific groups such as young people and women to encourage and support their employment in STEM fields. The various measures to promote STEM in Germany have provided new perspectives and new thinking for research and practice in STEM in other countries, represented by China. For example, china need to play an active role in subject competitions. China need to strengthen project-based learning in all disciplines of STEM education. To implement STEM teaching and learning that is specific to our region, teacher training and community involvement must be strengthened and organically linked to promote the sustainable development of STEM teaching and learning. There are still some limitations in this thesis, for example, the sample size is not large enough and there are not enough valid data. In future studies, research and investigation of this type of problem should be increased in order to obtain a larger sample size and sufficient valid data.

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