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An Exploration of the Feasibility of Practicing STEAM Pedagogy in Chinese Private Secondary Schools

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Abstract: *This paper explores the feasibility of implementing the Science, Technology, Engineering, Arts, and Mathematics (STEAM) interdisciplinary teaching method to private secondary schools in Beijing (in the private/non-traditional Chinese education system), by analysing two case studies in the UK. The research is qualitative, covering three interviews with STEAM education specialists. The purpose of this paper is to 1) find feasible ways to practice the STEAM pedagogy in Chinese private secondary schools; 2) investigate the gap between the technology innovative teaching method in China and STEAM pedagogy overseas; 3) summarise new ideas as Unique Selling Points (USPs) for future innovation in education. Based on the literature review, the paper addresses the following questions: whether it is feasible to implement STEAM pedagogy to Chinese private schools? What are the conditions for importing such a pedagogy? This paper argues that it is feasible to import STEAM pedagogy to a Chinese private secondary school when conditions are met six criteria – policy, funds, community development, curriculum design, evaluation system, and teacher training.*

Keywords: *STEAM, Pedagogy, Implementation, Education*

1. Introduction

The purpose of this paper is to explore feasible ways to inject the Science, Technology, Engineering, Arts and Mathematics (STEAM) interdisciplinary teaching methods into Chinese private secondary schools. By looking through literatures, studies mainly focus on two categories: one is the introduction and analysis of STEM and STEAM policies, laws, curriculum design, teacher training, and the evaluation system; the other category mainly comprises studies on localization, and instruction of STEM and STEAM in China's primary and secondary schools. However, there is a gap between foreign STEAM and China's STEAM. Based on the literature review, this paper addresses the following questions: is it feasible to inject STEAM pedagogy into Chinese private secondary schools? This paper argues that it is feasible to implement STEAM pedagogy to a Chinese private secondary school when conditions are met six criteria – policy, funds, community development, curriculum design, evaluation system, and teacher training.

2. Literature Review

2.1. Overview

Many theories have been proposed to explain why art integrated into science, technology, engineering, and mathematics (STEM) is important in modern society. Although the literature covers a wide range of these theories, this review will focus on three themes, which emerge repeatedly throughout the literature review. These themes are: education policies and funds; interdisciplinary curriculum design; and STEAM pedagogy influences on students. This section will primarily focus on their application to STEAM practice in general.

The Science, Technology, Engineering and Math (STEM) movement, and particularly STEM education, has a unique history, which began in the USA[1]. However, a recent study has shown that an unintentional consequence of the focus on STEM education has resulted in decreased creativity)[2]. Meanwhile, Harris[3] claims that the arts could be a method to infuse a student's academic curriculum with creativity. In that case, arts provide the missing component necessary to develop student interest

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and creativity in STEM subjects. Therefore, STEM becomes STEAM (science, technology, engineering, arts and mathematics).

STEAM is defined as 'the inclusion of liberal arts and humanities in STEM education'. In China, there are several business communities and schools have developed similar concepts, such as technology innovation education and Maker Education

STEM education was introduced to China in 2007. In the past ten years, the scope of STEM education has been continuously expanded and gradually developed into STEM+ and STEAM. From the statistics of China National Knowledge Infrastructure (CNKI), STEM is increasingly valued by teachers and educational researchers. Since STEAM education is a later development of STEM, the relevant literature has been published only recently, and is less numerous than the STEM literature. The research mainly focuses on two categories: one is the introduction and analysis of STEM and STEAM policies, laws, curriculum design, teacher training, and the evaluation system; the other category mainly comprises studies on localization, and instruction of STEM and STEAM in China's primary and secondary schools.

2.2. Foreign STEAM

2.2.1. Education Policies and Funds

The Education Policy Institute says schools in England have cut the number of pupils taking subjects such as dance and fine art, after government funding cuts and policy changes [4]. Meanwhile, Progress 8 was introduced in 2016 as a value-added measure determining the level of the school. It is a measurement that based on students' academic achievement in 8 subjects (English and Mathematics are double weighted) (Ibid. p4). Furthermore, the English Baccalaureate (EBacc) school performance indicator also evaluates students' academic scores in main subjects [5]. So, schools in the UK tend to be more exam-oriented in order to reach higher Progress 8 score.

While STEM education can be defined in different ways, it is likely that the real STEM movement was founded in the USA. Although the United States is a leader in scientific innovation, it has become less common in recent years for talented individuals to take up academic study in STEM subjects in the United States. Given this trend, various proposals were brought by the educational institutes and the business community. According to Kuenzi (2008), "In early 2006, the White House released the American Competitiveness Initiative. During the 109th Congress, three STEM education programs were passed and signed into law. In the spring and summer of 2007, some of the major STEM education legislative proposals were combined into the America Competes Act of 2007, passed by the 110th Congress and signed by the President on August 9, 2007."

2.2.2. Interdisciplinary Curriculum Design and Evaluation System

Traditional science training provides a solid foundation in facts and basic science techniques, but rarely facilitates creative, cross-disciplinary problem identification and solving skills[6].

Hetland et al.[7] has developed one of the landmark frameworks for STEAM pedagogy. Through observation and field study, Hetland et al. determined student success in the arts was based on eight styles of learning: engaging and persisting; expression; reflection; stretch and exploration; developing craft; envisioning; observation; and understanding the art community.

Hetland et al. claims that project-based learning (PBL) could be a method to infuse a student's academic curriculum with creativity. PBL is the primary promotion and application in STEAM education. For a specific STEAM project, it combines theory and practice, usually interdisciplinary, pluralistic, comprehensive and complex (Sochacka et al., 2016). PBL is based on the seven aspects of observing phenomena: asking questions; investigating problems; proposing hypotheses; verifying hypotheses; analysing data; and drawing conclusions (Ravitz, 2010). In addition, PBL has another key aspect, namely, the informal learning environment, such as after-school classes or summer camps. For instance, summer camps have been provided in the U.S. in different fields such as leadership, sports, or arts.

In 'A Common Measurement System for K-12 STEM education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking', Emily Saxton presents the idea of establishing a general evaluation system for STEM education in the K-12 phase. The author believes that the STEM education general evaluation system covers various variables, such as student learning, teacher training, career development, and school management. This book mainly describes the structure of the entire evaluation system and the relationship between various elements. The author says that the next stage is preliminary data collection, investigation and internal verification. This shows that, although

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there is no uniform standard from the government level, the academic community has begun an exploration of finding standards.

2.2.3. Effect of STEAM Pedagogy

Creative and critical thinking are emphasised in STEAM education, by encouraging students to seek answers based on their own experiments and validating results (Ravitz, 2010). This process not only allows students to understand the physical principles that make for a successful rocket launch, but also motivates students and increases their creativity.

Research shows that students have greater success in academic subjects when they have engaged in arts education (Burton et al., 1999)[8]. One study conducted by the University of California at Los Angeles examined data from 25,000 students in middle to high school, and determined that those students engaged in an arts education scored higher on standardised achievement exams[9]. Therefore, the impact of the arts on the scholastic success of children and youth is clearly documented in Critical Links, a research compendium.

The importance of social skills to student achievement is clear, and therefore it is evident that a STEM curriculum stands to benefit from the inclusion of the arts[10]. This would enable STEM students to gain critical thinking and communication abilities required for them to engage in reflection, persuasion, analysis and explication in all their subjects of study. Self-confidence, empathy, conflict-resolution, self-control, collaboration and social tolerance are all skills linked to arts education.

2.2.4. STEAM Concept in China

In a government paper 'Curriculum Reform' published in 2001, it was proposed to comprehensively promote quality education and achieve five 'changes'. The five goals are a) achieving an integrated curriculum in foundation education; b) focusing on social development and the learning experience; c) critical thinking development; d) the significance of course evaluation; e) the school management system becomes 'Nation-Province-School'. In the '13th Five-Year Plan for Education', issued by the Ministry of Education in June 2016, it was proposed that some of the developing regions should actively apply new technology for use in interdisciplinary learning (STEAM education) and Maker education.

Art education and art-integrated education are mentioned in several government documents, such as 'Education for Art (2014:1)', 'Education for Art (2015:5)', and 'Education Development (2015:71)'. Hu et al. (2015) argues that those policies mean that the art-integrated education that was not valued before has finally been affirmed at the national policy level, and the important significance of aesthetic education has once again been highlighted and emphasized. In 2017, the Ministry of Education issued three documents, such as the "Evaluation Standard of Artistic Qualities for Primary and Secondary School Students", and identified 102 experimental areas for primary and secondary school students in 31 provinces (Qin, 2017).

Fu and Wang claims that STEAM education has the following core characteristics: interdisciplinary; interesting; experiential; contextual; collaborative; design; artistic; empirical; and technically enhanced. The High School affiliated to South China University of Technology has made a meaningful exploration in STEAM education. The school offers a variety of STEAM courses, such as the 'Investigation-Explanation-Application' learning model in the 'Greenhouse Effect of Nature' course, which allows students to understand the principles and hazards, and also discuss how to reduce the greenhouse effect.

Hu et al. designed a STEAM project for high school students, where the learning objective was bridge design. The analysis of the final results of the students from 33 high schools showed that 100% of the students who participated in the activity chose to continue to go to college. 86% of students chose STEM relevant subjects as their major. This is one of the landmark studies of students' academic achievement under STEAM in China. Qin argues that in a large majority of cases, students' performance and grades can be collected and analysed, which clearly demonstrates the advantage of STEAM at this time. Therefore, the research has established that engagement with the arts results in superior outcomes in academic achievement. In addition, such engagement contributes to a positive school environment. Zhao claims that it is clear that engaging in artistic study results in superior student outcomes and contributes to a comprehensive scholastic pursuit.

In China, the focus of school education is on the entrance examinations, often to the neglect of the cultivation of a student's personality and morality. As a consequence, there is a strong possibility that Chinese students lack the social skills that education can help provide. One study demonstrated the relationship between behaviour problems among adolescents and the influential factors in these problems. By investigating 1410 students, aged from 12 to 18, in six middle schools in Beijing, Zheng discovered

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that there were 79 students with behaviour problems in subjects, and the prevalence rate of social disorder was 13.01%. In this study, the authors demonstrated young people were found to see learning as their main task, and they experienced a great deal of pressure.

2.3. Methodology

Firstly, the researcher found five potential companies and schools online, especially on the magazine called Culture Learning Alliances. STEAM Co. stand out because Nick Corston was active in STEAM Community and he designed a good website with useful context including his journey and people's feedback. Aureus School is a new successful school in Oxford shire, and Hannah Wilson is one of the partners with STEAM Co. She accepted the interview via email when she was in Africa. She is going to start a new STEAM primary school in September which is an evidence that STEAM has good influence in Aureus School so far. During the email interviews, the researcher followed One-Page Plan (see Appendix 1&2&3) framework. Combining with observations on websites and documents they had sent to the researcher, the findings were summarized.

Finally, an interview with a Chinese STEAM expert, Professor Ma Ning from Beijing Normal University, will be used for analysing the feasibility of implementation of STEAM into China. She is one of the editors of "STEAM Development Report 2017". With 45 minutes talking on the phone, the researcher followed semi-structured interview questions that had sent to her before the interview. (see Appendix 4).

The researcher was focused on two main areas in the data collection. First, structured and semi-structured interviews were conducted with the founders in each case and Professor Ma Ning. Second, published report "STEAM Development Report 2017" made by Department of Education in China was analysed as secondary data. Document analysis was also done to triangulate and clarify information gathered from interviews.

2.4. Findings and Discussion

Along with many established STEAM businesses and schools, STEAM Co. and the Aureus School are good examples from both points of views. In this section, interviews with Nick Corston from STEAM Co. and Hannah Wilson from the Aureus School will be illustrated as examples of STEAM practice in the UK. Firstly, the background of STEAM Co. and Aureus School will be introduced, followed by six criteria for establishing a STEAM business. The six criteria include Policy, Funds, Marketing, Curriculum Design, Evaluation System, and Teacher Training. All the evidences are collected from websites, documents, and interviews with founders.

2.4.1. STEAM Co. and Aureus School

STEAM Co., which stands for STEAM Collaboration CIC, was founded in 2011 by three parents, Nick Corston, Amanda Corston and Jacky Schroer, at St Saviour's Primary School in Paddington, London. It all started in the summer of 2010, at Camp Bestival, a summer festival, where the three parents came across the House of Fairy Tales. This was a collection of events and performances put on by a group of artists, led by British young artist, Gavin Turk, and his wife, Deborah Curtis, whose projects attracted many performers, artists and educators. They created a magical parallel world where learning is play and play is directed learning. Inspired by this event, the three parents decided to organise more opportunities for kids to unleash their creativity (Corston, 2018).

According to Nick Corston, STEAM Co. powers communities to inspire their kids with creativity. Approximately 3,860 students are currently involved in STEAM Co. Days, and over 469 volunteers contribute across a wide age range, with some over 50's, but primarily younger parents. Firstly, they focus on the work of teachers and help drive parental engagement, which is the number one driver in academic achievement, by connecting with schools to run STEAM Co. Days of Creativity. Secondly, they bring communities of carers, such as parents, creatives, and businesses together to work with teachers to inspire children. Thirdly, after six years, they decided to start to roll out across the UK by building up their profile. The response has been fantastic at every stop.

The Aureus School, a brand new, state of the art comprehensive school for ages 11-16, opened on the Great Western Park, Didcot, in September 2017 with their first cohort of Year 7 students (Wilson, 2018). When the Aureus School was built by Oxford County Council to serve an expanding South Oxfordshire community, they designated it as a STEM school. As a teacher of English and an advocate of the arts, head teacher Hannah Wilson redesigned it as a STEAM school. According to Hannah Wilson, their

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mission is: they will strive to educate the student holistically, so that each individual in our community may 'Grow, Learn and Flourish'. As can be seen, the Aureus School is a STEM school but the headmaster Hannah Wilson and her colleagues were keen to create a STEAM community, so that the whole school may develop STEM skills alongside developing an appreciation of the arts.

2.4.2. Six Criteria

Policy - Policy support is essential for establishing a STEAM school or institution. First, some policies could possible lower the tax. Second, policies could bring more potential resources, including customer resources and partnership resources. However, even if there is no positive policy, it is also very promising to lead a creative business. In both cases, there are two organizations both in the UK but the UK policy on STEAM education is not very positive. For example, the establishment of Progress 8 and Ebacc. However, according to Hannah Wilson, the opponents of these educational policies are supporters of STEAM, which means the policies actually have helped STEAM business to some extent.

Funds - All activities are inseparable from the support of funds. For STEAM Co., Nick Corston received approximately £52,000 funds, which has come from Barclays, Dell, BT, National Grid, Google and the Arts Council for specific events. The rest of funds are provided by the schools, from sponsorship and from parental donations. The Aureus School was built by Oxford County Council to serve an expanding South Oxfordshire community, so they are supported by council foundations (Wilson, 2018). Obviously, a strong base of funds is significant for any business.

Community Development - Every business or educational institute needs a strong community base. Before opening the Aureus School, Hannah Wilson and her colleagues were busy with marketing. They organized STEAM events for communities and families. They have also extended their office and events space to the Winchester Science Centre, which has a network of over 1,000 STEM ambassadors across the country. In addition, they collaborate with local stakeholders to shape their offer as a STEAM-specialists mixed school to create choice for the wider community in southern Oxfordshire. This year, since the first year of the secondary school was successful, Hannah is going to open a STEAM primary school nearby. Furthermore, Hannah said: "it is the community itself that helps with spreading STEAM." Their community includes students, parents, teachers, and carers, who get involved in STEAM practice. It can be said that it is an example of a successful STEAM school as it has a high-level of sustainability.

Curriculum Design - It is important to design a diverse STEAM curriculum. For example, STEAM Co. not only provides STEAM Co. Days, they also provide several different events for different needs. These are some examples of their highlight events: 1) Half Day Rocket Kids Session – Combining literacy, creativity and community engagement, it is perfect for Key Stage Two and Three students, as well as schools who want to know more about STEAM Co. Days without too much commitment; 2) Full Day Pop Up STEAM Co. Day – a whole day of creative thinking and doing activities out of the design truck; 3) Full Day Co Code Day – A rollercoaster of a technology day for a whole school, which includes Micro Bits and Bytes – a chance to code the BBC Micro: bit; 3D Worlds – hands on Virtual Reality, 3D photography, 3D modelling and 3D printing (Corston, 2018).

Evaluation System - Every educational institution needs the suitable evaluation system for this educational business, so that the teaching method could be examined validly and the leader could adjust it spontaneously. In both cases, both businesses are exploring the evaluation system. Hannah mentioned that they have an evaluation system, which conforms to an international standard, namely, 'A Common Measurement System for K-12 STEM education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking'. Hannah emphasized that a good evaluation system can not only improve our teaching level, but also improve the holistic development of students. However, this system should be flexible. Nick mentioned that the situation of each event is different, and the level of students is different. If you use the same evaluation system as the test, the result is either unreasonable or valuable. Thus, evaluation system is necessary for a STEAM business in order to examine the effectiveness of the teaching method.

Teacher Training - Aureus School's teacher team is strong, with various professional science teachers and innovative methods. However, Hannah said they need to train more teachers who are experts in STEAM pedagogy. In order to do that, they will organise events and teacher training programmes to give their teachers more inspiration and understanding of STEAM. In December of 2018, they are hosting the first STEAM roundtable, which will lead into the inaugural STEAM teachers' meeting. In that case, a better curriculum could be produced to improve students' achievement.

As for STEAM Co., they do not have regular teachers so far, but they update their course materials monthly. Also, they invite experts from multiple fields. For instance, they invite artists and scientists to

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come in and work on projects with students, so that they can apply their cross-curricular STEAM skills to real-life projects. Therefore, teacher training is primary for a STEAM business because teachers are always the basic and the most important element in educational field.

2.4.3. Discussion

After summarizing the characteristics of both STEAM Co. and the Aureus School, the current state of STEAM development in China will be explored in the Policy, Funding, Community Development, Curriculum Design, Evaluation Systems, and Teacher Training criteria through the interview with Professor Ma Ning, who specializes in STEAM pedagogy, technology studies, and teacher training. The results will determine whether it is feasible to import STEAM into China.

Compared with the UK, the Chinese government's support for art-integrated teaching method has just begun. Chinese government has always emphasized the importance of developing young people's innovative abilities. Before people know STEAM, there are other similar concepts – technology innovative courses and Maker Education. Art education and art-integrated education are mentioned in several government documents, such as 'Education for Art (2014:1)', 'Education for Art (2015:5)', and 'Education Development (2015:71)'. Hu et al. (2015) argues that those policies mean that the art-integrated education that was not valued before has finally been affirmed at the national policy level, and the important significance of aesthetic education has once again been highlighted and emphasized.

Not only political support but also financial support is important for establishing a new and innovative secondary school. In public schools, the Department of Education provides educational funds every year to encourage schools to purchase equipment and services, and provides basic conditions for students (Zheng, 2017). Since the Department of education in Beijing promoted the implementation of transdisciplinary curriculum innovation, the funds have been invested much more efficiently. In private secondary schools, according to Professor Ma, whether it bases in Beijing or other provinces, a private school has a strong financial support from its investors. Zheng (2017) mentioned more than 50% of public schools need more educational funds but only 4% of private schools said they do not have enough fund to support daily operation. Professor Ma mentioned that although private school do not need to worry about fund, it is necessary to spend the money in a right way. Nowadays, parents more concern about security environment and students' mental problems. So, private schools should use funds in the areas are needed. As it can be seen, in Chinese private secondary school, as long as it has a strong investor, the school could have enough funds but the head teachers should know how to use the money.

According to Professor Ma, domestic STEAM education started late and the understanding of STEAM education in China is too narrow. In particular, the guidance for families and society is not well accepted by them. For example, some parents do not believe project-based learning is more efficient than normal test-driven teaching methods, because it appears irrelevant to examination. On the other hand, as a new concept, it is necessary to find customer segments, namely, the targeted community. In that case, Professor Ma said the Department of Education, together with schools and institutions, have to work together and build the communities. If targeted customers and society accept and understand the concept of STEAM pedagogy, it is easier for students to feel the benefits.

In China, there are two main types of STEAM curriculum development. The first one is the secondary development of overseas courses. However, curriculum samples from overseas are difficult to comprehend and absorb, because there is no consideration of Chinese culture, and Chinese stakeholders are unclear about the context of STEAM. On the other hand, the cost of overseas courses is relatively expensive, because people need to pay for the STEAM patent. The second one is independent research from teachers, based on their own understanding and experiences. According to Professor Ma, this type of design will always lack continuity of courses and inspirations. Thus, how a good bridge can be built between the imported curriculum and the existing Chinese educational system still requires more attention.

Although the teaching methods are diverse, the results may not be satisfactory. It is time to use an evaluation system to examine the results. In China, according to the STEAM Development Report 2017, and Professor Ma, there is no special standard of STEAM validation. A majority of schools use grades and teachers' feedback as their measurement standard. As a consequence, there is a big gap that needs to be filled in the future. According to the survey in the report, 47% of teachers believe that the effect of STEAM is average (Zheng, 2017). From the current point of view, the rationale, scientific validity, diversity, and sustainability of the evaluation method and the evaluation process still need to be further explored.

In China, professionals in curriculum development are scarce. The first difficulty is the lack of

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systematic teacher training. STEAM education is completely different from traditional teaching methods. Teachers need to guide students to practice interdisciplinary courses, which is different from teaching directly from the textbooks Not only does the teacher need to continuously strengthen the study, but the teacher's role consciousness also needs to change – the teacher has become the guide [11].

3. Conclusion

This paper argues that it is feasible to import STEAM pedagogy to a Chinese private secondary school when conditions are met six criteria – policy, funds, community development, curriculum design, evaluation system, and teacher training. In order to do this, this paper considered to discover the criteria for establishing a STEAM business and a STEAM school in the UK. By comparing the six criteria summarized from STEAM Co. and the Aureus School (a STEAM School) with current STEAM practice in China, it is evident that there is a strong possibility of establishing a Chinese private secondary school with STEAM pedagogy. As such, this paper concludes that, while policy and funds are well-prepared for STEAM in China, according to the STEAM Development Report 2017, marketing and curriculum design have a good foundation, but still have a long way to go. The reasons for this include the difficulty of building customer communities and a lack of deep understanding of the STEAM concept. Furthermore, there is no standard evaluation system and training system for teachers, because STEAM is a new concept in China and not yet mature enough.

Nevertheless, given the lack of the businesses involved in STEAM practice in China, there are two further recommendations to fill the gap. First, design an evaluation system for STEAM pedagogy in China and sell it as a package. Not only can it help business communities to analyse the metrics, but it could also contribute to measuring achievement for schools and institutes. Second, it is necessary to start an educational institute to train teachers and leaders for STEAM. As Zhang said, teachers' quality is the basis of education. If there is a community for training teachers, there will be more high-quality educational institutes in China.

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