ATLANTIS PRESS
Advances in Social Science, Education and Humanities Research, volume 341
5th International Conference on Arts, Design and Contemporary Education (ICADCE 2019)

Research on the Application of Maker Education in K-12 Science Curriculum

Wanqiu Liang
College of Foreign Languages
Yanbian University
Yanji, China 133002

***Abstract*—With the continuous development of science and technology, higher requirements are put forward for K-12 science curriculum education. A series of new teaching forms have been widely applied. Meanwhile, as a new type of teaching mode, maker education has been practically applied in the K-12 science curriculum. This paper sorts out and analyzes relevant literatures on the basis of understanding the connotation of maker education and the status quo in China and foreign countries, as well as the current situation of science curriculum in China. It then summarizes the application of maker education in K-12 science curriculum in combination with the teaching content, teaching methods and learning manner, and puts forward the problems existing in maker education.**

Keywords—maker education; science curriculum; application research

I. INTRODUCTION

In the era of knowledge economy, the competition of talents becomes extremely fierce; hence, the cultivation of talents is even more important. The basic education stage is a key stage to cultivate talents. In the K-12 stage, it is not only needed to focus on cultivating students' knowledge in mathematics, Chinese language, English and other disciplines, and setting of science curriculum, but also needed to set up science curriculum. Providing science curriculum has its unique advantage to the improvement of students' innovative ability and practical ability, and can cultivate students' creative ability and practical ability to find and solve problems to a large extent. However, the teaching form in traditional science curriculum is mainly based on teacher teaching. Students are only instilled scientific knowledge, unable to form the ability of hands-on, collaboration and practice, and develop creative thinking. Hence, the transformation of the teaching form of science curriculum becomes very important. With the proposal of the current "Internet +" concept and the emergence of a large number of online courses in China and foreign countries, micro-course and MOOC play a more and more important role in supporting the STEAM education. Among them, Science in STEAM is a practical course for the purpose of cultivating students' creative ability. The educators pay more attention to learners' creation of works or products. Therefore, maker education emerges in response to the proper time and conditions. STEAM education is a teaching form based on program teaching. Maker education is more inclined to train learning ability and innovation ability. Therefore, the application research of maker education in science curriculum is very valuable. This paper analyzes the relevant literature, and gets to know about maker education, science course and the research status of maker Education in science curriculum. Then, the paper combs and analyzes the literature and finally concludes relevant research result, and also finds some problems to be solved in the application of maker education in K-12 science curriculum.

II. RESEARCH STATUS

A. Research Status of Maker Education

1) Development history of maker education: The word "Maker" was proposed by Chris Anderson in his book "Maker: New Industrial Revolution". Since 2010, 3D printing technology has received great attention from governments, industries, and even education in various countries. In 2012, the British magazine "Economist" published the article titled "The Third Industrial (Industry) Revolution" written by Markillie P. [1] which believed that 3D printing technology was one of the symbols of the third industrial revolution. Following after Markillie P., the famous American futurist Jeremy Rifkin's book "The Third Industrial Revolution: How the New Economic Model Changes the World" was published and was popular in many countries. Chris Anderson [2] took the initiative to propose the saying of "maker" in his new book "Maker: The New Industrial Revolution". In this book, he thought that maker is a person who turns the ideas having considerable technical challenges into real things. Since the beginning of 2013, the development of the American Maker Movement has injected a dose of stimulant for makers, and laid a solid foundation for the concept of maker. The maker movement is a product manufacturing method developed in recent years in the United States and takes DIY (Do-It-Yourself) mode and DIWO (Do- It-With-Others) mode as the main collaborative methods for product creation. The history of maker space can be traced back to the Fab Lab [3] as founded by Neil Gershenfeld from MIT. According to the definition on Wikipedia, maker space refers to open studios, laboratories,

and instrument processing rooms [4]. In maker space, makers work together to realize their ideas by using technology and hardware. On June 17, 2014, US President Barack Obama hosted the Maker Faire (also known as the Creative Carnival) in the White House, called on the people of the whole United States to participate in the creation and invention activities initiated by their communities, and designated June 18th of each year as the "National Maker Day".

2) Research status of maker education

a) Research status of maker education in foreign countries: On June 17, 2014, US President Barack Obama hosted the Maker Faire (also known as the Creative Carnival) in the White House, called on the people of the whole United States to participate in the creation and invention activities initiated by their communities, and designated June 18th of each year as the "National Maker Day". [5] Maker Ed is a non-profit organization founded by Dale Dougherty and a project of the Tides Center, a non-profit public charity. The idea of the project is that every child is a maker. The project is committed to making all young people form an interest, confidence and innovation in STEAM learning through maker activities. [6] More and more colleges and universities in foreign countries have begun to develop maker education, and treated maker education as an effective way to cultivate students' innovative consciousness and creativity. Every year, MIT opens a maker course toward graduate students to teach them how to do 3D printing and scanning, computer-controlled machinery, modeling and casting, embedded programming, and material synthesis. [7] From higher education to K-12 education, the booming maker movement has had a broad impact on education. The emergence of the Fabrication Laboratory (Fablab in short) focuses on learning of the principles of engineering, robotics, and design. [8] For example, the Fablab created by Professor Neil Gershenfeld of MIT is committed to make ordinary people available to manufacture (rather than procure or outsource) the tools they need to solve their problems. [9] For another example, the “FabLab@School” project is a transformation of the Fablab to facilitate applying it in primary and secondary schools. [10]

b) Research status of maker education in China: China's maker education pays more attention to theory and less attention to practice. From the perspective of epistemology, China's research on maker education is still at the stage of theoretical understanding; from the perspective of researchers' preference, theoretical research is mainly conducted in universities, and practice research is mainly conducted in primary and secondary schools; from the perspective of research subjects, most of the research focuses on scratch, and open source hardware and software (including Arduino and Arduino IDE, 3D printers, laser cutting machines, digital desktop modeling software). In terms of relevant theoretical researches in China, Professor Zhu Zhiting from East China Normal University, Dr. Yang Xianmin from Jiangsu Normal University, and Dr. Fu Qian from Beijing Normal University have conducted a series of valuable explorations on the theoretical issues of Maker Education. In terms of practice, in Graduate School at Shenzhen, Tsinghua University, Shenzhen University, and other universities, new educational places such as Maker Education and Maker Space have begun to take shape. In elementary and middle schools, Mr. Wu Junjie from Beijing Jingshan School and Xie Zuoru from Zhejiang Wenzhou Middle School and et al made a series of researches on the interviews of Maker Education and the courses of Maker Education. Among them, Xie Zuru and his collaborators developed Scratch, Arduino, and other courses. Their practice is regarded as an early attempt and exploration of the maker education curriculum. In the "Government Work Report", Premier Li Keqiang clearly stated that "let many makers show their talents and let many makers freely start their businesses". Followed by, the whole country raises a craze for being makers, and China's Maker Education develops rapidly. Maker contests are being held in Beijing, Shanghai, Shenzhen and many other places successively. In Luo Liang and Zhu Zhiting's "Open Source Hardware: A Leverage of Maker Education Practice", it is mentioned that open source hardware is a kind of development tools commonly used by most maker learning program and drives learning by means of program on the basis of three different maker space construction modes such as technology museum, library and school. In Yang Gang's "Maker Education: The New Path to the Development of Creative Education in China", he explains some well-known maker spaces in China such as Chaihuo Maker Space in Shenzhen, Maker Spaces in Beijing, Tsinghua University and Wenzhou Middle School and so on. A typical maker space includes new digital production equipment such as welding equipment, 3D printers, laser cutting machines, LEGO toys, and small circuit devices, as well as Arduino open source hardware and software platforms.

There is a different understanding of maker education. in Jiang Weishuo's "Maker culture and robot education", he proposed that maker education is developed around the makers, maker space, and education makers and is a learning activity that teenagers make creative works in regional maker space or school maker space; at the same time, it is also a process of experiencing the happiness of creation by self learning, cross-age and cross-domain learning, in the process of production, open source and sharing, design and production of creative works. In Zhu Zhiting and Sun Yanyan's "Maker Education: a Practical Field of ICT-Enabling Innovation Education", they proposed that on the basis of IT integration, maker education inherits the ideas of experience education, project learning method, innovative education and DIY concept. [13] In Yang Xianmin and Li Jihong's "The Potential Value of Maker Education and Its Disputes", they proposed that maker education is a new education mode that integrates information technology, adheres to the educational concept of “open innovation, inquiry experience”, focuses on “learning while creating” and aims to cultivate various innovative talents. [12] In general, the purpose of maker education is to focus on developing a process in which students can experience new

educational mode, improve their creative ability, and share their creative works.

B. Research Status of Science Curriculum

In Zhang Erqing's "The Construction of Science Curriculum Content Criterion", they pointed out that the main part of the Colorado Science Curriculum Content Criterion in USA consists of five areas: scientific inquiry, material science, life science, earth and space science, and scientific essence. Each part has specific indicators and provides inspiration for the science curriculum setting in China. In Wang Yun's "The Training of Students' Thinking should be Paid Attention to in Primary School Science Course: Reflections Aroused by a Science Lesson", it is believed that a good thinking habit can promote students' effective learning. [14] In Qi Yanjuan's "Cultivating students' scientific literacy in the teaching of science course", it is mentioned that from the perspective of literacy improvement, in science course, it is needed to cultivate students' science literacy and let students understand the essence and mutual relation between nature and science. In Tang Yonggao and Feng Xia's "Cultivation of students' inquiry spirit in the Science classroom — on how to implement inquiry learning in the course, science in a primary school", they pointed out that in terms of learning method, it is needed to get the way of inquiry learning applied to the science curriculum of primary school and cultivate students' consciousness of cooperating with each other [15].

III. Research Design

A. Data Source

The data used in this research is mainly sourced from CNKI. As the largest Chinese academic journal database in China, China Knowledge Network (CNKI) has a powerful reference value for the research of CNKI data. When searching the theme "Maker Education Science Course", 146 related articles can be searched; cancelling invalid records, 108 valid articles can be obtained; relevant research data were obtained through reading CNKI statistical data and relevant literature.

B. Research Method

Through a statistical analysis on relevant literatures, it is helpful to understand the situation of research subjects in different fields. The study uses quantitative analysis method and qualitative analysis method to conduct statistical analysis on four dimensions of Chinese literatures: sources, index and institutions, theoretical researches, and practical researches.

C. Analysis of the Number of Literatures

1) Data analysis: There are a total of 108 articles, including 10 master's thesis and 98 related journals. ("Fig. 1") The literatures were mainly published within 2014-2017, and the number of literatures is increasing year by year ("Fig. 2"). It can be seen that maker education is very hot in the field of science curriculum.

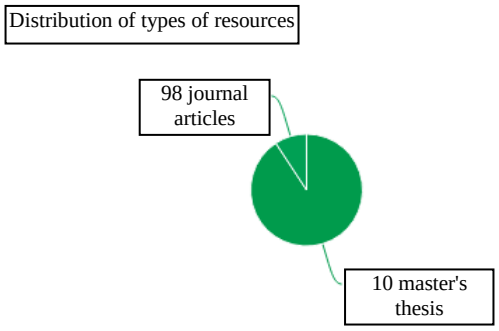

Fig. 1. Distribution of types of literatures.

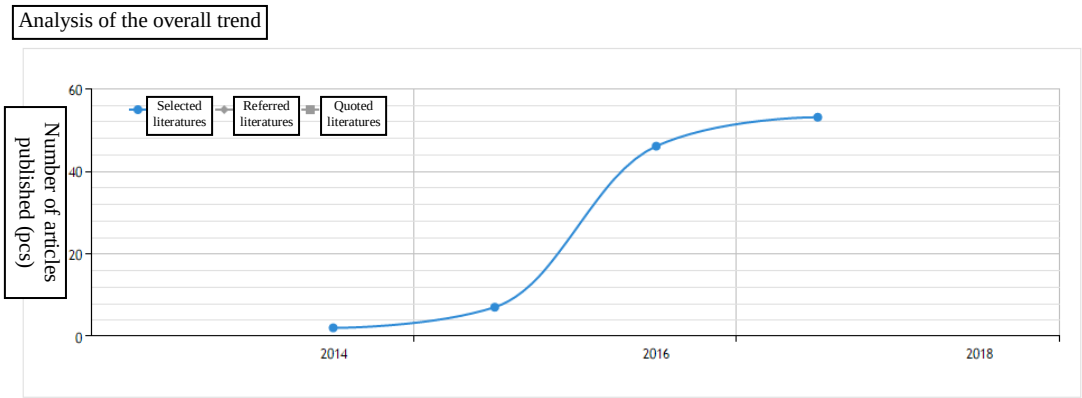

Fig. 2. Analysis of the overall trend of relevant literatures.

The literatures are sourced from different fields. Among them, the top five fields are respectively China audio-visual education, modern educational technology, audio-visual education research, education, and K-12 information technology education. ("Fig. 3") Through the analysis on relevant literatures, it can be seen that the top ranked journals are the core journals of the educational technology circles. The core journals have more papers than other journals, and can also be more valuable for making theoretical and practical researches on the application of maker education in K-12 science curriculum.

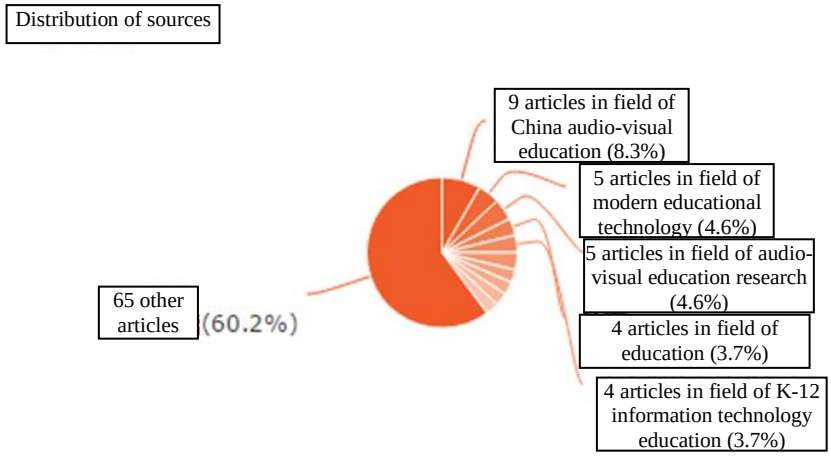

Fig. 3. Distribution of sources of literatures.

2) Analysis of literature index and institutions: Over an index analysis of relevant literatures, it is known that among the ("Fig. 4") selected 108 literatures, the total number of quoted literatures reached 960, the average number of citations of each literature reached 7.53times, and the ratio of numbers of downloads and citations reached 112.67. From the data, it can be seen that the articles relevant to maker education and science curriculum has a high number of citations; many people are interested in this aspect of research; and the application research of maker education in science curriculum is also under constant development.

Index analysis

Number of literatures	Total number of referred literatures	Total number of quoted literatures	Total number of downloaded literatures	Average number of references of each literature	Average number of citations of each literature	Average number of downloads of each literature	Ratio of numbers of downloads and citations
108	813	960	108162	7.53	8.89	1001.5	112.67

Fig. 4. Analysis of literature index.

In the analysis of the literature institutions, ("Fig. 5") the top three institutions are East China Normal University, Shaanxi Normal University and Beijing Normal University which are all key institutions related to education. They also have certain authority in the publication of articles, and also attach importance to the problems of maker education in the science curriculum. Hence literature institutions also have some research significance.

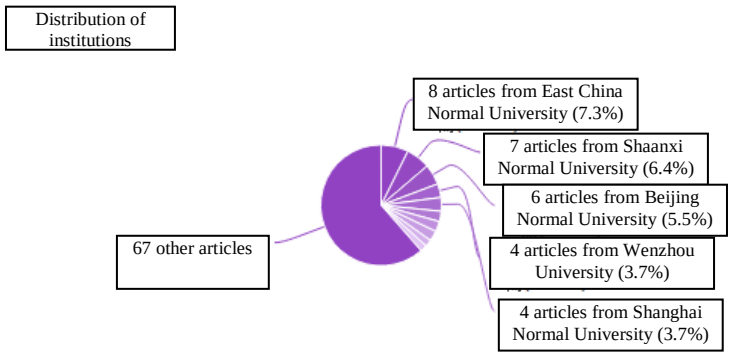

Fig. 5. Distribution of institutions of literatures.

3) Practical research analysis: The practical research analysis on maker education in K-12 science curriculum mainly includes the following three aspects: the combination of maker education and teaching content, the combination of maker education and teaching methods, and the combination of maker education and learning methods. By analysis, it is known that the teaching form of maker education applied in the K-12 science curriculum can fully exert the initiative of students, stimulate students to divergent thinking, and cultivate students' innovative ability.

a) Teaching content: In the teaching of K-12 science curriculum, the content of maker education is closely related to people's life. For instance in the "The organic integration of maker education and primary school science education", students are asked to look up and make field survey on relevant principles, and practically take photos of telecommunication tower, high-voltage wire tower in order to fully understand the scientific principle of high tower structure; after understanding the scientific principle of high tower structure, students are required to independently design a "innovative high tower". [16]

In Liu Manqing's "Initial exploration of implementing maker education in science teaching", it is believed that the science teaching content under the maker education should be connected with the real life, namely to learn connection circuit in physical field, design a new house, and let students use relevant open source hardware to make the voice control lamp and the burglar alarm, and dual-control solar power supply, and so on. [17] The teaching content in maker education can be selected in an open way. In Cheng Yanping's "Maker Education: a bridge integrated primary-school science curriculum with scientific and technological activities", it is mentioned that it is needed to reorganize the teaching content and combine science with engineering practice; and the teaching content should not only be what displayed in the textbook, but also be designed in an open way from many aspects of STEAM such as engineering, technology and arts. As mentioned in Gao Yuan's "The combination of primary-school science education with maker education", teacher plays a video on multimedia to show the mutual collision, separation and shift among continental plates and the subsequent formation of different landform. In this way, students easily understand that the great Himalayas were formed due to collision of two continental plates. The application of technology in the teaching reflects the principle of openness in maker education.

b) Teaching methods: In science teaching, teachers are the organizers of teaching and the guides of learning. In order to apply the thinking of maker education to the K-12 stage science teaching, teachers will be inevitably required to make greater changes according to the changes in students' learning methods. Especially with the continuous advancement of modern information technology and maker education mode, teachers must start from themselves, boldly change the traditional teaching mode, and teach according to the different characteristics of the textbook content and the different levels of students' experience. Guided teaching method is mainly adopted. As said in Liu Wendi's "Application of maker education in primary-school science curriculum", in the lesson of "File Downloading", the students have mastered basic downloading method; but in practice, they may not be able to copy a text, cannot download a file or play a video; at this time, the teacher will remind the student to independently make exploration, and guide the student to find a solution to the problem. [18] In the learning and thinking of primary-school science curriculum based on maker education, especially in learning the lesson "My Wind Direction", after the teacher inspires students, students are asked to independently design a wind vane and make innovative design; the teacher will also integrate into students' creation, share his thoughts and listen to students' ideas, and become a learner.

c) Learning methods: The learning methods in maker education can be divided into self learning and collaborative learning. In self learning method: As mentioned in Liu Wendi's "Application of maker education in primary-school science curriculum", when teaching the unit "science of water"in science of third grade of elementary school in combination with multimedia and the concept of maker education, teacher may previously ask students to collect relevant data and show it on the class; students can prepare the collected information into a fine PPT, and even into a micro-course or micro-video and so on. In this way, student can be encouraged to learn actively and gain more knowledge. [19] In collaborative learning method: As pointed out in the "Maker education is a new platform for improving primary-school science teaching" published in the round-table education magazine, in the lesson of "interesting tumbler" in science curriculum for third grade, teacher guides students to explore the secrets of the tumbler and bring students to 3D printer room and laser cutting room to modify the tumbler; in the process, students are divided into groups to do cooperative learning, man-machine interactive learning, use cooperative learning method to help each other and share their learning achievements. This way encourages students to create more things and is more beneficial to learning of science curriculum. [20]

IV. RESULT AND DISCUSSION

Through the combing and analysis of the application of maker education in K-12 science curriculum, the paper brings a new perspective on the maker education and science curriculum. By combing of relevant literatures, it is found that maker education is a hot topic in researches, with research value. Through the analysis of the content of relevant literatures, it is concluded that in the K-12 science curriculum, an effective integration of maker education and teaching methods, teaching content and learning methods can cultivate students' ability of innovation, practice and self-learning. In the process of analysis, problems still to be solved are also found:

First, it is difficult to cultivate teachers. Science curriculum has very high requirements for teachers. Teachers should not only have one major of professional knowledge,

but also integrate the contents of various disciplines, and have a large amount of knowledge reserve. The application of teaching methods is also important, with the aim of cultivating students' innovative ability.

Second, it is difficult to popularize maker education. The current maker course relies heavily on IT, AI and other technologies, relies too much on associated software and hardware kits, and also has very high requirements for a school's economic strength and social resources.

Third, the development of maker education in regions is uneven. Although maker education develops rapidly, there are obvious regional differences. It is well developed in the developed education areas, but difficult to be promoted in areas with underdeveloped or conservative education. This shows that maker education has high requirement for the external conditions such as technology, resources and teachers.

V. CONCLUSION

In the K-12 science curriculum, maker education has become an important topic. It is necessary to carry out maker education, to continuously improve the scientific literacy of K-12 students, enhance students' innovative ability, and lay a solid foundation for cultivating entrepreneurship and innovation talents.

REFERENCES

[1] Markillie P. The third industrial revolution [J]. Economist. 2012,(4):17-21.

[2] Gershenfeld N. Fab:the Coming Revolution on Your Desktop from Personal Computers to Personal Fabrication [M]. Basic Books. 2008.

[3] Hackerspace[DB/OL]. [2015-06-08]. http://en.wikipedia.org/wiki/Hackerspace#cite_ note-2.

[4] [USA] Chris Anderson (author), Xiao Xiao (trans.). Maker: New Industrial Revolution [M]. Beijing: China CITIC Press, 2012.47. (in Chinese)

[5] Li Ling, Wang Jie. “Maker”: Softly changing the education [N]. China Education Daily, 2014-09-23, (5). (in Chinese)

[6] Xie Zuoru. How to build a maker space suitable for primary and secondary schools — Taking Wenzhou Middle School as an example [J]. China Information Technology Education, 2014, (9): 13-15. (in Chinese)

[7] Makerspace. Makerspace Playbook [EB/OL]. http://spaces. makerspace.com, 2015-01-31.

[8] He Shizhong, Zhang Yujiang. Maker Movement — The Next Pivot of Learning Reform[J]. China Information Technology Education, 2014, (9): 5-7. (in Chinese)

[9] Zheng Yanlin, Li Luyi. Technology-supported learning based on creation [J]. Open Education Research, 2014, (6): 42-49. (in Chinese)

[10] Maker Education Initiative. The Maker Education Initiative’s Mission [EB/OL]. http://makered.org/about-us/mission, 2015-01-31.

[11] Chris Anderson. Maker: New Industrial Revolution [M]. Beijing: China CITIC Press, 2012. (in Chinese)

[12] Yang Xianmin, Li Jihong. The Potential Value of Maker Education and Its Disputes [J]. Modern Distance Education Research, 2015, (02): 23-34. (in Chinese)

[13] Zhang Lei, Jiang Qi, Yin Tao. Research on the Development of Maker Education in China under the Background of "Internet +"[J]. Software Guide (Education Technology), 2016, 15(05): 9-11. (in Chinese)

[14] Zhu Zhiting, Sun Yanyan. Maker Education: a Practical Field of ICT-Enabling Innovation Education [J]. China Educational Technology, 2015, (01): 14-21. (in Chinese)

[15] Jiang Weishuo. Talking about robot in the classroom (II) — Maker culture and robot education[J]. China Information Technology Education, 2013, (Z1): 33-36. (in Chinese)

[16] Zhao Chunhai. Exploring the implementation of Maker education in the science curriculum of primary schools [J]. Education Science Forum, 2017, (29): 61-63. (in Chinese)

[17] Chen Yu. Curriculum Development of Maker Education in Primary School [J]. China Computer & Communication (Theoretical Edition), 2017, (19): 239-241. (in Chinese)

[18] Wen Fake. The organic integration of maker education and primary school science education[J]. China Science & Technology Education, 2017, (08): 60-62. (in Chinese)

[19] Zhao Jianhua. Small Maker Shows Big Ideas, Small Craftsmen Has Big Dreams — The Practice and Exploration of "Maker Education" in Experimental Primary School in Nantong Development Zone[J]. Jiangsu Education Research. 2017,(Z5):45-48. (in Chinese)

[20] Fu Qian, Liu Pengfei. Toward An Origami Curriculum Based on Maker Education [J]. Journal of Open Learning, 2017, 22(03): 50-54. (in Chinese)