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The Teaching Case Design of STEM Based on the Environment of Combining Museum and School—Water Resources Project*

YANG DAN
Beijing Jianhua Experimental School, Beijing, No.66 Yuquan Road, Haidian District, Beijing, China. E-mail: 2951824195@qq.com

XIAOLIN ZHANG
School of Educational Technology, Faculty of Education, Beijing Normal University, No. 19, XinJieKouWai St., HaiDian District, Beijing 100875, P. R. China.

LUYAO WANG
School of Educational Technology, Faculty of Education, Beijing Normal University, No. 19, XinJieKouWai St., HaiDian District, Beijing 100875, P. R. China.

Under the guidance of STEM concept, the theme of this paper is "Designing water purification solution based on water pollution of China". This paper integrates the resources from school, museum and water utility factory to develop a comprehensive learning practice, which involves multi-subject knowledge in biology, chemistry, math, physics and engineering. The students are guided to research the water shortage and pollution status in China, and independently inquire to find solutions for water purification through collecting water in daily life. During the overall process, students are collaborated to analyze issues, design the solution, practice, share ideas and assess the effectiveness. Consequently, the practice makes full use of local resources like water museum to add humanistic color to this study.

Keywords: formal and informal education; STEM; combination of museum and school activity

1. Introduction

Based on the STEM definition [1, 2], the design of learning activities in this study takes "designing water purification program" as the theme, which can bridge formal and informal education. We carried out learning activities by combining with rich resources of local tap water museums, to explore engineering process of water purification, and to deeply inspire teenagers' interest. Taking this as an example, this paper explores the STEM Education and teaching model under the environment of Museum-School Collaboration.

Learning in the past mainly refers to the academic education in schools. School is recognized as the formal learning settings where people learn most of their knowledge. However, in the era of knowledge explosion, people's learning has changed from traditional learning to life-long learning [3]. In addition to formal learning, learning refers more to informal learning, since simulating scientific inquiry in formal STEM courses is insufficient [4, 5]. In the real world, scientific practice possesses characteristics that are different from classroom practice, including scientific attitude and spirit, extensively shared tools and technology, and social interaction [6–9]. Therefore, to meet these real-world demands, STEM courses should extend outside the classroom. For instance, the United States has been committed to STEM Education for nearly 30 years. However, the effect is not significant over the years due to the limitation of the single school education. Thus, Smithsonian Institution was specially added to the U.S. Committee on STEM Education as a member so that informal STEM Education can maintain consistency with school STEM Education and can be improved [10, 11].

Informal STEM education (or ISE) are some learning activities that range from professionally-designed settings outside the classroom to everyday, spontaneous learning taken up by individuals and social groups [12]. ISE learning presents numerous advantages. First, it generally offers many opportunities to learn and explore the real world, and students define problems from everyday life and search for solutions [13–18]. Second, this type of learning is social and requires students to learn from group cooperation, to communicate and to share [19, 20]. Third, it can transform students into autonomous learners who accept their learning responsibilities, ask questions, make decisions, analyze, criticize and create. The most important difference between formal learning and informal learning is that formal learning is initiated and organized by the outside world, while informal learning is a kind of self-initiated, self-regulated and self-responsible learning. Informal STEM learning also encourages students to approach

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actual scientific practice step-by-step through scientific and social resources, which is essential preparation for one's future life. In summary, we should promote Informal STEM education and at the same time strengthen formal STEM education.

The most worth mentioning is that Museum-School Collaboration has become a new type of teaching method which springs up recently [21–23]. Using this teaching method, students cannot only learn related knowledge but also can cultivate their ability of autonomous learning and promote their interests in study. Museums have tens of thousands of educational resources and cultural items. It is evidence that some institutions, such as natural museums, science centers, nature centers, zoos and so on, play an important role in Informal STEM education. For instance, ISE institutions can help K-12 teachers and students to strengthen "E" in STEM education. Since STEM emerged, it was interdisciplinary integration, which focus more on scientific inquiry and less on engineering in life [24–26]. Museums provide a better platform for cultivating student's interest in engineering [27–29]. On the other hand, schools share the same mission on cultural preservation and inheritance. Therefore, both are natural partners for STEM education. Museum-School Collaboration is an effective pathway to integrate both formal and informal resources. It is not only beneficial to schools, but also has a great role in promoting the development of museums. We should share complementary Strengths to build the future of STEM education.

Over the past ten years, America and UK have been widely promulgated the "American National Science Education Standards" and the "British National Science Education Standards" respectively. Based on these standards [30–32], schools redesigned teaching curriculums based on science and technology museums. To achieve the effective combination of formal education and informal education, the Museum-School Collaboration of European and American countries has entered into the deep integration stage.

However, STEM Education in China, especially STEM Education outside school should give full play to the advantages of science and technology museums, in order to further improve STEM Education. In September 2013, the China Youth Research Center conducted a questionnaire survey of scientific learning situation among 5,696 primary and secondary school students from 64 schools of 8 cities. Data show that primary and secondary school students rarely go to science and technology museums and lack willingness to take up scientific and technical careers; scientific activities at school seem to "see more but do less"; students' demands for extracurricular scientific activities have not been met yet so that they hope to increase opportunities for them to learn in nature and museums.

Therefore, we should think about how to take advantage of the rich education resources and infrastructures in various museums and how does various museums play their own characteristics to provide more and more effective approaches and ways for STEM Education. Meanwhile, a set of STEM Education and teaching model under the environment of Museum-School Collaboration, need to be implemented systematically and studied solidly.

2. Case design

The current world development and human survival are facing many problems such as energy crisis, waste of resources, environmental pollution, disaster prevention and mitigation. Solving these problems is closely related to the field of STEM. In the study of informal education, there are many educators at home and abroad exploring these values to improve education practice. This study selects the United States Arizona Water Resources Project related to the design theme and the water purification teaching case of Beijing Jianhua Experimental School, and explores the STEM Education and teaching model under the environment of Museum-School Collaboration. See Table 1.

3. Method

3.1 Subjects and context

The participants in this study were 52 grade 7 students at Beijing Jianhua Experimental School in China and registered for a STEM course related to water purification. There are 6 class hours a week for 20-week semester. The content of this course consisted of two main parts: (a) Study the Water Purification Program against Water Pollution Problems through multidisciplinary methods and (b) Apply the knowledge and experience into practice.

3.2 Implementing

Firstly, invite professional teachers and students who attended the water purification course to revise the teaching process and planning. Then, select two teaching classes with equal students' learning ability in Beijing Jianhua Experimental School. Teachers of the school lead the teaching and researchers take the participatory observation, record and collect the formative data. The details are as follows:

(1) Consult and test the former concept of two classes respectively, and make minor adjustment on the teaching plan;

Table 1. Comparison of Water Resources Projects

	The United States Arizona Water Resources Project	**The Water Purification Teaching Case of Beijing Jianhua Experimental School**	**Designing the Water Purification Program against Water Pollution Problems (research cases)**
Involved Subject	Mathematics, physics, geography, technology, humanities	Chemistry, mathematics, physics, biology, geography	Chemistry, mathematics, physics, biology, geography, technology, history, humanities
Learning Way	Overall project of Arizona	Integrate subjects and visit the site	STEM project teaching, Museum-School collaboration
Practical Activity	Dispose collected sample data and make water-saving device	Filter and test wastewater, visit	Collect data, detect filter, visit, make
Time of Duration	Nine months	Three weeks	One month
Initiator	Government, 44 enterprises, schools, universities, parents	Tap water plants and schools	Beijing Tap Water Museum, School
Target Audience	Grade 4	Grade 7	Grade 7
Curriculum Development	WISI Two-day Course	Students make the model of the tap water plant	Museum educational activities
Evaluation Method	Achievement exhibition on seminar	Assessment, reporting	Practice record form, sharing and reporting

Fig. 1. General Situation of the Beijing Tap-Water Museum Visited by Students before.

(2) After a class finishes the STEM teaching, visit the water plant; the other class carries out part of the teaching content in the Beijing Tap-Water Museum, and uses its resources for teaching, as shown in Fig. 1;
(3) Inquire students' feeling in a form of questionnaire and retell the water purification flow chart;
(4) A month later, ask students of the two classes who participated in the experimental teaching before to draw a concept map about the knowledge of water purification.

4. Result

Classify the collected data, collect and analyze students' reports, scales, concept maps, interviews and other information formed in the learning process.

4.1 Investigation report

There are reports about students conducting research at home with various survey methods (see Figs. 2 and 3). According to the actual situation of their own home, some students made containers to measure the amount of water for one day, some of them classified and summarized the total household water consumption for different objects and different functions. Share the diversity of reports with everyone in class, open students' thoughts and inspire students to be better at discovering the way to deal with the problem in life, which reflects the project-oriented teaching process.

4.2 Make statistics on students' feedback scales after visiting the water museum

We can know from the data (Table 2) that most students think that the knowledge of water is very interesting. For the item of "applying what I have learned to the design and practice process of domestic water-saving" and the item of "boldly imagining and designing water-saving programs according to a certain background of knowledge", 23% of students think that their ability has not been largely improved, mainly because that there were a lot of knowledge to convey when they visited Museums

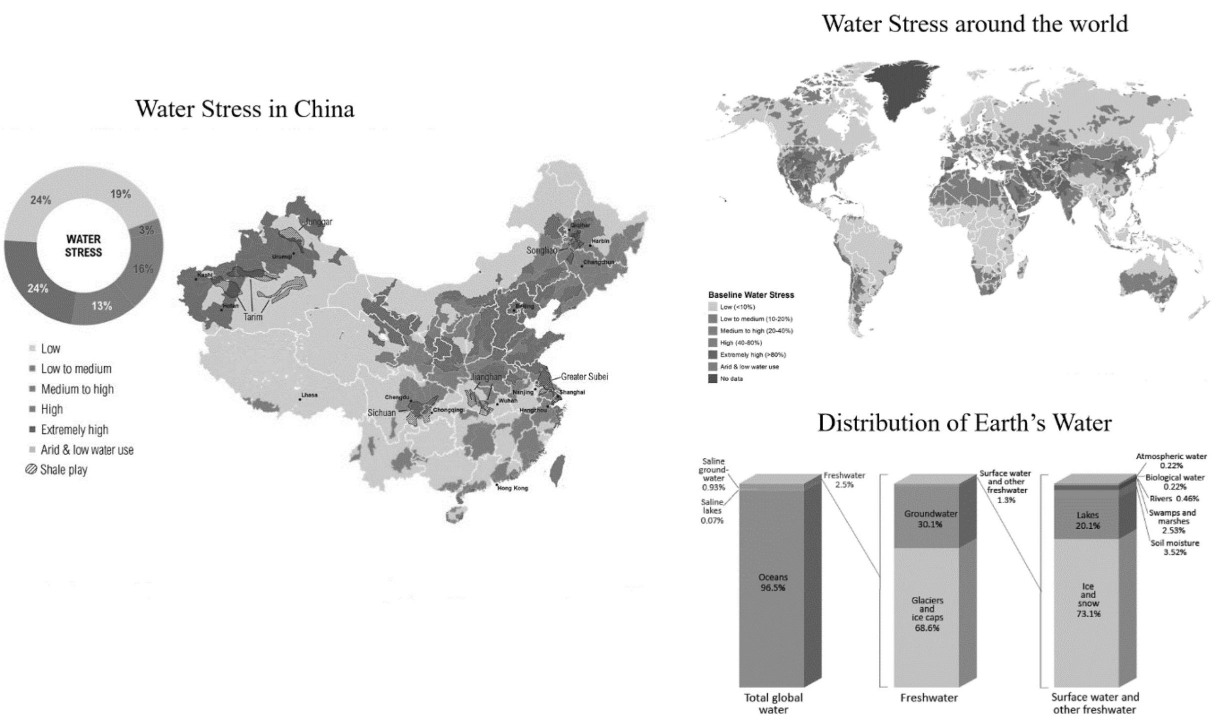

Fig. 2. Example One of Student's Investigation Report on Water Consumption around world and in China.

Daily Household Water Consumption

	Drink	Bathe	Cook	Wash	Mop	Water the plants	Restroom	Total
Brother	1.5L	20L	8L	37.L	0L	0L	30L	97L
Father	1L	22L	0L	37.L	0L	0L	24L	84.5L
Mather	2L	23L	9L	37.L	5L	1L	30L	107.5L
Myself	1.5L	22L	0L	37.L	0L	0L	24L	85L
Total	6L	87L	17L	150L	5L	1L	108L	374L

Fig. 3. Example Two of Student's Investigation Report on Household Water Consumption

and students' ability of transferring ability also needs the guidance of teachers. 83% of students can give further explanations on related topics of water, 87% of students can design water-saving programs, and 84% of students will penetrate water-saving awareness into the life bit by bit. Visiting has a certain impact to students' living habits and concerns. Most students like this kind of teaching method which can relax themselves into the learning environment and improve their attention to knowledge itself.

4.3 Concept map and creative consciousness of saving water

Due to the recognition on water resources after the visit, the real situation in Beijing, as well as the distribution and utilization of water resources in China and in the world (Table 3), children have clear concept map about water resources, and they understand more about the culture of water.

4.4 Interview

Before the formal interview, 7 students were randomly drawn from the class for the interview, which was agreed by them. The structural interview method was adopted, and certain stipulations and settings were set for the topic of the interview. As the interviewer, the teaching assistant had clarified the interview's purpose and determined the interview's contents, and mastered the basic skills and operation procedures for interviews in advance. The interviewer was acquainted with students during the visit, and he told them that the interview had nothing to do with academic record, who guided the interviewees to answer the questions in natural and relaxed attitude. According to the requirements of the interview outline, the interviewer encouraged the interviewees to speak out freely. The interviewer started the interview after the Museum visit activity, and then expressed thanks to the interviewees. The contents of the interview were recorded with voice

Table 2. Students' Feedback Scales after Visiting the Water Museum

	Strongly Disagree	Relatively Disagree	Neutrality	Relatively Agree	Strongly Agree
1. I think that the content of water-related knowledge itself is interesting.	0	0	3 people 12%	13 people 50%	10 people 38%
2. I can apply what I have learned to the design and practice process of domestic water-saving.	0	0	6 people 23%	15 people 58%	4 people 15%
3. I have a comprehensive understanding of the development of Beijing Tap-water culture by visiting.	0	0	6 people 23%	13 people 50%	7 people 27%
4. I can boldly imagine and design water-saving programs according to a certain background of knowledge.	0	0	6 people 23%	9 people 35%	11 people 42%
5. I can make some explanations on some problems and phenomena through visiting and studying.	0	0	7 people 27%	9 people 35%	10 people 38%
6. I will continue to focus on related reports about Beijing water resources situation and news.	0	1 people 4%	8 people 31%	10 people 38%	7 people 27%
7. I will change the behavior of using water and enhance water-saving awareness in life bit by bit through visiting and studying.	0	0	4 people 15%	11 people 42%	11 people 42%
8. Combining the classroom teaching and visiting Museums can both ensure knowledge explanation and practical observation which is good for my study.	0	0	4 people 15%	16 people 62%	6 people 23%
9. This kind of teaching form is lively and interesting, making me take a great interest in water engineering knowledge, physics, chemistry and other natural subjects and humanities knowledge.	0	0	8 people 31%	10 people 38%	8 people 31%
10. This way of learning no longer focuses on my performance scores, making me relax myself and put myself into the learning environment.	0	2 people 8%	6 people 23%	4 people 15%	14 people 54%

Table 3. Students' Concept Map and Creative Consciousness of Saving Water

Listing	Contents in water-related knowledge concept map of students before the visit	Contents newly added in water-related knowledge concept map of students after the visit
Student A	Water is widely distributed, with sources including rivers, lakes, seas and underground. But there is not sufficient fresh water, and we need to protect water resources.	How to cycle: water cycle: sea-land, sea-air, inland. How to transfer: the processing and treatment flow of water resources, changing to drinking water. Taking the water plant as an example: getting water, purifying water, distributing water. Cultural knowledge: it was built as early as in the Qing Dynasty.
Student B	Beijing is a city with water shortage, and the South-to-North Water Diversion relieves the water shortage. Water purification can be realized by processes such as filtration, adsorption and sedimentation.	The meaning of water body, and the three ways for water circulation. The first water plant was established in 1906; the World Water Day enhances people's water-saving awareness; the production technology process of water plant.
Student C	Among the Chinese traditional five elements, water occupies a significant position; places with water resources are livable places. Water is a key point for people's livelihood, and it is the significant basis for the existence of the outer space.	People cannot live without water. "As good as water" is a kind of attitude. Water circulation; the meaning of tap water; the history and treatment process of water plants.

recording equipment, which will be converted to text document and analyzed after the interview.

According to experience and feeling of students after the visit, they like the visit very much, and are attracted by it.

5. Discussion

STEM courses in schools and informal Museum activities are natural partners, which have their own advantages and defects respectively. We should share their complementary Strengths to build better STEM education. The combination of original STEM courses and informal Museum activities has the following significant advantages: Firstly, students broaden their knowledge during the visit in Museums. A lot of water-related knowledge and culture exhibited in museums cannot be reached by students in class, giving them feeling of freshness. Secondly, the items on exhibition in museums present the knowledge in a vivid and specific way. For example, items on exhibition such as sand table increase students' interest; Beijing Tap-Water Museum exhibits a lot of local water utilization conditions; the water culture and the water utilization distribution in various regions make the process of education more localized. In this way, students understand that the knowledge they learn is closely related to their lives, but not irrelevant. Therefore, students will have better understanding of related knowledge in the future. Some students are surprise about water utilization data. Some of them express that they know water shortage, but have no idea about the actual data. They have in-depth understanding of water shortage during the visit, and they express that they will save water in the future.

6. Conclusions

Through summarizing the data, we can find that most students are extremely interested in this way of learning—visiting Museums, which has largely expanded their knowledge. This study combines the formal education form and the informal education form by taking advantage of the water consumption situation, water culture and water distribution in various districts of Beijing displayed in Beijing Tap-Water Museum, and makes the process of education more localized. Participants can better understand that the knowledge they have learned is closely related to their own lives. The Museum-School Collaboration activity obviously enhances their learning motivation, interests, water-saving consciousness.

In conclusion, this paper focuses on the key features of student-centered and life-connected STEMs, designs and connects formal and informal STEM Education models, as well as provides an important strategy for primary and secondary school educators to develop STEM projects.

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Yang Dan is a K12 teacher at Beijing Jianhua Experimental School. She received her Ph.D. degree from the University of Chinese Academy of Sciences. Her research interests include project based learning in science teaching and STEM course.

Xiaolin Zhang is a graduate student in the Department of Education at the Beijing Normal University. Her research interests include curriculum theory, development and assessment in STEM.

Luyao Wang is a graduate student in the Department of Education at the Beijing Normal University. Her research interests focus on innovation in STEM research.