STEM 3.0 for Chinese Students with Sea Perch Underwater Robots: an Experimental Summer Camp for Hands-on Thinkers in Shanghai

1. STEM in China: challenges and opportunities.

After almost 40 years since the first national university entrance examination held in 1977 [1], we see a swiftly growing interest from all aspects of Chinese educational sectors in the reform of the traditional exam-orientated, subject-learning education style to a system with an increasing emphasis on the hands-on practicing of knowledge using. One of the most popular ideas is STEM education, which was first introduced into China in 2001. The industry started booming from 2012, as we saw an appearance of thousands of private and public sectors promoting the education of STEM subjects, such as coding, robotics, etc.

Despite the public hype on STEM education, we saw many challenges facing Chinese STEM educators. To begin with, the STEM education developed in China only for a very short time, and therefore, there is a lack of high-quality teachers, class subjects, and educational culture. However, most importantly, Chinese STEM education faces two major challenges. The first point is *the lack of engagement from the student*, as the Chinese students are used to play the role of the receiver, instead of the participant in the class, and, besides, they do not have much experience in the hands-on practice. The second challenge is *the lack of the teaching structure for the STEM educator*, as the Chinese teachers in the public education system are used to be the knowledge giver, and they will use the same methods to teach the STEM subjects with a focus on the knowledge learning and examination skills.

2. Concept and Framework of STEM 3.0

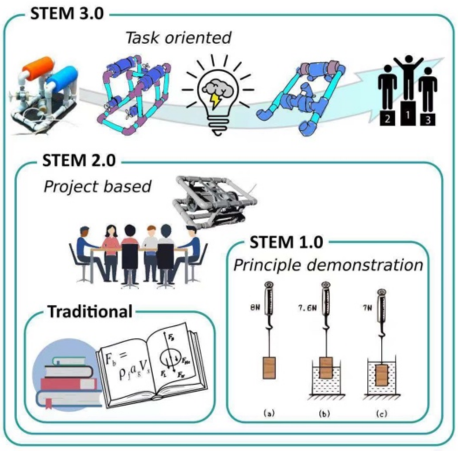

Figure 1. Concept of the “STEM 3.0” learning and teaching method and its relationship to the “Triditional”, “STEM 1.0” and “STEM 2.0” methods.

In order to address these two issues, we propose a new idea of “STEM 3.0” teaching methods for the Chinese students, which evolved from and can be dated back to Prof. Harold “Doc” Edgerton’s idea (early 50s) [2] of learning via scientific principle demonstration using interactive devices (“STEM 1.0”) and Prof. Kim Vandiver’s idea (late 90s and early 00s) [3] of hands-on learning experience via a well-defined step-by-step project (“STEM 2.0”). The key elements of “STEM 3.0” teaching method is first to use interactive scientific demonstrations and step-by-step projects to prepare students with required theoretical and practical backgrounds, and then via the announcement of a given task for a simulated real-world problem to encourage them as hands-on thinkers to find their creative solutions. Fig. 1 demonstrates the concept of the “STEM 3.0” learning and teaching method and describes its relationship with the “Traditional”, “STEM 1.0” and “STEM 2.0” methods. Moreover, Fig. 2 displays a flowchart that lists out the key steps in the framework for a successful implementation of the “STEM 3.0” method in classroom teaching.

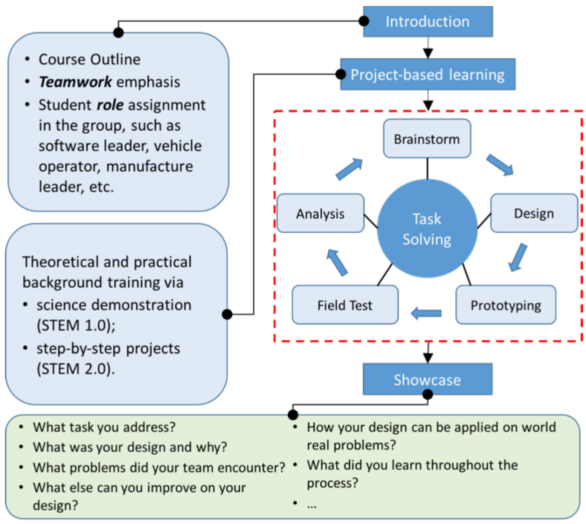

Figure 2. Framework for the implementation of the STEM 3.0 in the classroom.

3. Implementation of STEM 3.0 in an Experimental Summer Science Camp Using “Sea Perch” Robots

In order to assess the validity of the “STEM 3.0” teaching method whether it is useful in facilitating Chinese students’ engagement and interest in learning STEM subjects, we implemented and tested this idea in two science camps in summer 2019 for 12 days in total, with more than 120 students attended. The main project target we selected is a simple underwater robot called “Sea Perch”, which was first proposed as a concept by Harry Bohm [4] and developed by Dr. Thomas Consi at MIT Sea Grant 20 years ago [5] in an undergraduate curriculum. A 3D sketch of the standard “Sea Perch” robots is shown in Fig. 3 (D).

Based on the framework of “STEM 3.0” teaching shown in Fig. 2, we divided the 6-day camp into two phases: a. Learning the technical background with standard “Sea Perch” robot building (the first to the third day); b. Creative problem/task solving as a hands-on thinker (the third to the sixth day). The main activity of each day can be summarized as follows,

Day 1: Role assignment and theoratical backgroud.
Day 2: Standard “Sea Perch” robot building

Day 3: Debugging and announcement of the task
Day 4-5: Group brainstorm to solve the problem
Day 6: Competition and group showtime

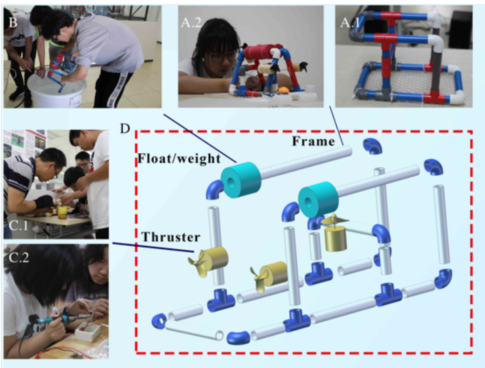

Figure 3. Key ***educational*** components of the "Sea Perch" underwater robots. A.1 and A.2: Frame assembly for structural integrity; B: Floater placement for hydrostatics; C.1 and C.2: Thruster construction for underwater proplusion, waterproof and controller design; D. 3D sketch of the "Sea Perch" underwater robots.

In the *step-by-step project-based learning phase*, the "Sea Perch" robot turns out to be an excellent candidate as it is a low-cost and easy-to-build robot with standard structures that can achieve basic functions of underwater maneuvering. These characters make it especially suitable for a beginner with a limited background of hands-on STEM subjects (most of the Chinese students fit in such a category). In addition, though easy-to-build, "Sea Perch" as a whole system, can be divided into several key educational components: a. Frame assembly for knowledge of structural integrity, shown in Fig. 3 (A.1) and (A.2); b. Floater placement for the knowledge of hydrostatics, shown in Fig. 3 (B); c. Construction and control of the thrusters for the knowledge of underwater propulsion, waterproof, and electronic design, shown in Fig. 3 (C.1) and (C.2). It is important to note that the interactive demonstration and mini-project-based teaching method can and should be used when conveying the knowledge of each key component. Furthermore, the success of the "Sea Perch" not only depends on each component but also relays on the final assembly, which leaves students an important engineering experience that problems need to be addressed systemically.

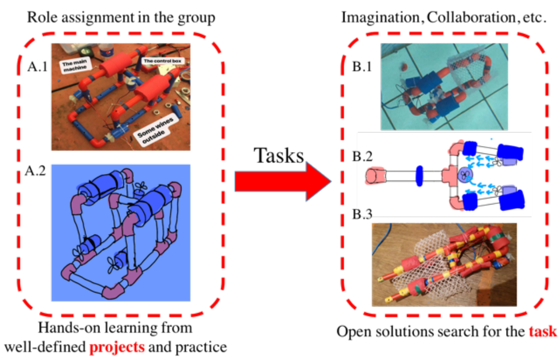

Figure 4. Evolution of "Sea Perch" robot from the ***standard*** version (A.1 and A.2) by the end of the camp day 2 to ***personally designed*** version based on the ***tasks*** assigned for the final competion.

In the *task-based open solution searching phase* for the current summer camp, we defined two tasks with different constraints and goals: a. Navigating in an open water area with obstacles; b. Treasure hunting in open and confined water region. Based on the skills and experience they learned during the first phase as well as the goal and constraints of the tasks, students of each groups showed exceptional creativity and evolve their standard "Sea Perch" robot into their unique design of robots with different sizes, shapes and functionalities with the sole purpose to solve the problem and finish the task. Fig. 4 (B.1 – B.3) plots three samples of students' own designed and constructed vehicles, showing their vast difference between each other and from the standard version in Fig. 4 (A.1) and (A.2). During this phase, we discovered students exhibiting an increasing interest and focus, since they are "creating their own baby" (quote from one of the students attending the camp.). Even though their initial "baby" mostly fails to function correctly, to begin with, they would not be frustrated and give up, but improve their design from their failure. Shown in Fig. 5, students were testing their own designed vehicle in task 2 of the treasure hunting. Moreover, at the showtime, when each student group, winning or losing, demonstrate their robots, they would most likely not only describe the vehicle design and performance but more interestingly, predict what their vehicle may be applied in the real world to solve some challenging problem we are facing nowadays.

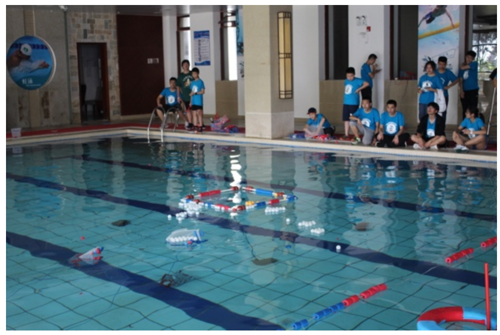

Figure 5. Photo of students testing their personally designed underwater robots in the swimming pool.

In summary, this paper describes a new concept and the corresponding framework to implement the "STEM 3.0" teaching method to address the challenges and opportunities of STEM education in China. An example of a large scale 2019 underwater robot summer camp in Shanghai, featuring the use of sea perch underwater robots, is given as a demonstration of the successful test of the method, featuring encouragingly positive feedbacks from students.

References

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