Case Study on “STEM+Computational Thinking” Education Model in Chinese K-12 Schools

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Abstract. This study puts forward a "STEM+ Computational Thinking" learning model based on STEM education and computational thinking theory, especially on summarizing the practical experience of computational thinking-based STEM project in China’s K-12 schools. The model includes two main lines run through the whole learning process, scientific inquiry and engineering practice. It divides the practice process into three progressive parts: comprehensive perception, automatic processing, remote control. In this paper, the author uses the case of the heartrate remote monitoring system to show the model’s three progressive parts: building the hardware production, programing sensor automatic perceive system, and programing mobile terminal remote control APP. The case shows that this "STEM+ Computational Thinking" learning model both has the multidisciplinary integration attribute of STEM education and has the creative characteristics of computational thinking. Practice shows the cases developed with this model have good effect during teacher training and students' classroom learning. It has very strong maneuverability in cultivating students' scientific and technological accomplishment and improving their computational thinking ability which is an advantage in popularizing the computer science curriculum and STEM education.

Keywords: STEM Education, Computational Thinking, the heartrate remote monitoring system, case study, Student-centered self-regulation learning

I. INTRODUCTION

STEM is an acronym stands for science, technology, engineering, and mathematics. The development of STEM education has evolved from four independent disciplines to Integrated-STEM curriculum(Yu & Hu, 2015). STEM education emphasizes the skills to application of interdisciplinary integration of knowledge to real-life situations. An Integrated-STEM curriculum is typically based around finding a solution to a real-world problem and tends to emphasize project-based learning. STEM encompasses fields that are collectively considered the core technological underpinnings of an advanced society(Harland, 2013).

STEM grew in popularity due to the government and edutaors found students were not be prepared to work in the fastest-growing STEM career sectors and could not meet the need of the future society. The U.S. Department of Education's National Commission on Excellence in Education released an opening statement in 1983 : A Nation at Risk: The Imperative for Educational Reform(National Commission on Excellence in Education, 1983). It is said, “Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world”(National Commission on Excellence in Education,1983). The report went on to say that the future success and civility of the nation (even globally) is tied directly to a high achieving education system that is focused on all learners. In this report, the National Commission called for reform focused on preparation of all students to achieve maximum potential in content understanding, critical thinking, and problem solving. It identified the areas of mathematics, science, and technology as critical for a prosperous society in the “new information age”(National Commission on Excellence in Education, 1983). Since then, countries around the world have made STEM education a key part of education reform in the 21st century, including China. That effort has been formalized in many ways, including using the language of STEM in Next Gen Science Standards in USA and new core curriculum critia in China. So, teachers everywhere are expected (by parents, administrators, etc.) to provide a STEM-rich curriculum. This has brought great pressure on the frontline teachers. Teacher trainers were asked to provide teachers with theoretical and practical cases of STEM courses during the training process. It is expected to enhance their curriculum development and execution ability through case-based teaching.

Computer science inherently draws on mathematical thinking and engineering thinking, given that we build systems that interact with the real world(Wing , J.M., 2006;J.M., Wing, 2017) As one of core thinkings of computer science, computational thinking (CT) is taking an approach to solving problems, designing systems and understanding human behavior that draws on concepts fundamental to computing. And Computational thinking is important not only for computer science but also will be a fundamental skill used by everyone in the world by the middle of the 21st Century(J.M., Wing, 2017). It could be one key approach to support STEM education to infuse CT elements within STEM topics. The future would be an Artificial Intelligent (AI) era, the real world problem would be need use AI technologies(The State Council of China, 2017; Dai, 2017) For the education meaning of prepair today’s students to fit future society need, it is better to choose topics of STEM projection related to AI, such as smart home, intelligent iransportation, etc. It has often been found that students appreciate hands-on work, and find that they learn more with courses that include a project than those relying solely on conventional lectures and tests(Xu, 2017). For promote students’ learning intresting and transfer the evaluation from paper test to product creativity, product-oriented teaching strategies following the theory of backward-design are a good way to go(Auerbach, Concordel, Kornatowski & Floreano, 2018; Wiggins, 1999). For create AI product, open sources hardware are technological solution path to the real word problem(Gibb, 2015). These choices also support the STEM education’ aims to cultivate students' scientific and technological literacy, blend approach that encourages hands-on experience and gives students the chance to gain and apply relevant, “real world” knowledge in the classroom.

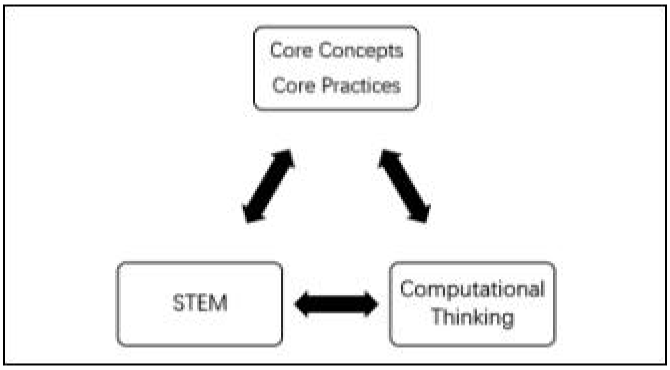


Fig 1. The relationship among core concepts of subjects, computational thinking and STEM educationrelation. The computational thinking could be cultivated in multidispilines project-based STEM education.

American K-12 Computer Science Framework published in 2016 pointed out: Computational thinking can be widely used in science, technology, engineering, mathematics (STEM), and many subjects such as art and humanities(ACM, 2018). On the other hand, the framework advocates the training of computing thinking based on STEM Education(ACM, 2018; NRC, 2012). The corresponding standards have an important guiding role and promoting effect on the training of Computational Thinking and the implementation of STEM Education. The findings of the US National Science Foundation (NSF) show that students can take into account both the concept and practice of computer science and the cultivation of Computational Thinking in mathematics and science(ACM, 2018; NRC, 2012) (see Figure 1).

In recent years, the Chinese government has attached great importance to the cultivation of students' STEM literacy and Computational Thinking ability in K-12 stage education(The State Council of China, 2017; MEPC, 2017 & 2018; Swaid, 2015). Education researchers are encouraged to carry out cooperative work with K-12 schools' teachers in STEM and computer science subject teaching and learning. The idea is that in order to be prepared for jobs and compete with students, students need to be able to solve problems, find and use evidence, collaborate on projects, and think critically. Integrated-STEM curriculum teach "21st-century skills," or tools students need to have if they wish to succeed in the workplace of the "future." Because Beijing Institute of Education(BIE), it's main work is teacher training, STEM & Maker education research center of BIE, with a passion for promoting STEM literacy in we always want to find some ways to turn research into practice. And believe in exciting students about STEM through fun, hands-on experiences where real learning occurs. We develop and teach the activity-based curricula to younger students and their teachers in order to encourage others to lead the programs on their own.

In this context, it would be perfect if a STEM project including two main design lines, science inquiry and engineering practice procedure, was designed to solve real world problem of AI era with the CT(Portz, Stephen & Portz, 2014; Wang, 2014; Basham, Israel & Maynard, 2010). Corresponding to AI, Intelligent manufacturing, Intelligent robot, cloud computing and other important STEM industries that will change the future social life, it is particularly important for future citizens to master the ability of using computational thinking to solve problems(Basham, Israel & Maynard, 2010;Israel, Pearson & Tapia, 2015; Zanella, Bui, Castellani & Tapia, 2014). A "STEM + Computational Thinking" education model idea formed in mind when we plan to develop STEM curriculums. In those STEM project students would experiment with different materials and computer-aided designs to build a hardware product and programing software control system capable of perfect as one or more smart home function or other smart city functions(NRC, 2011).

Research group in STEM & Maker Innovation Education Center of BIE, there are 10 formal teachers and many outside experts and frontline teachers. We focus on developing lessons and techniques that bring together STEM disciplines and concepts through creative hands-on projects and experiments. We had recruit frontier teachers from K-12 schools as trainees in STEM project supported by BIE, and then they would practice what they get from our training class into their class. After implementing many practical experiments on exploring the STEM project based on Computational Thinking, "STEM+ Computational Thinking" learning model, based on Project-based Learning(PBL) theory, studies how to train computational thinking during computational thinking-related STEM project learning, become more and more clear. Think of Science and Engineering education align the ideals of constructivism and accountability, the study process of this model is include two main lines, science inquiring and engineering practice, these two lines run through three progressive learning parts: hardware products building, Automation, and software system implementation (here include Arduino IDE coding and APP Inventor coding).

The model intentionally guide students to solve problems by using STEM knowledge of computer science, such as perception sensor, coding, automatic control, information and communication, so as to train students to use computational thinking to solve practical problems. This paper elaborate on this model and its application in teaching practice based on the case "Heart health small patron saint - Heart Health Monitoring System", hereinafter referred to as the Heart Monitoring System. The three parts of the heart monitoring system respectively corresponds to the three progressive stage: comprehensive sense, reliable delivery, intelligent processing, it is actually a Internet of Things three hierarchical layers.

II. CASE OF STEM PROJECT-BASED LEARNING AND COMPUTATIONAL THINKING

"STEM + Computational Thinking" model aims to use interdisciplinary knowledge to solve real world problems, and make the students' computational thinking fully develop. The model also stresses student-centered independent learning, inquiry-based learning, and cooperative learning aiming at cultivating the habit of seeking interdisciplinary connections, interaction and using interdisciplinary methods, so the students could experience the whole process from finding problems to solving problems. The reason why chose the heart monitoring system as teaching case is that it enables students to intentionally use the integration of computer science with mathematics, engineering, science and other disciplines to solve problems(Israel, Pearson & Tapia, 2015), promoting the development of computer science education and improving the students' thinking ability in the process of STEM project.

A. Two Main Learning Lines of STEM Education Run Through "STEM+Computational Thinking" Model

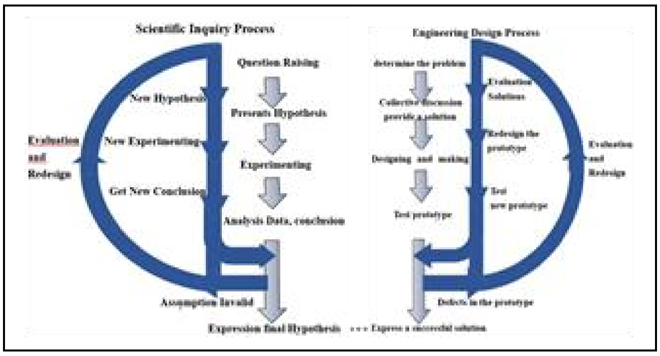


Fig 2. The structure of the "STEM + computational thinking" education model consists of two main lines run through the whole

According to previous research findings and on the basic of practice experiment summarized, "STEM + computational thinking" model give three important indicators for identifying effective STEM project: Student-Centered Learning, Product-oriented design, and Learning Progressions(NRC, 2011; Brown & Eric, 2016). The structure of the model consists of two main lines run through the whole STEM project learning process, scientific inquiry and engineering practice (see Figure 2). They experience the whole project process from finding out the problem to determining the problem, and solving the problem. In this part, students should familiarize with the hardware components, like sensors, Arduino micro controller, etc., and then, set up the actual products through product oriented design and realization. These works require them to have scientific research capabilities and engineering practice skills, and develop the ability to solve complex problems.

One of the essential characteristics of STEM education model is taking students as the center of learning(Yu & Hu, 2015). The project-based learning need students have self-regulation and co-regulation abilities. Self-regulation is the process by which individuals monitor, control, and reflect on their learning(Zimmerman, 2013). Self-regulated learning (SRL) includes the cognitive, metacognitive, behavioral, motivational, and emotional/affective aspects of learning(Panadero, Andrade, Brookhart, 2018;Lawanto, Butler, Cartier, Santoso & Goodridge et al, 2013). As the importance of self-regulated learning is well acknowledged by research nowadays(Panadero & Järvelä, 2015;Hadwin, Järvelä & Miller, 2011; Panadero, 2017), Self-regulated students tend to be more organized, hardworking, interested, and self-critical. They are able to set study goals, analyze their performance, persist in the face of difficulties, and identify the behaviors that affect their learning. In the whole learning process, students need to develop abilities of question raising, supposition and assumption, making plans, experimenting, evidence collecting, explanation and conclusion, inflection and evaluation, expression and communication, etc. Interventions to promote self-regulated learning can empower students at risk and raise the educational level of a society(Panadero & Järvelä, 2015). Here teachers could supplies abundance materials to lead and support the students' self-regulation learning process. But it is difficult to frontier teachers. How to let Self- and Co-Regulated Learning (SCRL)happen? Here the model suggests providing students with abundance good designed learning support materials: table need to fill, choice question, multiple-choice question, fill in the blank, matching, flow chart Table completion, diagrammatic, etc. All this materials must be well-designed semi-finished products. The advantage of this is that teachers can leave different contents on the basis of students' foundation. At the same time, the learning support materials can also constrain students' self-learning. The semi-finished materials not only help students focus on the main task and following the progress, but also teach them how to do self-learning and cooperative learning under the lead of materials. It help students be able to coordinate and co-regulate learning in a group, too.

Table Ⅰ A case ofase of the well-designed SEMI-finished table materials provide to students to help students define question

Why need measure	where need measure (Actual scene)	need remote or not	Online need or not
Heart rate measurement after exercise	Playing fields	Yes. It will convenient by remote control and record	Yes. It will useful transfer heart rate to doctor in time

Define question 1: Refer to the literature, discuss the actual scene that requires heart rate measurement, record thescene mentioned by the team members and fill in the table below. it is very useful for group collaboration learning.

In this case study, when the model was used in real classroom, Frontier teachers found it was more difficult to find the questions and setting forth them than answer during the first stage of project-based learning. So teacher supply tables to help students define problems, such as table I, and other materials to help students develop computer program and present their solutions could be designed step by step, each step completes a specific task to achieve a specific training goal.

The first step is defining questions to be solved by this project. The model put emphasis on connection of the studying content and actual life and the ability of the student solving the true problem. Through the science inquiry, they found out the questions the real world exist and gave better solutions. During the Heart Monitoring System case, students found that with the arrival of the 21st century, China is facing the issue of an aging society, thus caring for the old people and improving their quality of life is of great significance for society.

They define their question is with China entering the aging society, designing home health monitor system becomes important for the elderly who live alone (empty nest elderly), it is also necessary and important for the hospital and community nurses to know the elderly's health state in a real time. The following question was which physiological index should be monitored? From the literature research, students found the related studies have shown that heart disease and stroke are the two most important killers that occur outside the hospital. The heart rate (the number of heartbeat within a unit time) is a routine physiological indicator of clinical examination. Monitoring heart rate can predict most of the heart disease or stroke. For engineering practice process line, we need a better system for monitoring heart rate. The project would be designed to create remote monitoring heart rate system to monitor the health of the elderly.

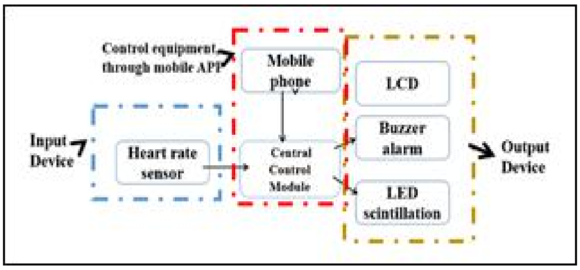


Fig 3. A case of hardware composition of the Heart Monitoring System designed and make by student.

The second step is so-called engineering practice. After determining the problem, the overall design idea of the implementation parts is based on the realization of the Heart Monitoring System as one part of smart home project of the Internet of things(IoT, 2015). Teachers could provide learning materials related to the Internet of things, Students learned that the Internet of Things (commonly abbreviated as IoT) is the network of physical devices, vehicles, home appliances and other items(even heart monitors) embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect to the Internet and exchange data through the IoT(Burrus, 2014). In this way, students designed the engineering practice part of the project according to the hierarchical structure of the IoT: All the components, including remotes, dashboards, networks, gateways, analytics, data storage, and security, those all are part of the Internet of Things ecosystem(Diega, Guido, Walden & Ian, 2016). Figure 3 is a case of the design structure of a student work.

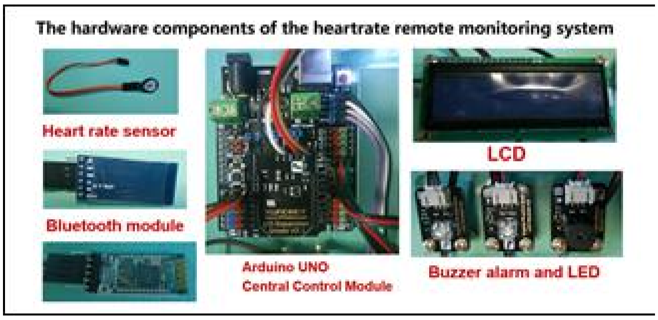
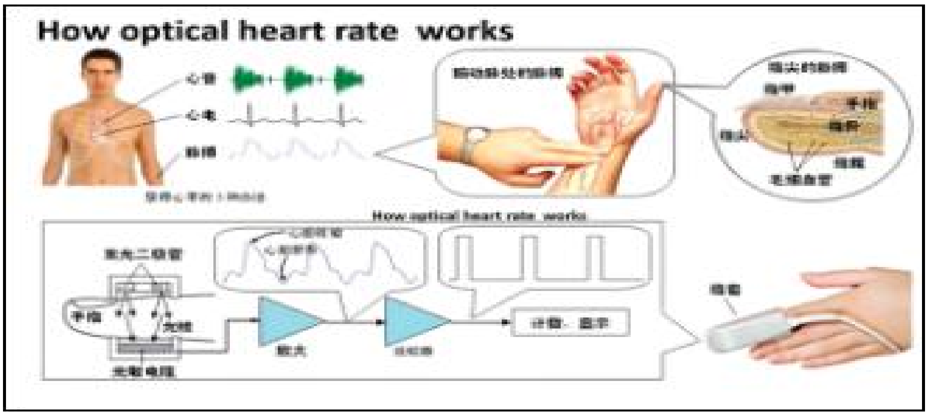


Fig 4. The hardware components of a case of heartrate remote monitoring system, it would be selectly used by students themselves depend on their designed system functions.

The third step is to create the hardware system and test their functions. Once the design is complete, the function of the system is clear, next work is select opensource hardware and make the connection to assemble the hardware system. Any stand-alone internet-connected device that can be monitored and/or controlled from a remote location is considered an IoT device(Diega, Guido, Walden & Ian, 2016). With more smaller, more powerful chips, almost all products can be an Internet of Things devices(Dasgupta, Rynearson, Purzer, Ehsan & Cardella,2017; Azman, Arsat & Mohamed, 2017). In this case, the components of the Heart Monitoring System include but are not limited to heart rate sensor, Arduino UNO chip, Blue Tooth or WIFI Module, LED lights, buzzer alarm, LCD modules, etc. (See Figure 4). In this process, students must use STEM knowledge to understand the principle of fingertip heart rate sensor, and use electronic control and other computer science knowledge to design and finish this project.

The fourth step is coding and software function test. The project selects the open source software--App Inventor towed visual programming platform, which students can easily learn to develop a simple APP on their mobile phones. With Bluetooth they build communication with mobile or computer, and then they could do set up and test: recording or analysis of the heart rate to judge the health state, finished remote alarm and monitor function, thus achieving the goal of long distance monitoring and controlling towards family heath. The last step is test the system function as a whole body.

TABLE Ⅱ. A CASE OF THE WELL-DESIGNED SEMI-FINISHED PRODUCTS TABLE MATERIALS



provide to students to help students understand the principle of fingertip heart rate measurement worked. It is a tool for students self-learning.

From the five steps of the case this paper use, students could understand how STEM education improves student self-regulation and co-regulation learning(Fernandez-Rio, Cecchini, Méndez-Gimenez, Mendez-Alonso & Prieto, 2017). Teachers prepare the theory chart for students, but some name is blank where need students to fill in blank (See table II). Use this method encapsulate knowledge the students don't need know at this time. So the same chart would be different for different grade or class(Zimmerman & Schunk, 2011).

B. Computational Thinking-Based Problem Solving is The Developing Ideas and The Main Characteristics of "STEM+Computational Thinking" Model

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Computational thinking means understanding how technology works, how the Internet works, and learning to solve problems with CT(Wing, J.M, 2006). Following the previous research, the concepts of CT include decompose, patterns, abstractions, algorithms. logical reasoning, …(J.M, Wing; Azman, Arsat & Mohamed, 2017)."STEM + computational thinking" model is a computational thinking-based STEM education model. The work condition of the Heartrate Monitoring System in reality is much more complex than in classroom. Computational thinking is reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation(Wing, J.M, 2006). The model simulates the layered decision-making and piece-wise linearized processing procedure for solving complex problems. Thinking like a computer scientist means more than being able to program a computer. For the integration of CT into ideation process(CFW, 2011), it requires thinking at multiple levels of abstraction.

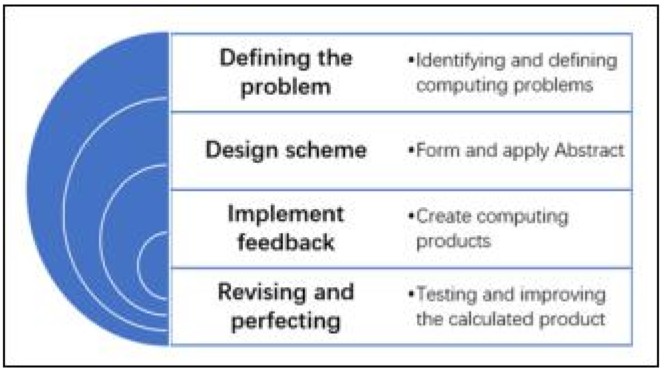

Fig 5. The process of the computational thinking to solve the problem: a design and practice process from a perspective of engineering practice in "STEM + computational thinking" education model.

"STEM + computational thinking" model just from the practice convenient in STEM classroom, so the model just give a design and practice process from a perspective of engineering practice, it includes four major aspects of a defining the problem, design scheme, implementation feedback, revision and improvement (See figure 5).

On case study of the Heartrate Monitoring System project, Computational thinking at last be implemented in the this four teaching process, the main technology is programing, it includes the design of the hardware terminal Arduino automatic control program in Arduino IDE, and the design of remote control terminal(mobile phone or computer) APP. In the process of realizing the interaction between human thinking and machine action, the whole process understands the level of the overall perception of the IoT, the intelligent processing and the reliable transmission. It is the core concept of CT application at here.

The application of CT to the STEM project-based learning in practice was introduced above as A and B parts. However, according to the teaching characteristics in the course of practice, they should be carry out as a computational thinking-based STEM project(Yadav, Zhou & Mayfield, 2011;Yadav, Mayfield & Zhou, 2014; Duncan, Golan & Hmelo-Silver, 2009) . The part A and Part B had a very consistent rhythm.

III. THREE PROGRESSIVELY LEARNING PARTS OF THE "STEM + COMPUTATIONAL THINKING" MODEL

As we talked above, referring to the three hierarchical structure of IoT(Burrus, 2014; Brown & Eric, 2016), we designed three progressively learning parts in our "STEM + Computational Thinking" model, which are the first part "the full capacity to perceive objects", the second part "having the capabilities of reliable transmission" and the third part "intelligence processing for information and remote control". The carefully designed parts builds understanding of the core ideas of STEM and CT. Each part is composed of two main lines: science inquiry and engineering practice we talked above. Every part is truly connected and build upon one another across the whole project-learning(Schwarz, Reiser, Davis, Kenyon, Acher &Fortus et al , 2009), progressively moving students toward the product-oriented real world problem solving(Hess & Karin, 2011).

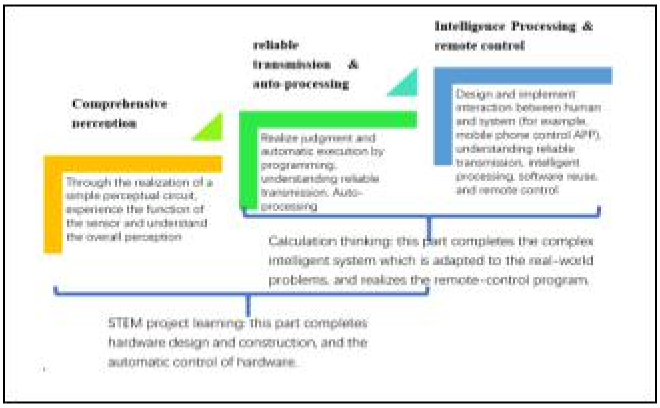

Fig 6. “STEM+ Computational Thinking” are a three progressive parts model.

This learning progression is reflected in the three parts of the program, which are carried out step by step: basic inquiry, medium inquiry, extensive and deep exploration in three stages(CSTA, 2016; Gulwani, 2014). For the Heartrate remote system project, our “STEM+ Computational Thinking” are a three-part progressive model, as shown in Figure 6.

A. Initial Part: The Full Capacity to Perceive Objects (Comprehensive Perception)

Fig 7. A case of the hardware system of the heartrate remote monitoring system the students build.

As the basic function of project, the main goal of this part is technology learning, include recognizing components, hands-on practice to building a hardware terminal production through connected and test, understanding the "comprehensive perception" of the IoT(see the Figure 7). During this part, we must give students much more individual practice time, permit them by building only one sensor simple perception system that only has a single function, let them feel easy to know the sensors function one by one. And then familiar with the scientific knowledge of the hardware components needed by the heart rate monitoring system, familiar with the basic computer science knowledge, such as Arduino IDE programming environment, understanding and judging circulation structure(Hautemaniere, 2016; GEGC, 2018). For example, the program realizes the signal perception of the fingertip pulse sensor, the LED light goes out, the buzzer excite the shutoff condition and so on.

B. Intermediate Part: Having the Capabilities of Reliable Transmission（Reliable Transmission and Intelligence Processing）

With the aim of solving the problems, at this time the students, on the basis of scientific inquiry and the engineering design process, build a heart rate monitor hardware system(see Figure 7), design and complete the Arduino terminal hardware automatic processing program on Computational Thinking, understand the characteristics of IOT reliable transmission, intelligent processing.

C. Realized System by Programming Part（Intelligence Processing and Remote control）

Fig 8. The App Inventor programing environment and the mobile phone control APP UI of heartrate remote monitoring system. It is the part to develop a dashboard to remote monitoring the heart reate.

This part would design an APP Dashboard to mobile phone, displays information about the IoT ecosystem to users and enables them to control their IoT ecosystem. This part focuses on the ability to develop software design and system debugging ability training. In this stage, students follow the problem-solving process based on computational thinking，design and implement the mobile terminal control application of the remote terminal in App Inventor environment(see Figure 8)，debugging coordination of hardware terminals and software system, understand relationship of the three progressively learning Parts.

IV. APPLICATION AND IMPLICATIONS

“STEM+ Computational Thinking” model emphasizes CT concepts through hands-on learning experiences, suitable for all K-12 students. STEM & Maker Innovation Education Center of BIE have arranged 3 workshops with K-12 teachers, used the “Heart health small patron saint - heart health monitoring system” case to practice this ”STEM+ Computational Thinking” model, each workshop was half a day long. Another 8 teacher training classes also had finished to practice this case and another two cases on this model, every class was three days long. Until the moment of writing this paper, total of more than 260 K-12 teachers take part in these teacher training class as students. The trainees in workshop were mixed grade teachers, they come from preschool to high school. But Every class is divided, just for primary school teacher or just suitable to middle school teachers, or high school teachers. The workshops and training class were supported with hands-on labs, and multimedia materials, utilizing several kinds of technology tools to enforce use STEM+CT to solve the real word problems. Teachers are taught how to use opensource hardware to build productions, understand the engineering practice, created software system through coding and testing to find best solution to the problems they defined by themselves through science investigation and function need analyses. Because the model need multidisciplinary knowledge to construct a real world question solutions, the product had not clearly different among different subject teachers.

We also used this case in “App Inventor Teacher Training Workshop” grant by Google (Educator Grants) CS4HS: Computer Science for High School (BIE gained the grant in 2017 and 2018). It is a three days’ workshop, 40 in-service teachers, most them are information technology and science teacher(Fernandez-Rio, Cecchini, Méndez-Gimenez, Mendez-Alonso & Prieto, 2017). Before 2017, The training only teach teachers how to use APP Inventor develop APP software, In 2017 and 2018 workshop, this model introduced. Compare to only use APP Inventor coding before, the open source hardware product building let the learning process more interesting, and the product-oriented let the coding have more meaning, the APP is not only APP in mobile phone, but also an APP could remote control something. The more important is, the teachers in workshop is no longer simply learning programming techniques, because they have to define a real problem that needs to be solved at first, they actually have to go through the whole process of scientific inquiry. In the operation stage, because the evaluation criterion is the solution to the actual problem, this undoubtedly improves their engineering practice ability.

About a third of the teachers went back to school and tried this case in their classroom, they sent to me more production created by their students, some of them could developed more cases depended on this model. According to the feedback from the teachers who had practice this model in their classroom, because unlike the previous pure software environment study, the hands-on parts of construction of real hardware system has raised the interest of students to learn computational thinking. In turn, the engineering practice part provides the basis of practical evaluation for the study of scientific knowledge. This model can replace the traditional knowledge memory test by investigating the ability of applying knowledge to solve problem products, it overcomes the disadvantages of traditional memory knowledge assessment. They said that the effect is good but still have some difficulties, such as technology barriers, creative ability, finding some questions deserved do research, and lack of the classroom time…, etc. These all require further research.

In 2017, the case “Heart health small patron saint - heart health monitoring system” has been authorized by the Beijing municipal commission of education, as one of government "Open scientific practice in junior high school" course be offered to students in the first year of junior high school in Beijing(Meyrick, 2011). The course was asked total take 120 minutes long for each class, 80 minutes must hands-on time, no more than 30 minutes lecture, and 10 minutes shared product in class. More than 900 students select this case study on government website, totally more than 30 classes. Our research group members serve as teachers directly to students. The after-school questionnaire on government website shows effectively that this case is highly valued by most of students(Meyrick, 2011). This course would be continue and we had developed more case based on this model, and most had passed the government assessment and would be select on website at the next term beginning, September, 2018,.

A main aim of “STEM+ Computational Thinking” model is through scientific inquiry and engineering practice to improve students' scientific literacy and practical ability. The model teach students to think like computer scientists, encourage students to solve problems as rigorously as an engineer, promote students' critical thinking, enhance students' engineering design ability, innovation ability, and creative ability, self-regulation and co-regulation, etc. The teacher's classroom experiment show that the results of “STEM+ Computational Thinking” model has positive facilitation to the study of students. The model’s product-oriented engineering practices greatly increase students' interest in learning computer science, especially using computational thinking to solve the problems. The multiple kinds of works designed and created by students showed that this educational model obtained a good effect so that students' enthusiasm and creativities were totally inspired. Good results have been achieved in the aspect of development of students comprehensive quality and practical operations capability. If making good use of the model, it could improve students' ability to self-regulation and co-regulation learning efficiency, help students understand and memorize learning tasks and evaluate their learning results.

V. Summary and prospects

The potential for STEM education is vast. STEM education is an opportunity to provide meaningful 21st century education for all students. Moreover, the STEM initiative provides an opportunity to educate society about how to measure educational outcomes in the modern world. Finally, STEM education affords a chance to reassess and overcome the barriers in the current curriculum and instruction and to provide a meaningful STEM education to students(Lawanto, Butler, Cartier, Santoso &Goodridge et al, 2013).

Except heart rate remote monitoring system, we also developed smart home lighting system, biped robot system and other STEM projects based on “STEM+ Computational Thinking” model, encourage teachers to offer this kinds of courses to students(Diega, Guido, Walden & Ian, 2016; Yadav, Mayfield & Zhou,2014; Duncan, Golan &Hmelo-Silver, 2009). Because the model has the multi-disciplinary integration characteristics of STEM and the creative characteristics of computational thinking, it has strong operability for training K-12 students' engineering and technological literacy and improving computational thinking ability. Because STEM is project-based learning oriented, its practical implementation reduces the teacher’s computer science difficulties and the inquiry and cooperation involved in the process stimulate students learning enthusiasm.

In the future, we will continue the research on the basis of this model through improving model, continuous deepening development and promotion of the new curriculum, affective strategies directly impacting on students' learning process and learning results. Through developing more classroom resources to reduce the burden of teachers, through enhancing the STEM and the computational thinking case study, do some different degree encapsulate for different students to meet students’ needs of learning the computer science and STEM subjects, thus promoting STEM education and computer science with the computational thinking as the core in K-12 stage, promoting students interest in learning, at last promoting China’s education reform and to give children more intelligent information ability to adapt to the future society.

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