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*Research Article in Curriculum Development*

# Case Study on the Development and Implementation of STEM Projects: "DIY Traffic Lights"

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**Abstract**: A popular education mode in today's era of knowledge economy is STEM education, whose fundamental goal is to cultivate innovative scientific and technological talents, as well as talents with interdisciplinary knowledge literacy and the ability to solve real problems. This article combs the connotation, educational value and application mode of STEM, and discusses students' learning process in the STEM project of "DIY traffic lights".

**Keywords**: STEM project; Curriculum development, Curriculum implementation

## 1. Introduction

STEM is the abbreviation of science, technology, engineering and mathematics (Fan, 2011). The abbreviation of the four disciplines covers almost all fields related to science, technology, engineering and mathematics, and even psychology, economics, sociology and political science (Green, 2007). It is an interdisciplinary field biased towards engineering technology. STEM education is a qualitative description of education methods. The implementation of interdisciplinary integrated education focuses on cultivating innovative and compound talents. With the continuous improvement of the requirements of all walks of life for the overall quality of talents, STEM education has become a hot topic of concern for education experts and scholars around the world. The Horizon Report 2015 (Basic Education Edition; Bybee, 2010) points out that STEM will become a key factor in the development of school education in the future and will be widely promoted and applied worldwide. As a new form of education to cultivate talents with comprehensive scientific literacy and innovative inquiry ability, STEM education will be the key to the success of education in the 21st century (NRC, 2011).

A Framework for K-12 Science Education by NRC (National Research Center) of the U.S. (hereinafter referred to as the Framework) and Next Generation Science Standards (hereinafter referred to as NGSS) developed on the Framework are particularly prominent. They not only put engineering practice and scientific practice together, emphasize "the use of mathematics and computer thinking", but also include the interaction between engineering design and engineering, science, technology and society in the core concepts of the curriculum. It shows the aspiration of the first scientific and technological power to integrate STEM disciplines and develop scientific education (China, 2022). The new compulsory education science curriculum standard issued by the People's Republic of China in 2022 states that science is a comprehensive basic curriculum reflecting the nature of science, which is practical. The 2022

science standard integrates the field of technology and engineering and especially emphasizes the importance of technology and engineering in science curriculum. STEM is originally biased towards engineering technology. In this case, the development and implementation of STEM projects are very important.

## 2. Core Orientations of STEM Education

### 2.1. Fundamental objective

The fundamental objective of STEM education is to cultivate talents with scientific and technological innovation capability (Hu & Liu, 2022). STEM emphasizes engineering design, scientific thinking and system thinking in STEM, encourages students to understand the application, performance and operating principle of daily technology, and encourages students to experiment, invent and create together. It attaches great importance to scientific inquiry, find problems in life, exploring problems, solving problems, and solving problems in real life. For example, the case discussed in this paper starts with students finding traffic problem at the school gate. Then they conduct research, analyze, design, and finally solve the problem.

### 2.2. STEM course content: to lay a solid foundation of knowledge

The research shows that deep understanding and flexible application of scientific and technological knowledge is a necessary condition for the development of teenagers' scientific and technological innovation quality, but the relationship between them is not linear. With the increase of scientific and technological knowledge, its impact on the quality of scientific and technological innovation gradually decreases. STEM course content requires students to deeply understand the core concepts of disciplines and interdisciplinary core concepts, and also emphasizes engineering and practice. Designing STEM course content based on core concepts, especially interdisciplinary core concepts, engineering and practice, and advanced learning can enable students to gradually understand the links between knowledge, form flexible knowledge networks in the brain, and build a reasonable knowledge structure (Hu & Liu, 2022). In the following cases, mathematical calculation, engineering design, statistical analysis, etc. are involved. When students participate in STEM learning, they can deeply think, compare and analyze, design and make, etc., and finally build knowledge frameworks.

### 2.3. STEM curriculum system: to reflect the advancement of learning

The Advancement of learning is a major feature in the revision of the new curriculum standards. The design of STEM curriculum content needs to consider the advancement of learning. The development of students' STEM integration ability and innovation ability is a gradual process. On the one hand, it needs to go through the process from single learning to comprehensive learning, and then to interdisciplinary learning. On the other hand, it requires to go through the process from method training, scientific inquiry, and then to scientific creation (Hu & Liu, 2022).

### 2.4. STEM effective teaching: to meet the requirements of creative teaching

Creative teaching is the main channel for cultivating innovative talents. One teaching philosophy of STEM is project-based, based on which STEM is a process of planning, designing, improving and solving specific problems. 2022 Science Standards by China's Ministry of Education clarifies that STEM is an evidence-based teaching process, which requires students to show the elements of project activities, choose the materials and tools they need, collect evidence and interpret the evidence (Hu & Liu,2022). STEM attaches importance to independent inquiry and cooperation and communication, and reflects the idea of independent construction. It is a process of self-monitored thinking. It is also an important process to cultivate critical thinking. STEM emphasizes inquiry practice in real situations, in order for students to analyze, select and think critically in the process of inquiry practice.

2.5. STEM evaluation: to promote student's all-round development

STEM is a comprehensive curriculum. In the implementation of STEM curriculum, it is not proper to only evaluate learning results. China's 2022 Science Standards is to build a quality oriented comprehensive evaluation system. In STEM project learning, teachers should pay attention to students' real performance and thinking activities in exploration and practice, and make evaluation work to incentivize and promote students to achieve more. At the same time, students involved in STEM project will find their own strengths and weaknesses through self-reflection and self -supervision. Thus, students can carry forward their strengths, complement their weaknesses, and promote their own overall development as a holistic person.

**3. STEM Education Model Design**

Based on the connotation, characteristics and core orientations of STEM, a model of STEM education is built, with a view to providing theoretical reference and practical reference for the design and implementation of STEM education in the future.

3.1. Oriented to the real situation and real life

Science comes from life and returns to life. STEM education focuses on students' connection between study and real life. It emphasizes the concept of learning by doing and learning in doing, and carries out inquiry learning in real situations. The knowledge applied in STEM education comes from real situations so that teachers are expected to create real situations for students, and students are expected to explore by using multiple disciplines, based on which to foster students' ability to find, analyze and solve problems in the process of exploration. The real problem is the main line throughout the whole learning process. By transforming the core problem into a series of learning tasks, students can explore and practice through in-depth thinking to achieve the construction and understanding of knowledge. Using "DIY Traffic Lights" as a case study, students focus on the real situation of traffic jam at the school entrance, analyze the possible causes and seek possible solutions.

3.2. Attaching importance to inquiry practice and strengthen practical experience

STEM learning lies in experience and thinking, from which the traditional paper and pencil test is different. STEM attaches importance to the learning process, emphasizes students' own active participation process. Only when students reflect and practice in the process of practice can they practice the deep level construction. STEM education enhances students' learning experience by providing students with a variety of real situations and advanced tools. Students apply science, technology, engineering, mathematics and other disciplines to solve practical problems in a cooperative and exploratory way (Yang & Ren, 2015). In the project of "DIY Traffic Lights", when students are investigating and setting up different pick-up and drop off points at the school gate, they should combine the statistics of the situation of parents' pickup and drop off. When making the traffic signal model, we should build and write the program based on the statistical survey data.

3.3. Providing technical support for students to implement activities effectively

Yakman, an American scholar, opened Scratch on MIT website in June 2011. It is popular, for the statistics shows 17204968 projects have been shared on the website (Yakman, 2016). In STEM education, students use technical tools to analyze and solve problems under the guidance of teachers. In this process, students' hands-on practice, exploration and discovery abilities are trained to foster their technical literacy (Wu, 2013).

In a word, STEM education is an interdisciplinary education driven by real problem solving, based on the learning process and multi technology integration, with the fundamental goal of cultivating talents

with comprehensive scientific literacy and innovative practical ability. Students' ability to acquire knowledge, explore consciousness, integrate disciplines, cultivate skills and solve problems has made a qualitative leap, which is a concrete manifestation of achieving STEM education goals (Qin & Fu, 2017).

3.4. Adapting the content to students taste to stimulate their interest

It is in children's nature to explore the world in their own terms. One of STEM's mission is to let children return to real life, learn by doing, explore by playing, so that to liberate their bodies. The problems familiarized by children are expected to be turned into interesting STEM project learning tasks. Learning content and activities are supposed to be carefully designed. At the same time, we should also consider that the content should stimulate students' interest, neither too simple nor too difficult. Thus, we should fully investigate and analyze the real situation of students.

3.5. Evaluating students' comprehensively to promote students' well-rounded development

Evaluation is implements in order to promote students' all-rounded development rather than evaluate learning results, as the traditional result-oriented evaluation does. STEM uses a multi-dimensional evaluation method. Based on process evaluation, STEM emphasizes the diversification of evaluation subjects, the individuation of evaluation objects and the comprehensiveness of evaluation results. Teacher are expected to record the performance of each child in STEM learning, find out the progress and highlights of each child, and promote the overall development of students.

## 4. STEM Project Development and Implementation: "DIY Traffic Lights"

4.1. Scenario of the project

As our city experiences heavy traffic, one of the typical urban diseases, and our school gate is located at the connection of three main streets, the roads in front of the school gate are always jammed when parents and their vehicles (cars, electronical bikes etc.) gather in the morning to take children to school and bring them home in the afternoon.

Based on this scenario, the research questions are: What causes the traffic jams near the school gate? What can we do to solve this problem? In this case, what are factors we are going to consider, what materials do we need to prepare and what research(es) will we do?

We are accessing to the solution by a series of inquiry activities, through which we will be able to understand simple circuit, learn to control light on and off, to make LED light and design and make traffic lights.

4.1.1. Learning objectives

The project accesses every aspect of STEM for its full completion. Therefore, the learning objectives of this project can be categorized based on the aspects of STEM:

Science (S):
To know about basic components and parts of simple circuits;
To understand connection modes and functions of different types of switches;
To know about short circuits and know relative safety measures.

Technology (T):
To connect circuits correctly;
To make traffic lights by using proper methods.

Engineering (E):

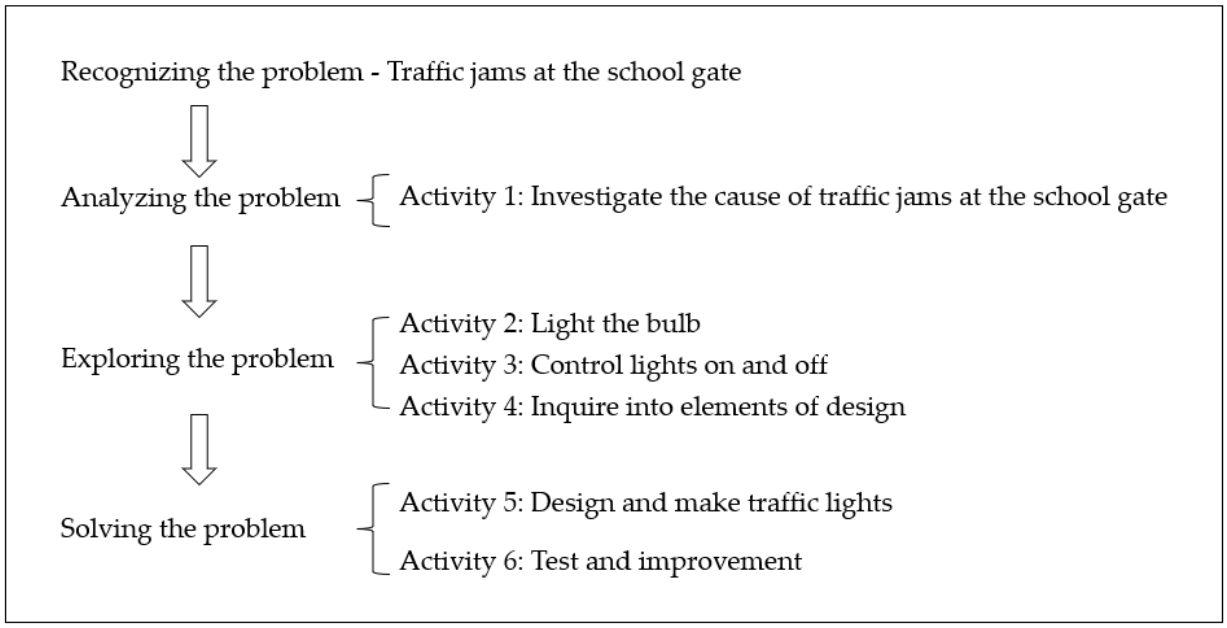
To design and make a LED light;
To optimize the design through iteration and make the product reproducible.

Mathematics (M):
To analyze the reasons of traffic jams based on the collected data
To optimize the design through measuring and calculating

Targeted grades: Grade 5 and Grade 6 (10~12 years old）

Duration: 6-8 school hours

4.1.2. Problem-solving Process




4.1.3. Material list

| **Non consumables** |
|---|
| Conductor (with red and black skin) |
| Small bulbs |
| controllers |
| Touch switches |
| Optically controlled switches |
| Voice switches |
| Multifunctional alarms |
| Tilt switches |
| Key switches |
| Buzzers |
| Colorful lamps |

| **Consumables** |
|---|
| No. 5 batteries (1.5V) |
| Batteries (9V) |
| Double sided adhesive tapes (0.5cm width) |

4.1.4. Safety matters

When connecting the circuit, students should make sure that no short circuits are formed. They should use electricity in a safe manner and prevent electric shock and fire. Finally, when striping and cutting the wires, they should pay attention when they use any tools.

4.2 Project process

4.2.1. Recognizing the problem of traffic jams nearby our school

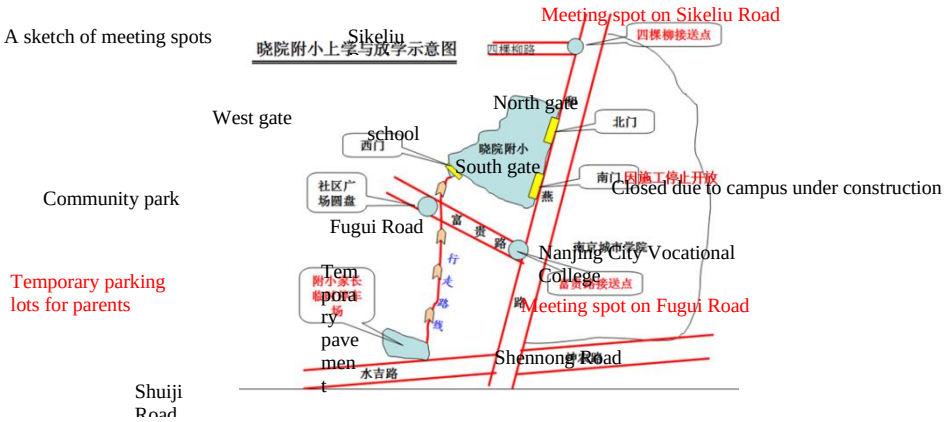
Step 1. Lead-in

Students observe the pictures below and share what they see in them.

Step 2. Students discuss the causes of traffic jams nearby our school.

The teacher can ask students:

- What, based on your experience, forms the traffic jams nearby our school?
- What do you think is needed to inquiry the problem of traffic jams around our school?
- How are you going to implement your inquiry? Do you need some help?




Note: Students might say they can solve the problem simply by specifying different meeting spots with their parents, in which case teachers can inspire them to think about diverting the crowd by the design of traffic lights.

4.2.2. Analyzing the problem

***Activity 1: Investigate the cause of traffic jams at the school gate***

Step 1. Lead-in

The teacher asks students to talk about possible causes of traffic jams near the school.

Note: It might be done by investigating the vehicles by which children are taken to and off school, and specific places parents and children specify to meet.

Step 2. Students observe the pictures below, in which parents wait outside the school gate.

Note: They can see the main street is within 3 meters from the school gate. They can also see parents pick up children by cars, e-bikes or bikes. When it rains, parents ride slowly carefully, holding umbrellas and/or wearing raincoats. The traffic is even worse in the rainy days.

Step 3. Students design questionnaires in groups.

Note: students carry out group discussions and design questionnaires, based on which each group have a captain to communicate the design before the whole class. Then each group edit their final questionnaire, conduct the survey and collect data.

Step 4. Students do statistics analyses.

Note: The analyses are based on the vehicles that parents use to pick up children to and from school.

Step 5. Design solutions.

Students locate the different meeting spots on their design sketch according to the vehicles by which parents pick up children.

Note: Teachers inspire students to consider the diversion of the flow by using traffic lights.

4.2.3. Inquiring the problem

***Activity 2: Light the bulb***

Step 1. Lead-in

Students need to know how to light the bulb and what materials are required in order to make traffic lights. So, the teacher can talk about batteries and small light bulbs, and guide students to observe their structure.

The teacher can ask students:

- Observe these small bulbs, what is their structure like?

- What is the function of the structure?
- Where does the light bulb shine?

Note: Students are probably familiar with small light bulbs. Inspire them to observe the structure and think about its function.

Step 2. Students light bulbs.

The teacher can ask students the following questions to inspire them to think and do:
- What materials are needed for the experiment? What is needed to connect the bulbs?
- How will you connect bulbs? Try to draw a diagram first.

Then teachers can explain how to draw a diagram of batteries, wires, and small bulbs. Students discuss their design in groups before drawing their design on the Record sheet 1 in their engineering experiments.

Note: Students can connect the circuit individually or in a group. Team work is highly expected and evaluated in the activity.

Step 3. Students complete their experiments according to their individual or group design, record the experimental result and write down the problems they are encountered with and pertinent solutions.

The teacher can ask students the following questions to inspire them to think and do:
- Is your light bulb on? If not, what is the possible reason?
- Is there anything in common among your trials when the bulb is on?

Note: Teachers encourage students to draw their designs first, and then do the connection accordingly.

Step 4. Students present results, have discussions and draw conclusions, while teachers guide them to understand the principles of physics of lighting bulbs.

**Record sheet 1: Lighting the bulb**

Please design an experimental scheme for lighting up the small bulbs and draw all the schemes you have designed. The material diagram is as follows.

bulb


battery

My design:

① ② ③

Experimental record:

① ② ③

bright Not bright bright Not bright bright Not bright

☐ ☐ ☐ ☐ ☐ ☐

Note: the bulb is bright( √ ) and not bright (×).

*Activity 3: Control lights on and off*

Step 1. Lead-in

The teacher askes students the following questions:

- Do you know about the secret of the work of circuit?
- We have known how to light bulbs, but how can we break the circuit to light it off?

Step 2. Task 1--- Control bulbs on and off by switches

The teacher Introduces to students all the materials and ask them to review simple circuits used in their daily life. Let them observe the structure of different materials and figure out how to use them.




control bulb switch battery

The teacher can check if students have known the function of the above materials and ask them to keep the following in minds:

- Get the experimental materials, and carefully observe the equipment;
- Carefully observe the characteristics of the socket and the card slot when connecting wires;
- Take turns experimenting in groups after lighting up;
- Modify their connection diagrams when the experiment is done.

Note: Let students try to explore by themselves how to use touch switches to control the light on and off according to the method of exploring a simple circuit to light a small light bulb.

Step 3. Task 2 - Control bulbs on and off by light

The teacher can tell students: at night, the streetlights will automatically turn on; in the daytime, the lights will go out. Do you know why? Let's talk about it.

Then the teacher can introduce how light control switches work:

When the light value is above or below than a certain value, indicating that the light value is or is not enough, light control switches turn on or off so lights are on or off.

Students observe the light control switches and talk about the characteristics of their shapes. Then they try to make a lamp controlled by light switch.

| Locations | Places | LUX |
|---|---|---|
| School | Classrooms<br>Laboratories<br>Reading room | 700——300 |
| | Computer rooms | 1500——300 |
| Home | Do homework | 1000——500 |
| | Do reading | 750——300 |

***Activity 4: Inquire elements of design***

Step 1. Lead-in

The teacher shows the picture on the right (in the picture two students are doing their exercises), and ask students: What is the problem with the classroom?

Note: students are likely to figure out the room is not bright enough.

Step 2. The teacher tells students different switches and electrical appliances. There are light control switches, tilt switches, voice control switches, touch switches, proximity switches, magnetic switches, etc. Electrical appliances cover lights, LEDs, motors, buzzers, etc.

Step 3. The teacher can ask students to design their own work by combining different types of switches, lights, motors, etc. Students should complete Record sheet 2.

**Record sheet 2: Designing my work**

Please put a " √ " in the selected ☐

☐Scenario 1: Incorrect writing posture ☐Scenario 2: optional _____

Experimental Materials:

Switches: ☐key switch☐ touch switch ☐tilt switch ☐ light control switch ☐distance switch ☐sound control switch ☐ others_____

Electrical appliances: ☐ motor ☐ buzzer ☐ colorful lights ☐ others_____

My design:

Step 4. Students test their designs, and the teacher can ask students to keep the following in minds during the test process:

- Complete their designs;
- What problems arise during the test? What are the possible solutions?
- What problems arise during the modification process? What help is in need?

Note: The producing process is supposed to go in accordance with the design drawings, and records must be done during the test process. and the test needs to be modified repeatedly until a satisfactory result is achieved.

4.2.4. Solving the problem

***Activity 5: Design and make traffic lights***

Step 1. Lead-in

The teacher inspires students to solve the problem of traffic jams at the gate of school based on the prior activities, eventually draw their attention to making a traffic light to divert people flow. Then the teacher asks students: What materials are necessary to make traffic lights?

Step 2. Students design the circuit diagrams of traffic lights to light up 1 bulb, 2 bulbs and 3 bulbs, and they keep in mind this question: Are there any changes in terms of materials and connection methods while lighten up different numbers of bulbs?

Note: Students can change the colors of one bulb or use 3 different bulbs (red, yellow, and green) to actualize the changes of colors of traffic lights.

Step 3. Students develop their designs. Then Each group presents their design to the whole class. All students discuss the feasibility of each design.

Step 4. The teacher hands out the following assessment table and help students to understand the design assessment criteria.

**Design assessment table**

| items / score | deliverables | | | wiring | |
|---|---|---|---|---|---|
| | red light on | green light on | time interval | safety | tidiness |
| Raw score | | | | | |
| Weight | 1 | 1 | 3 | 3 | 2 |
| Weighted score | | | | | |
| Total score | | | | | |

Note: The maximum original score for each item is 10 points.

Students are graded by their peers, who are asked to be fair on their evaluations.

The two key evaluation criteria are the deliverables, including whether the light can be turned on and the time interval, and the wiring, including whether safety precautions were followed and the tidiness of the design.

All students should understand the weighting for each evaluation criteria: the higher the weight, the more important that criterion is.

Step 5. Students select the materials by themselves according to their designs (referred to record sheet 3), and keep in their minds the safety matter when using glue guns.

**Record sheet 3: Building your model of traffic lights**

1. What materials are in need to build the traffic lights?

2. What problems arise while building the mode?

3. Outcome of my work

Good result:

***Activity 6: Test and improve traffic lights***

Step 1. Students present their modes of traffic lights in groups. They are supposed to answer the following problems in their presentations:

- Is the mode almost the same as they anticipated?
- Is their product consistent with their design?
- What is the cost?

Step 2. The teacher can organize students to make comments or give comments and/or suggestions by themselves in accordance with the above assessment criteria of outlook (whether the light is on and whether there is a time interval and wiring (safety and tidiness).

Step 3. Students modify the work and debug it. They are supposed to clarify: What need modifying? Why? What is the effect after modification?

Step 4. Students conduct mutual evaluation. They perform on-site evaluation by sticking stars (from 3 stars to 0, decreasing in order).

Step 5. The teacher organizes a project recapitulation. Students discuss what they have learned from the project and what needs improving in their future projects.

## 5. Conclusions

STEM education, as a new educational paradigm, is different from the traditional teaching and learning methods. At present, STEM education within China has not yet come to a complete theoretical system and a highly operational model. This paper summarizes the five value orientations and five application model design concepts of STEM education by combing the existing research home and abroad. Based on the value orientation and application design concepts, the STEM project "DIY Traffic Lights" is developed and implemented. Many problems and challenges still exist in STEM education, as how to design systematic STEM curriculum and STEM syllabus, how to let more teachers actively participate in STEM education rather than the monologue of individual disciplines, how to design an effective evaluation system to truly promote the all-rounded development of students. These problems all need the in-depth thinking and research of front-line teachers, the guidance of education experts, and the advice of all sectors of society on science and technology education.

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