Jockey Club STEAM Education Resources Sharing Scheme

Science Experiments x Micro:bit

Teachers' Guides

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School of Science and Technology
Hong Kong Metropolitan University

Ho Man Tin, Kowloon, Hong Kong

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Jockey Club STEAM Education Resources Sharing Scheme is a 4-year project (2019-2023) funded by The Hong Kong Jockey Club Charities Trust and operated by the School of Science and Technology, Hong Kong Metropolitan University.

Traditionally, knowledge is transferred to students through a teacher-centred approach. Teachers teach students based on a subject-based curriculum that aims for content acquisition.However, little attention is given to how students learn and apply the knowledge to tackle matters in and beyond classrooms. Moreover, the knowledge domains are covered in terms of individual subjects, such as Physics, Biology, Chemistry, and Mathematics. Students learn individual subjects separately without holistic integration. As a result, students may not be sufficiently equipped to solve authentic problems in the real world.

"While Hong Kong students perform well in science, technology and mathematics, they may focus on disciplinary studies and may not evenly participate in hands-on activities in schools. Therefore, it is necessary to strengthen the ability of students to integrate and apply their knowledge and skills across different subject disciplines through solving daily life problems with practical solutions and innovative designs." (Curriculum Development Council, 2015).

Under this Scheme, the operational team will create a set of STEAM modules for secondary schools to strengthen students' ability to integrate and apply their knowledge and skills across different subject disciplines with a special focus on the use of innovative teaching pedagogies for STEAM education, i.e.

Science
Technology
Engineering
Arts
Mathematics

At least 20 modules would be developed to target students of average ability in solving authentic problems in daily life. Each module would provide 4 to 40 contact hours of student activities. In addition, students would do preparation or follow-up activities during non-contact hours. The ratio between contact hours and non-contact hours is approximately 1:1.

This document provides a detailed module plan for learning, teaching and assessment activities. The module will provide an opportunity for students to learn STEAM through hands-on and minds-on activities that integrate knowledge and skills across Science, Technology, Engineering, Arts and Mathematics under real-world contexts.

1 Module Outline

1.1 Module Title: Science Experiments x Micro:bit

Writing a program is never the ultimate goal of programming. Instead, programmers always design different programs to facilitate human activities like experiments. Without computers and programs, almost no scientific research can be done in the modern world. In STEAM education, however, seldom we find learning activities integrating programming and science experiments.

Fortunately, micro:bit is an excellent tool for students to learn about coding and programming. An electronic sensor is one of the patterns of micro:bit and it is extremely useful in STEAM education and science experiments. One of the advantages of using electronic sensors compared to traditional measuring tools such as thermometers and pH paper is that the data we obtained could be easily and accurately recorded and digitalized. Furthermore, the data is already digitalized, it can be transferred over a network. We can monitor the data easily by using our computer or mobile device over the Internet. This is known as the Internet of Things (IoT).

In this module, STEAM activities that adopt coding and micro:bit to facilitate science experiments, such as measuring water flow rates, water turbidity and temperature will be illustrated step-by-step. This module will also show you how to use micro:bit to put IoT into practice. IoT methods such as makecode, Excel and cloud services will be introduced and illustrated with real examples.

1.2 Participants Recommended for this Module

- ☑ Junior Secondary School Students (please specify: S1-S3)
- ☑ Senior Secondary School Students (please specify: S4-S6)
- ☐ Others (please specify: ____________________)

1.3 Module Aims

The module "Science Experiments x Micro:bit" aims to:

- ◆ Introduce the knowledge of coding, electronic sensors and data logging technology related to science experiments
- ◆ Raise students' awareness of how we apply the knowledge of technology and engineering to tackle different problems
- ◆ Provide a chance for students to make use of technology and engineering knowledge to facilitate science experiments commonly found in secondary school education
- ◆ Advance students' application of subject knowledge and skills learnt in the school curriculum of Information communications technology, Integrated Science, Biology, Chemistry and Physics

1.4 Module Learning Outcomes

Upon the completion of the module, students should be able to:

- apply different basic concepts of coding using micro:bit;
- make different codes for different useful functions;
- setup different electronic sensors with different functions;
- record the data collected from micro:bit and sensors using different methods;
- create their own codes.

1.5 Learning & Teaching Approach / Practice

There is no doubt that electronic devices are useful. The quality of life is enhanced, and the precision and accuracy of science experiments are improved significantly. For example, in the laboratory, you can find numerous expensive and advanced electronic apparatuses, which are well designed by programmers and engineers. It is also possible for you to build up your own electronic apparatus if you acquire sufficient knowledge of coding and electronic engineering. Therefore, in this module, different basic coding concepts using micro:bit will be introduced. Students will be able to build different electronic sensors using parts like jump wires and relays. Finally, they will combine what they learnt to design their own electronic apparatus. This module will adopt problem-based, project-based learning and experimental approaches to help the students master the knowledge.

In this module, students will learn from practice. They will make 4 to 5 electronic apparatuses one by one which will be paired with a science experiment respectively. They will learn basic coding and related science during the process. After that, students will be invited and guided to create their own electronic apparatus.

At the end of the module, students will increase their understanding of the STEAM-related subject matter investigated. In addition. transferrable skills such as problem-solving, creativity and critical thinking will also be enhanced.

1.6 Nature of STEAM Activity

Element	Description	Composition
Science	Water quality, heat production in living things, rate of reactions, photosynthesis, speed and kinetic energy	✪✪✪✪
Technology	Coding using micro:bit	✪✪✪✪✪
Engineering	Assembly of different electronic sensors	✪✪✪✪✪
Arts	Design the electronic apparatus they made	✪✪✪✪
Mathematics	Percentages, rates, ratios and proportions, calibration, graph plotting	✪✪✪

1.7 Mapping of Key Learning Areas (KLAs)

Unit	Science Education	Technology Education	Mathematics Education	Arts Education
1	◆ Dissolving (SJ2.2) ◆ The weather machine (SSE1.2.1) ◆ Cellular energetics (SB1.5) ◆ Rate of chemical reaction (SC9.1) ◆ Factors affecting rate of reaction (SC9.2)	◆ Computer system (TK1.1) ◆ Concpets of system (TK8.1) ◆ Information processing and presentation (TK16.1) ◆ Programming concepts (TK2.1 and 2.2 and 2.3) ◆ Application of systems (TK9.2 and 9.4, 9.5) ◆ System integration (TE6.1) ◆ Control and automation (TE7.1)	◆ Using percentages (MJ5.1, 5.2) ◆ Rates, ratios and proportions (MJ6.1, 6.2)	

Unit	Science Education	Technology Education	Mathematics Education	Arts Education
2	◆ Photosynthesis (SJ7.2) ◆ Motion (SJ11.1) ◆ Electromagnetic spectrum (SJ14.7) ◆ Cellular energetics (SB1.5) ◆ Essential life processes in plants (SB3.1) ◆ Work, energy and power (SP2.4.3)	◆ Computer system (TK1.1) ◆ Concpets of system (TK8.1) ◆ Information processing and presentation (TK16.1) ◆ Programming concepts (TK2.1 and 2.2 and 2.3) ◆ Application of systems (TK9.2 and 9.4, 9.5) ◆ System integration (TE6.1) ◆ Control and automation (TE7.1)	◆ Using percentages (MJ5.1, 5.2) ◆ Rates, ratios and proportions (MJ6.1, 6.2)	◆ Design of the programme and the appearance of the apparatus
3		◆ Information processing and presentation (TK 16.3) ◆ Computer networks (TE1.3) ◆ Collecting data in makecode ◆ Collecting data using Excel ◆ Collecting data using cloud service	◆ Presentation of data (MJ29.3, 29.6)	◆ Design of the programme and the appearance of the apparatus

Unit	Science Education	Technology Education	Mathematics Education	Arts Education
4	◆ Water purification (SJ2.3) ◆ Importance of water to the physical environment (SS1.3.3) ◆ Effects of human activities on the balance of water distribution and water quality (SS1.4.2)	◆ Computer system (TK1.1) ◆ Concpets of system (TK8.1) ◆ Information processing and presentation (TK16.1) ◆ Programming concepts (TK2.1 and 2.2 and 2.3) ◆ Application of systems (TK9.2 and 9.4, 9.5) ◆ System integration (TE6.1) ◆ Control and automation (TE7.1) ◆ Information processing and presentation (TK 16.3) ◆ Computer networks (TE1.3) ◆ Collecting data in makecode ◆ Collecting data using Excel ◆ Collecting data using cloud service	◆ Using percentages (MJ5.1, 5.2) ◆ Rates, ratios and proportions (MJ6.1, 6.2)	◆ Design of the programme and the appearance of the apparatus

Remark: Mapping the skill sets in this module with the respective KLAs in the school curriculum that would be covered.

1.8 Module Structure

	Units	Contact Hours
1	Water Temperature and Water Quality	155 mins
2	Light and Speed	150 mins
3	Lazy Data Logging	120 mins
4	Missions and Project Learning	210 mins
	Total	**10 hours 35 mins**

Remark: A total of ***1.5*** *non-contact hours of the module is recommended.*

2 Module Design

Writing a program is never the ultimate goal of programming. Instead, programmers always design different programs to facilitate human activities like experiments. In STEAM education, however, we seldom find learning activities that integrate programming and science experiments.

In this module, students will learn from practice. They will make 4 to 5 electronic apparatuses one by one which will be paired with a science experiment respectively. They will learn basic coding and related science during the process. After that, students will be invited and guided to create their own electronic apparatus.

In Unit 1, we will focus on water temperature and water quality measurements. For temperature, students will make a thermometer measuring water temperature using micro:bit and sensors. Two experiments about heat production and rate of reaction will be used to demonstrate its power. For water quality, students will make a turbidity device and a water flow rate meter using micro:bit which the usages will be demonstrated by a water filtration experiment later.

In Unit 2, students will make a simple light intensity device to study the relationship between light intensity and the rate of photosynthesis of plants. Furthermore, a timer and a timing gate will be made for students to investigate the science of speed and kinetic energy.

After making a lot of different devices using micro:bit, in Unit 3, students will be taught to use different methods for data logging which is important to scientific investigation. IoT methods such as makecode, Excel and cloud service will be illustrated step-by-step with examples.

In Unit 4, students will need to apply what they have learnt from Units 1 to 3 to complete 3 tasks. After that, students will be encouraged to create and design their own codes and apparatus to solve the problems identified by themselves as an individual or group project.

2.1 Unit 1: Water Temperature and Water Quality

In Unit 1, we will focus on water temperature and water quality measurements. For water temperature, students will make a thermometer measuring water temperature using micro:bit and sensors. Two experiments about heat production and the rate of reaction will be used to demonstrate the power of it. For water quality, students will make a turbidity device and a water flow rate meter using micro:bit which the usages will be demonstrated by a water filtration experiment in Unit 4.

2.1.1 Objectives

Upon completion of *Unit 1*, students should be able to:

- Write a program for the water temperature device;
- Assemble the water temperature device;

- ◆ Write programs for the water turbidity device and water flow rate meter;
- ◆ Assemble the water turbidity device and water flow rate meter;
- ◆ Use the devices to facilitate the science experiments.

2.1.2 Pre-requisite (if appropriate)

Nil.

2.1.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction: ◆ Arouse students' interest in relevant real-life issues. ◆ To explain the learning objectives of this unit.	10 mins	◆ PowerPoint slides
(2) The temperature and water temperature devices: ◆ To teach the codes using micro:bit ◆ To assemble the water temperature device	30 mins	◆ PowerPoint slides
(3) Using the water temperature device for science experiments ◆ To introduce two experiments ◆ Experiment: Heat production ◆ Experiment: Rate of reaction	15 mins	◆ PowerPoint slides
(4) The turbidity device and flow rate meter: ◆ To explain the underlying principles of the sensors ◆ To teach the codes using micro:bit ◆ To assemble the two devices ◆ To test the two devices	90 mins	◆ PowerPoint slides
(5) Debriefing: ◆ To review the knowledge covered in this lesson ◆ To briefly introduce the next lesson	10 mins	◆ PowerPoint slides ◆ Notes
Total	**155 mins**	

2.1.4 Assessment (if appropriate)

- ◆ Student's knowledge of coding and sensors will be assessed through their performance and readiness for the apparatuses.
- ◆ Student's knowledge of the experiments will be assessed through multiple-choice questions and short questions.
- ◆ Overall students' participation would be reviewed.

2.2 Unit 2: Light and Speed

In Unit 1, we have used micro:bit and sensors to facilitate some science experiments and we will make it further.
In Unit 2, students will make a simple light intensity device to study the relationship between light intensity and the rate of photosynthesis of plants. Furthermore, a timer and a timing gate will be made for students to investigate the science of speed and kinetic energy.

2.2.1 Objectives

Upon completion of *Unit 2,* students should be able to:
- write a program for the light intensity device;
- write programs for the timer and the timing gate;
- assemble the timing gate;
- use the devices to facilitate the science experiments;
- apply equations to calculate speed and kinetic energy.

2.2.2 Pre-requisite (if appropriate)

Nil.

2.2.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction: ◆ To recap the major ideas of the previous lesson ◆ To explain the learning objectives of this unit	10 mins	◆ PowerPoint slides
(2) The light intensity device: ◆ To teach the codes using micro:bit ◆ To test the device	10 mins	◆ PowerPoint slides
(3) Using the light intensity device for science experiments ◆ To introduce photosynthesis ◆ Experiment: Rate of photosynthesis	30 mins	◆ PowerPoint slides
(4) The timer and timing gate: ◆ To teach the codes using micro:bit ◆ To test the timer ◆ To assemble the timing gate	45 mins	◆ PowerPoint slides
(5) Speed and kinetic energy: ◆ To explain the science of speed and kinetic energy ◆ To use the timing gate to find out the speed and kinetic energy of a moving car	45 mins	◆ PowerPoint slides ◆
(6) Debriefing: ◆ To review the knowledge covered in this lesson ◆ To briefly introduce the next lesson	10 mins	◆ PowerPoint slides
Total	**150 mins**	

2.2.4 Assessment (if appropriate)

- Student's knowledge of the coding and sensors will be assessed through their performance and readiness for the apparatuses
- Student's knowledge of photosynthesis, speed and kinetic energy will be assessed through multiple-choice questions and short-questions
- Overall students' participation would be reviewed

2.3 Unit 3: Lazy Data Logging

One of the advantages of using electronic sensors compared to traditional measuring tools such as thermometers and pH paper is that the data we obtained could be easily and accurately recorded and digitalized. Furthermore, the data is already digitalized, it can be transferred over a network and we can monitor the data easily by using our computer or mobile device over the Internet. This is known as the Internet of Things (IoT).

After making a lot of different devices using micro:bit, in Unit 3, students will be taught to use different methods for data logging which is important to scientific investigation. IoT methods such as makecode, Excel and cloud service will be illustrated step-by-step with examples.

2.3.1 Objectives

Upon completion of *Unit 3*, students should be able to:

- Write programs for data logging using micro:bit
- Log data using MakeCode
- Log data using Excel
- Log data using cloud service

2.3.2 Pre-requisite (if appropriate)

Nil.

2.3.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction: ◆ To recap knowledge of the previous lessons ◆ To explain the learning objectives of this lesson	5 mins	◆ PowerPoint slides
(2) Data logging using MakeCode: ◆ To teach the codes using micro:bit ◆ To test the data logging system	20 mins	◆ PowerPoint slides
(3) Data logging using Excel: ◆ To teach the steps using micro:bit ◆ To test the data logging system	45 mins	◆ PowerPoint slides
(4) Data logging using cloud service: ◆ To teach the codes using micro:bit ◆ To test the data logging system	40 mins	◆ PowerPoint slides
(5) Debriefing: ◆ To review the knowledge covered in this lesson ◆ To briefly introduce the next lesson	10 mins	◆ PowerPoint slides
Total	**120 mins**	

2.3.4 Assessment (if appropriate)

- ◆ Student's knowledge of different IoT methods will be assessed through their performance and readiness for the data logging system
- ◆ Overall students' participation would be reviewed

2.4 Unit 4: Missions and Project Learning

In Unit 4, students will need to apply what they have learnt about coding, sensors and IoT from Units 1 to 3 to complete 2 missions and 1 project. After that, students should be encouraged to create and design their own codes and apparatus to solve the problems identified by themselves as an individual or group project.

2.4.1 Objectives

Upon completion of *Unit 4*, students should be able to:

- ◆ Combine the micro:bit sensors and data logging system
- ◆ Log the data collected by the apparatus using MakeCode
- ◆ Log the data collected by the apparatus using the cloud service
- ◆ Create and design their own apparatus to solve problems

2.4.2 Pre-requisite (if appropriate)

Nil.

2.4.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction: ◆ To recap knowledge of the previous lessons ◆ To explain the learning objectives of this lesson	10 min	◆ PowerPoint slides
(2) Mission 1: ◆ To make a water turbidity device and flow rate meter ◆ To apply the system to the experiment	60 min	◆ PowerPoint slides
(3) Mission 2: ◆ To make a water temperature device using MakeCode for data logging ◆ To apply the system to the experiment	60 min	◆ PowerPoint slides
(4) Project learning: ◆ To make a system with a turbidity sensor, light sensor and water temperature sensor using the cloud for data logging ◆ To apply the system to an aquaponics system	60 min	◆ PowerPoint slides
(5) Debriefing: ◆ To review the knowledge covered in all units	20 min	◆ PowerPoint slides ◆ Notes
Total	**210 min**	

2.4.4 Assessment (if appropriate)

- ◆ Student's performance will be assessed through their performance and the readiness of the systems they made
- ◆ Overall students' participation would be reviewed

3 Resources

3.1 Resources for Unit 1

- Teachers' Guide
- PowerPoint slides
- Notes

3.2 Resources for Unit 2

- Teachers' Guide
- PowerPoint slides
- Activity book
- Notes

3.3 Resources for Unit 3

- Teachers' Guide
- PowerPoint slides
- Online videos
- Activity book
- Notes

3.4 Resources for Unit 4

- Teachers' Guide
- PowerPoint slides
- Activity book
- Notes

4 References

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5 Project Team

Dr. LI Tin-Lok Matthew
School of Science and Technology, Hong Kong Metropolitan University