Jockey Club STEAM Education Resources Sharing Scheme

Water You Drink

Teachers' Guide

First Edition December 2020

School of Science and Technology
Hong Kong Metropolitan University

Ho Man Tin, Kowloon, Hong Kong

Contents

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 at 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 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 integrates knowledge and skills across Science, Technology, Engineering, Arts and Mathematics under real-world contexts.

1. Module Outline

1.1 Module Title: Water You Drink

In general, most students are confused about technology and engineering in STEAM education. They often mix up the two disciplines and cannot grasp the basic concepts of each discipline. This module aims to clarify students' understanding of technology and engineering and to guide students to apply technology and engineering to solve real-world problems.

Water You Drink aims to introduce students to five common concepts of technology and engineering. Students will apply those concepts to build three water system design prototypes, including a water filtration system, a water level monitoring system, and a water pumping system. They will demonstrate their understanding of the five common concepts of technology and engineering shown in Section 1.5.

The module is compiled with the following three units,
- Unit 1 – Water filtration system
- Unit 2 – Water level monitoring system
- Unit 3 – Water pumping system

1.2 Participants Recommended for this Module

☑ Junior Secondary School Students
☐ Senior Secondary School Students
☑ Others (please specify: students who are interested in Engineering with strong algorithm background)

1.3 Module Aims

The module *Water you drink* aims to:

- Advance students' application of STEAM education, especially technology and engineering, to solve authentic problems
- Equip students with the concept of engineering system design to solve drinking water quality matters in Hong Kong, including the concept of the feedback loop and its application, the application of algorithmic thinking and the basic engineering analysis skill of evaluating the equipment specification
- Provide students with hands-on experience in building three water product systems

1.4 Module Learning Outcomes

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

- Define a system in different real-life situations, including input, output, process, and feedback loop
- Apply the concept of the feedback loop to an engineering design
- Apply algorithmic programming skills to an engineering design
- Justify whether an engineering design is a system or not
- Evaluate an engineered system based on its product specification
- Build a water filtration system, a water level monitoring system and a water pumping system

1.5 Learning & Teaching Approach / Practice

The module will use “design and make”(a learning and teaching approach) to engage students in solving real-life problems.

In basic definition, technology is a tool, whereas engineering is a method for problem-solving. Both disciplines are closely related and have been of immense importance. To engage students to learn both disciplines, this module is designed to teach students five of the most common technology and engineering concepts, which are shown as follows:

1. System design –
   A system is one of the core principles of engineering design. It allows engineers to automate a problem-solving process and to review the effectiveness of the process. A typical system has four major components, input, output, process, and feedback loop.

2. Feedback loop –
   A feedback loop is part of the system that extracts data from the system’s output and routes those data back as input for processing.

3. Sensor technology –
   A sensor plays a key role in the feedback loop. It detects the physical, biological, or chemical properties of a physical environment, and digitalises those properties into readable data for the process.

4. Algorithm –
   An algorithm is a list of procedures in the processing unit of the system. It enables the system to follow a pre-set problem-solving operation.

5. Engineering analysis skill –
   Engineering is a process of problem-solving, and it involves many decision makings, especially in equipment selection. Engineering analysis is a skillset

to evaluate the system design based on the equipment list and its specification.

1.6 Nature of STEAM Activity

Element	Description	Composition
<u>S</u>cience	Apply the scientific concept of energy conversion to system design	✪
<u>T</u>echnology	Use sensors to detect the parameters of physical environments. Practise algorithm writing	✪✪✪
<u>E</u>ngineering	Practise system design and use a feedback loop to improve the problem-solving process. Perform engineering analysis by evaluating the equipment specification.	✪✪✪
<u>A</u>rts	Design the systems and present their implementations in the context of geography.	✪
<u>M</u>athematics	Apply the concept of rate and volume calculations to the design project	✪✪

1.7 Mapping of Key Learning Area (KLA)

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others *(please specify)*
1	◆ SJ2.1 The water cycle ◆ SJ2.3 Water purification, ◆ SJ2.4 Further treatment of drinking water	◆ Sensor application ◆ System design ◆ Water filtration system design	◆ MJ6.1 - 6.2 Rates, ratios and proportions	◆ Geography	◆ System design

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others *(please specify)*
2	◆ SJ2.5 Water conservation and pollution ◆ SJ8.1-8.4 Making use of electricity	◆ TK2.1 Problem solving procedures and techniques ◆ Algorithm writing ◆ Feedback loop	◆ MJ6.1- 6.2 Rates, ratios, and proportions ◆ MJ7.1 Algebraic expressions ◆ MJ8.1 – 8.3 Linear equations in one unknown ◆ MJ14.1 Linear inequalities in one unknown	◆ Geography	◆ System design
3	◆ SJ5.1 Energy change	◆ TK11.6 Technology and living ◆ Algorithm writing	◆ MJ6.1- 6.2 Rates, Ratios, and Proportions ◆ MJ8.1 – 8.3 Linear equations in one unknown ◆ MJ14.1 Linear inequalities in one unknown	◆ Geography	◆ System design ◆ Engineering analysis skill

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 filtration system	1.25
2	Water level monitoring system	1.5
3	Water pumping system	1.25
	Total	**4 hours**

*Remark: A total of **2** non-contact hours of the module is recommended.*

1.9 Thematic Area

- ☑ Environment and Health
- ☐ Food and Biotechnology
- ☐ Biochemistry
- ☐ Digital Transformation
- ☐ S.M.A.R.T.

2. Study Units

There are three study units integrating science, technology, engineering, arts and mathematics in this module.

Water scarcity and pollution have been a global issue for decades. According to “World Economic Forum”, two-thirds of the world’s population still encounter water scarcity for at least one month every year. More than 700 million people globally have no reliable access to clean and safe water all year round.

Considering the increasing world population and wide-ranging effects of globalisation, this module is intended to arouse students’ awareness of water management’s importance and encourage them to play their part to ease water stress as global citizens.

In this module, Unit 1 is to develop a water filtration system. Unit 2 and Unit 3 are about to build a water level monitoring system and water pumping system, respectively. Students will be asked to apply the five most commonly used technology and engineering concepts throughout these three units.

2.1 Unit 1: Water filtration system

This unit aims to lead students to explore the global water problem’s significance and provide hands-on experience to apply their STEAM education to address the problem. With the teacher’s facilitation, students will grasp an overview of the water management of Hong Kong, such as the water supply system and the water treatment system. Students will investigate where their tap water comes from and explore what kinds of systems would be needed to have drinking water at home.

Since one of the common water treatments is filtration, in this unit, students will be engaged in an experiment on the filtering mechanism and how a water filtration system using sand and gravel would be built. Students will also learn some basic filtration mechanisms such as freeboard, filtration rate, removal efficiency, etc.

2.1.1 Objectives

By building and designing a water filtration system, students will gain hands-on experience in system design and apply system design in engineering design. This unit would let students apply their mathematical skills to calculate the filtration rate and removal rate of their water filtration design and evaluate the systems.

2.1.2 Pre-requisite (if appropriate)

- Mathematical concepts such as rate calculation, volume calculation
- Basic concept about filtration

2.1.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction to global water problems and their significance ◆ Engage students to think about the water problems using the inquiry method ◆ State the STEAM education, module aims/learning outcomes and learning objectives & assessment (if any) of this unit	10 min	◆ PPT
(2) Explain the concept of a system ◆ Review the water cycle and relate it to the water resource management system of Hong Kong ◆ Explain the system with its three components, input, process, output	15 min	◆ PPT
(3) Design the water filtration ◆ Describe the objective of water filtration ◆ Explain the mechanisms of filtration ◆ Show the case studies of typical filtration design ◆ Demonstrate how to design a water filtration ◆ Teach students to calculate the filtration rate and removal rate and record those calculations in their learning portfolio	35 min	◆ Acrylic cylinder ◆ Filter media: fine sand, coarse sand, gravel ◆ Water sensor: Turbidity
(4) Conclusion ◆ Review how to define an engineered system and evaluate a water filtration system design	15 min	◆ PPT
Total	**1 hr 15 min**	

Remark: *(*) Around **ONE** non-contact hour is expected*

2.1.4 Assessment

Students work in the learning portfolio, and their water filtration system will be reviewed during and after the class.

2.2 Unit 2: Water level monitoring system

In the previous unit, students study the overview of the global water crisis and the water management system of Hong Kong. Students learnt how to design a filtration system that physically treats the polluted water and evaluates the filtration system based on its removal efficiency and filtration rate. Through the hands-on workshop in Unit 1, students have a general idea of system design.

In this unit, students will further practise designing an engineered system and applying the feedback loop to design a water level monitoring system. A water level monitoring system is widely used in the water supply system and other Hong Kong drainage systems. Students will have a case study on the newly built underground storm-water storage tank in Happy Valley and learn about the water level monitoring system's mechanism, especially the sensor application. Furthermore, students learn how to distinguish the two major types of electronic sensors, analogue and digital.

To implement a feedback loop to the water level monitoring system design, students will learn how to write an algorithm in both pseudocode and the drag-and-drop programming language (*Scratch*). Algorithm writing involves the two basic concepts of computational thinking, which are logic and algorithm. Students will learn about four common logical operators and the three properties of the algorithm. Equipping with basic computational thinking skills such as logic and algorithm, students can design many engineering solutions that involve computing and automation.

2.2.1 Objectives

This unit extends the concepts of system design and introduces students to the feedback loop concept, the basics of sensor technology and algorithm writing. This unit demonstrates to students the types of electronic sensors and how to write an algorithm for a microcontroller using the drag-and-drop programming language.

2.2.2 Pre-requisite (if appropriate)

Nil.

2.2.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction: ◆ Re-cap the key components of an engineered system ◆ State the learning objectives and relate them to previous classes	15 min	◆ PPT

Description	Duration (hr/min)	Resources
(2) Explain the application of an electronic sensor: ◆ Explain the feedback loop and its three crucial steps, goal setting, measurement, adjustment, and how electronic sensors take into place. ◆ Explain the two major types of sensors, analogue and digital ◆ Relate the application of the sensor to the concept of a feedback loop	15 min	◆ PPT ◆ Micro:bit, ultra-sonic sensors and humidity sensors
(3) Teach students how to write an algorithm for a water level monitoring system ◆ Explain the concept of a conditional statement, logical operators, and algorithm ◆ Apply those concepts to write an algorithm in both pseudocode and drag-and-drop programming language ◆ Guide students to design their water level monitoring system using the *Micro:bit*	45 min	◆ PPT ◆ Micro:bit, ultra-sonic sensors and humidity sensors ◆ Water tank ◆ Laptop
(4) Conclusion: ◆ Review the concept of a feedback loop ◆ Review the application of electronic sensor ◆ Review how to write the algorithm	15 min	◆ PPT
Total	**1 hr 30 min**	

Remark: *(*) Around **ONE** non-contact hour is expected*

2.2.4 Assessment

Students work in the learning portfolio, and their water level monitoring system will be reviewed during and after the class.

2.3 Unit 3: Water pumping system

In Unit 2, students learn how to design and build a water level monitoring system. The water level monitoring system indicates the total volume of the water in the basin. Upon completing the previous unit, students understand algorithm writing, feedback loops, and sensor applications.

In this unit, students will practise their algorithmic writing skills and extend their understanding of the control system design. Students will continue with their previous projects and modify their water level monitoring systems to water pumping systems. The water pumping systems should activate a series of 5V submersible pumps based on the tank's water level. By designing and building the water pumping system, students will apply the scientific concept of energy conversion. The submersible pumps consume electrical energy and generate hydraulic energy to the tank. Students will also learn how to justify their water pumping system as a control system with their prior knowledge of system design.

The water pumping systems completed by students are imitating the actual water pumping stations in a real-world scenario. Students will learn how to review the equipment specifications of their design and compare those specifications with industrial standards. Students will learn the basics of engineering analysis skills. For instance, two types of micro-controller, *Micro:bit*, and *Arduino* will be displayed for the students to review. Students will learn how to compare the two microcontrollers by analysing the product specification of the two pieces of equipment. Students will also learn the key criteria for selecting the proper equipment for their future engineering design.

2.3.1 Objectives

This unit emphasises another important engineering mindset, which is a basic engineering analysis skill. This unit invites students to design a complete control system, a water pumping system, including input, process, output and a feedback loop. The water pumping system is the extension of a water level monitoring system with two submersible pumps as outputs. By designing and making the water pumping system, students learn how to evaluate the equipment specification as part of their engineering analysis skills training.

2.3.2 Pre-requisite (if appropriate)

Nil.

2.3.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Re-cap the key learning objectives of the previous units ◆ Review the key components of a control system and application of a feedback loop ◆ Review the procedure of writing an algorithm and its application in engineering design	5 min	◆ PPT
(2) Explain the common practices of engineering analysis skills ◆ Overview of the general routine of an engineer ◆ Emphasise the importance of evaluating the product specification for the engineering design	10 min	◆ PPT

Description	Duration (hr/min)	Resources
(3) Guide students on how to modify the water level monitoring system to the water pumping system ◆ Inform students of the objective of the water pumping system ◆ Demonstrate to students how to modify the algorithm and include the submersible pump as the output ◆ Draw connections between the water pumping system created by the students and industrial large-scale the water pumping system based on their specification ◆ Guide students to practice engineering analysis skill	45 min	◆ PPT ◆ *Micro:bit*, ultra-sonic sensors, humidity sensors and water pumps
(4) Conclusion ◆ Review the concept of engineering analysis skill ◆ Review the application of the control system in solving an engineering problem ◆ Review the procedure of designing a control system and writing algorithms	15 min	◆ PPT
Total	**1 hr 15 min**	

2.3.4 Assessment

Students work in the learning portfolio, and their water pumping system will be reviewed during and after the class.

3. Workshop (Activity)

3.1 Experiment 1 – Water filtration system

3.1.1 Purpose

To design and build a water filtration system

3.1.2 Introduction

In this experiment, students will learn how to design a water filtration system. Through the experiment, students will learn about the concept of an engineered system.

At the beginning of the experiment, we will introduce students to the filtration mechanism concept and explain the typical pollutants found in the water source to students. We will then teach students how to use the sensor to evaluate their water filtration system and demonstrate how to fine-tune the water filtration system.

3.1.3 Duration

1 hour and 15 minutes of the workshop

3.1.4 Objective

1. To apply the concept of the filtration mechanism
2. To apply the concept of system design
3. To evaluate the removal efficiency of the filter based on the flow rate and the water quality of the influent and effluent

3.1.5 Equipment

1. Filter media: fine sand, coarse sand, gravel
2. Filtration container: Acrylic cylinder
3. Water sensors: Turbidity

3.1.6 Materials

Learning Portfolio

3.1.7 Procedures

1. Divide the class of students into 3-4 per group
2. Brief the class about the equipment, the safety issue, the project booklet, etc.

3. Students will start to design and make a filtration system while the teacher may assist those with fewer abilities
4. Run the filtration test
5. Record the following in the project booklet:
    a. the characteristics of the water filtration
    b. the characteristics of untreated water samples
    c. the characteristics of the treated water
6. Review the result of the experiment and conclude the important design criteria for the filtration
7. Facilitate the students to fine-tune their design based on the result
8. Rerun the filtration test and record the result

3.1.8 Result and Discussion

Conclude the learning activities of the class
Activity 1 – Demonstrate how to build the filtration system
Activity 2 – Evaluate the performance of the filtration system based on its filtration rate and removal rate

3.2 Experiment 2 – Water level monitoring system

3.2.1 Purpose

To design and build a water level monitoring system

3.2.2 Introduction

Students will design a water level monitoring system using the Micro:bit and sensors in this experiment.

At the beginning of the experiment, we will review the control system concept and feedback loop in the previous unit. In this unit, students will study the basics of computational thinking, such as logic and algorithm. Students will learn how to write an algorithm that measures the volume of the water in the water tank and build a water level monitoring system using *Micro:bit* and sensors.

3.2.3 Duration

1 hour 30 minutes of the workshop

3.2.4 Objective

1. To learn the two major types of sensors, analogue and digital
2. To formulate a solution that's executable by a computer or microprocessor
3. To practise writing algorithms in pseudocode and drag-and-drop programming language (*Scratch*)

3.2.5 Equipment

1. Sensors (Ultra-sonic, humidity sensor)
2. *Micro:bit* and cable accessory
3. Laptop
4. Bucket of water for water monitoring device
5. Measurement tools such as measuring tape and timer

3.2.6 Materials

Learning portfolio

3.2.7 Procedures

1. Divide the class of students into 3-4 per group
2. Brief the class about the equipment, the safety issue, the learning portfolio, learning objectives, etc.

3. Students will start to design and build a water level monitoring system while the teacher may assist those with fewer abilities
4. Students will follow the written procedure to write an algorithm that measures the water volume of water tanks
5. Run the water level monitoring system
6. Evaluate the performance:
    a. the accuracy of the water level monitoring system
    b. the user experience of the system
7. Review the trial run and facilitate the students to fine-tune their designs
8. Run the second trial and provide feedback to students
9. Conclude the learning activities of the class

3.2.8 Result and Discussion

Activity 1 – Write the algorithm for the water level monitoring system in pseudocode and drag-and-drop programming language (*Scratch*)
Activity 2 – Design the water level monitoring system

3.3 Experiment 3 – Water lifting system

3.3.1 Purpose

To design and build a water pumping system

3.3.2 Introduction

In this experiment, students will further expand their knowledge in algorithm writing and include a control output to the system. Students will practise their algorithm writing skills and transform their water level monitoring system into a water pumping system.

Students will learn how to perform engineering analysis and have a chance to select the type of submersible pumps for their design.

3.3.3 Duration

1 hour and 15 minutes of the workshop

3.3.4 Objective

- To design a complete control system with input (sensors) and output (submersible pump), and process (micro-processor – *Micro:bit*)
- To practise engineering analysis skills such as understanding and comparing the products' specification

3.3.5 Equipment

1. Water tank
2. *Micro:bit*, ultra-sonic sensors and humidity sensors
3. 5V submersible pump

3.3.6 Materials

Learning portfolio

3.3.7 Procedures

1. Divide the class of students into 3-4 per group
2. Brief the class about the equipment, the safety issue, the learning portfolio, learning objectives, review the learning content of the last unit, etc.
3. Students will start to build a complete control system with input (sensor), output (water pump) and process (microprocessor with a written algorithm)
4. Students will perform engineering analysis on their designed systems based on the equipment specification.

5. Review the students’ work and provide feedback to the students and facilitate the students to fine-tune their design

3.3.8 Result and Discussion

Conclude the learning activities
Activity 1 – Design the complete control system (water pumping system)
Activity 2 – Invite students to evaluate their design based on the system performance and equipment specification

4. References

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5. Project Team

Mr LEE Cheuk Lam Kelvin
Jockey Club STEAM Education Resources Sharing Scheme,
Hong Kong Metropolitan University