Jockey Club STEAM Education Resources Sharing Scheme

To be a Food Detective

Teachers' Guide

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

1. Module Outline

1.1. Module Title: To be a Food Detective

One of the ways for promoting students' interest in Science, Technology, Engineering, Art, and Mathematics is to help students to appreciate how STEAM can help solve different real-life problems, promoting quality of life, and protecting human lives.

As a result, this module, "To be a Food Detective", aims to let students apply a number of molecular biology techniques to investigate the presence of adulteration in food products, such as luncheon meat and sausage, which is an important food trade and food safety problem.

The module consists of the following 5 units,

- Unit 1 – Building a Thermocycler;
- Unit 2 – DNA Extraction
- Unit 3 – Polymerase Chain Reaction (PCR); and
- Unit 4 – Restriction Fragment Length Polymorphism (RFLP)

In Unit 1, students will build a thermocycler using Arduino. Students will also decorate the casting of the thermocycler. The thermocycler will be used for the PCR of Unit 3. In Unit 2, students will extract the DNA of the constituting meat from the processed meat samples. In Unit 3, students will amplify the cytochrome gene from the DNA extracted in Unit 2 by PCR, using the thermocycler built in Unit 1 or the thermocycler of other brands. Students will also perform an agarose gel electrophoresis to confirm whether the gene is successfully amplified. In Unit 4, students will digest the amplified cytochrome gene using the technique of restriction fragment length polymorphism. Students will perform another agarose gel electrophoresis of the digested DNA for visualising the digestion pattern of the gene (DNA fingerprinting). Teachers will also assess if the students have met the learning outcomes.

1.2. Participants Recommended for this Module

£ Junior Secondary School Students

R Senior Secondary School Students

R Others (please specify: students who have studied Biology)

1.3. Module Aims

The module "*To be a Food Detective*" aims to:

- *Introduce* students to the principles of different common molecular biology techniques and their applications in food testing
- *Illustrate* how engineering advances the development of science
- *Provide* students with practical experience in building thermocyclers and different molecular biology techniques

1.4. Module Learning Outcomes

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

- *Understand the principle and practice of PCR*
- *Recognise/outline the applications of DNA fingerprinting.*
- *Analyse and evaluate manufactured products*

1.5. Nature of STEAM Activity

Element	Description	Composition
Science	• Extraction of DNA from food samples • Gene amplification by PCR • Identification of meat species by restriction fragment length polymorphism	μμμμ
Technology	• Application of Arduino circuit and programme codes for thermocycler control	μμ
Engineering	• Build a thermocycler and perform product evaluation	μμμ
Arts	• Design of thermocycler casting	μ
Mathematics	• Determination of DNA size by mathematical methods by using a standard curve	μ

1.6. Mapping of Key Learning Areas (KLAs)

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others
1	SB1.1 Biomolecules: carbohydrates, lipids, proteins and nucleic acids				
2		TE6.2 Interconnection of systems and sub-systems TK9.4 Mechanical, electrical, electronic and pneumatic control systems TK5.11 Product Design		to design the casing of the thermocycler	

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others
3	SB2.2 Chromosomes, genes and nucleic acids SB8.1 Polymerase chain reaction (PCR) and its application		MS9.1 More about graphs of functions		
4	SB2.2 Biotechnology		MS9.1 More about graphs of functions		

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

1.7. Module Structure

Units		Contact Hours
1	Building a Thermocycler	5
2	DNA Extraction	4
3	Polymerase Chain Reaction (PCR)	4.5
4	Restriction Fragment Length Polymorphism (RFLP)	5.5
	Total	**19 hours**

2. Module Design

2.1. Unit 1: Building a Thermocycler

Polymerase Chain Reaction (PCR) is a common molecular biology technique used for gene detection and gene amplification. Polymerase chain reaction involves multiple cycles of temperature changes, which allow (1) the denaturation of double-stranded DNA, (2) the annealing of primer to a specific DNA region, and (3) the extension of primers to form a new DNA strand by DNA polymerase. The optimal reaction temperature of the three steps is 96 °C, 50 °C – 65 °C, and 72 °C, respectively.

The control of the temperature of the reaction mixture was previously achieved by using water baths of three different temperatures. The reaction mixture was cycled between the three water baths at multiple short intervals of time. This is laborious and the control of the temperature mixture is not accurate.

This was changed with the invention of thermocyclers, which can heat up or cool down to a specific temperature rapidly. This provides precise control of the temperature of the reaction mixture. However, a thermocycler is expensive and may not be affordable.

In this Unit, students will learn the working principle of a thermocycler, the electric circuits for its temperature control and build a simple functional light bulb thermocycler for the subsequent experiment.

The light bulb thermocycler consists of three layers that house the circuit board, a light bulb and cooling fan, and the adapter for holding reaction vials (Figure 1). The temperature of a reaction vial is sensed by a thermistor. An Arduino UNO board loaded with programme codes will be used for controlling the temperature. The light bulb and the cooling fan will be used for heating up and cooling down the reaction vial respectively.

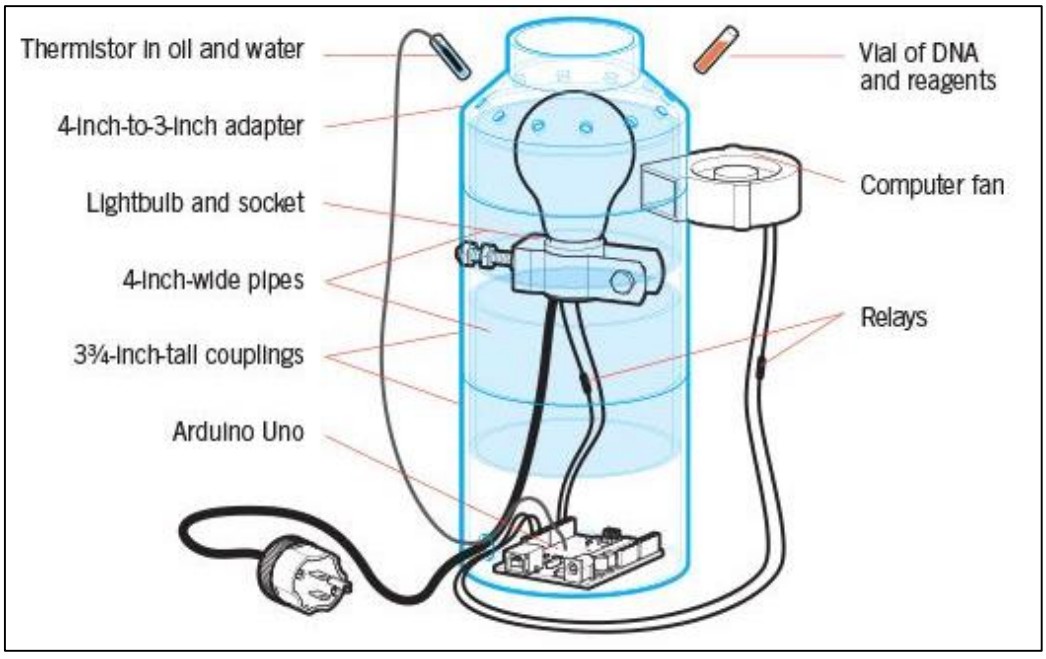

Figure 1. The general structure of the lightbulb thermocycler.

2.1.1. Objectives

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

- *Utilise* design tools, materials, and information
- *Understand* the basic principles of electronic systems and various forms of system and control
- *Use* programmable control boards and kits
- *Interpret* truth tables for simple logic gates
- *Construct* simple programmable control systems to solve control problems
- *Analyse* and *evaluate* manufactured products

2.1.2. Description of Activity

Description	Duration	Resources
(1) Introduction ◆ Teacher briefs about STEAM education, objectives, assessment criteria, group arrangement, lab safety, etc.	10 min	◆ Learning Portfolio (Teacher version) ◆ PPT (P1 – 3)
(2) Demonstration on principle and components of a thermocycler ◆ The teacher introduces the working principle and development of a thermocycler ◆ The teacher uses PPT slides to illustrate the components of a lightbulb thermocycler ◆ Students watch a video on thermocycler development	1 hr	◆ PPT (P4 – 10) ◆ PPT (P11 – 18) ◆ Video on Thermocycler ◆ Learning Portfolio (P4-10)
(3) Hands-on Activity ◆ Students in group design and build their own thermocycler for subsequent experiments ◆ Students in group conduct a product evaluation of the thermocycler, record and analyse the findings in the learning portfolio ◆ Decoration of the casting of a thermocycler	3 hr 50 min	◆ PPT (P19 – 43) ◆ Learning Portfolio (P4 – 10) ◆ PCR Arduino Code Cycle

Description	Duration	Resources
(4) Take-home Assignment for Unit 1 ◆ Students will review/self-learn the basic operation of Arduino and study the notes in the learning portfolio for Unit 1		◆ Student Worksheet in Learning Portfolio for Unit 1 (P9 - 10)
Total	**5 hours**	

2.1.3. Assessment (if appropriate)

Student's group work in the learning portfolio and the performance in building their own thermocycler will be reviewed during and after the class.

2.2. Unit 2: DNA Extraction

The first step of most molecular biology experiments is the extraction of nucleic acids, either deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). Cells are usually lysed with detergent and lysis buffer to release the nucleic acids inside. The nucleic acid is then precipitated with ethanol and dissolved in nuclease-free water. In modern days, research and testing laboratories routinely use commercially available DNA/RNA extraction kits* for extracting nucleic acid.

In this unit, the structure and function of DNA, types of Nucleotides, and the principle & properties of DNA extraction will be introduced. By extracting DNA from the samples as the first part of the downstream experimentation, students shall conduct a scientific investigation on the presence of adulteration in commercially available meat products (such as luncheon meat and sausage).

** Please refer to Learning Portfolio for ordering information on the kit*

2.2.1. Objectives

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

- *Describe* the structural and functional relationships of chromosomes, genes and nucleic acids
- *Explain* the principle of DNA extraction

2.2.2. Description of Activity

Description	Duration	Resources
(1) Pre-lab Assignment ◆ Students in groups search about current problems of food adulteration on the internet and discuss how science and technology help in tackling the problem		◆ Learning Portfolio (P11) ◆ Student Worksheet in Learning Portfolio for Unit 2 (P14)
(2) Introduction ◆ Teacher briefs about STEAM education, objectives, assessment criteria, group arrangement, lab safety, etc. ◆ The teacher reviews the learning of the previous unit, briefs on the lab safety and the challenge of this unit, etc.	15 min	◆ Learning Portfolio (Teacher Version) ◆ PPT (P1-4)
(3) Demonstration of the DNA Structure and Principle of DNA Extraction ◆ The teacher introduces the working principle and development of a thermocycler ◆ The teacher uses PPT slides to illustrate the components of a lightbulb thermocycler ◆ Students watch a video on thermocycler development	45 min	◆ Learning Portfolio (P11) ◆ PPT (P5 – 21) ◆ Student Worksheet in Learning Portfolio for Unit 2 (P14)
(4) Hands-on Activity 1 ◆ Students in groups extract the DNA of meat samples using a DNA extraction kit ◆ Students answer the relevant questions in the worksheet	1 hr	◆ PPT (P25) ◆ Learning Portfolio (P11 – 15) ◆ Student Worksheet in Learning Portfolio for Unit 2 (P14 – 15)
(5) Demonstration on the application of agarose gel electrophoresis (during the waiting time of PCR) ◆ The teacher introduces the principle of agarose gel electrophoresis ◆ Students watch a video on the application of agarose gel electrophoresis	1 hr	◆ PPT (P22 – 34) ◆ Learning Portfolio (P12 – 13) ◆ Video on agarose gel electrophoresis

Description	Duration	Resources
(6) Hands-on Activity 2 ◆ Students in groups conduct the agarose gel electrophoresis experiment. ◆ The teacher facilitates the whole class to initially interpret the results and how they would be further examined in subsequent Units to detect the presence of adulteration	1 hr	◆ PPT ◆ Learning Portfolio (P12 – 13) ◆ Student Worksheet in Learning Portfolio for Unit 2 (P15)
Total	**4 hours**	

2.2.3. Assessment (if appropriate)

Student's group work in the learning portfolio and the performance in the experiment will be reviewed during and after the class.

2.3. Unit 3: Polymerase Chain Reaction (PCR)

As mentioned in previous units, polymerase chain reaction (PCR) is an important invention for advancing the development of molecular biology and is an essential technique in all molecular biology research. This simple but powerful technique has also found a number of applications in forensic investigation, environmental monitoring, and food safety monitoring.

In this unit, the principle and its applications will be introduced. Students can also perform the PCR for replicating the target DNA for downstream experiments and examine the result of the PCR by using agarose gel electrophoresis. Students will have to determine the PCR product size from the result of the gel electrophoresis. A successful PCR should result in a PCR product (a band in the agarose gel) of the correct size.

2.3.1. Objectives

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

- *Outline* the principle and practice of PCR
- *Outline* the principle of agarose gel electrophoresis
- *Determine* the PCR product size by using a mathematical approach
- *Recognise* the wide application of PCR
- *Obtain* practical experience in performing a PCR

2.3.2. Description of Activity

Description	Duration	Resources
(1) Introduction ◆ The teacher reviews the learning of the previous unit, briefs on the lab safety and the challenge of this unit, etc.	10 min	◆ Learning Portfolio (Teacher version) ◆ PPT (P1 – 4)
(2) Demonstration on Principle and application of PCR ◆ The teacher introduces the principle and application of PCR ◆ Students watch a video on the application of PCR	1 hr 20 min	◆ PPT (P5 – 15) ◆ Learning Portfolio (P16 – 21) ◆ Video on PCR
(3) Hands-on Activity 1 ◆ Students in groups conduct the PCR experiment ◆ Each student completes the revision exercises	2 hr	◆ Learning Portfolio (P16 – 21)
(4) Hands-on Activity 2 ◆ Students in groups conduct the agarose gel electrophoresis experiment ◆ Students in groups conduct a product evaluation of the experiment, record and analyse the findings in the learning portfolio	1 hr	◆ PPT of Unit 2 (P22 – 34) ◆ Learning Portfolio (P17 – 18) ◆ Student Worksheet in Learning Portfolio for Unit 2 (P19 – 21)
Total	**4.5 hours**	

2.3.3. Assessment (if appropriate)

Student's group work in the learning portfolio and the performance in the PCR product size determination will be reviewed during and after the class.

2.4. Unit 4: Restriction Fragment Length Polymorphism (RFLP)

Restriction fragment length polymorphism (RFLP) is a traditional and major technique for detecting DNA polymorphism and is commonly used in identifying gene mutations, differentiating the identity of different individuals in forensic science, determining animal and plant species in ecology, and detecting food adulteration in food safety science.

In this unit, the principle and application of RFLP and DNA fingerprinting will be introduced. Students can perform RFLP and agarose gel electrophoresis analysis of the

RFLP products to determine whether the meat samples examined in previous units were adulterated and the species of the adulterant.

2.4.1. Objectives

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

- *Recognise/outline* the applications of DNA fingerprinting.
- *Apply* RFLP in food authentication

2.4.2. Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction ◆ The teacher reviews the learning of the previous unit, briefs on the lab safety and the challenge of this unit, etc.	10 min	◆ Learning Portfolio (Teacher version) ◆ PPT (P1 – 4)
(2) Demonstration on Principle of RFLP and its application in DNA fingerprinting ◆ The teacher introduces the principle and application of RFLP ◆ Teacher introduces the application of RFLP in DNA fingerprinting ◆ Students watch a video on the application of RFLP	1 hr 20 min	◆ PPT (P5 – 15) ◆ PPT (P16 – 19) ◆ Learning Portfolio (P22 – 26) ◆ Video on RFLP and DNA fingerprinting
(3) Hands-on Activity ◆ Students in groups conduct the RFLP and agarose gel electrophoresis experiment ◆ Each student completes the revision exercises ◆ Students in groups conduct a product evaluation of the experiment, record and analyse the findings in the learning portfolio	4 hr	◆ Learning Portfolio (P22 – 26) ◆ Student Worksheet in Learning Portfolio for Unit 2 (P24 – 26)
Total	**5.5 hours**	

2.4.3. Assessment (if appropriate)

Student's group work in the learning portfolio and the performance in the RFLP product size determination will be reviewed during and after the class.

3. Resources

3.1. Resources for Unit 1 – Building a Thermocycler

- PPT (Unit 1);
- Video on Thermocycler;
- PCR Arduino Code Cycle;
- Learning Portfolio; and
- Learning Portfolio (Teacher Version).

3.2. Resources for Unit 2 – DNA Extraction

- PPT (Unit 2);
- Learning Portfolio; and
- Learning Portfolio (Teacher Version).

3.3. Resources for Unit 3 – Polymerase Chain Reaction (PCR)

- PPT (Unit 3);
- Video on PCR;
- Video on agarose gel electrophoresis;
- Learning Portfolio; and
- Learning Portfolio (Teacher Version).

3.4. Resources for Unit 4 – Restriction Fragment Length Polymorphism (RFLP)

- PPT (Unit 4);
- Video on RFLP and DNA fingerprinting;
- Learning Portfolio; and
- Learning Portfolio (Teacher Version).

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5. Acknowledgement

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