Jockey Club STEAM Education Resources Sharing Scheme

Photos in a Coffee Can

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 aimed 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 mind-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: Photos in a Coffee Can

Photographers used 'film', a transparent strip coated with light-sensitive silver halide, to take photos in the past. Although digital photography has largely replaced it nowadays, developing film from scratch is a fun experience. Students will learn the scientific principles behind each photo from the developing process. The developing film involves many chemical reactions and, of course, requires many chemicals, but most are not environmentally friendly. Therefore, many innovative and creative use of household products has been tested by numerous artists to develop film.

Surprisingly, instant coffee powder and vitamin C can be used as the primary and secondary reducing agents or called developing agents, which are the essential chemicals for film development. These two substances participate in a series of chemical reactions during film development and give good quality of the final photo. Apart from film development, the scientific principles of photography will also be introduced. This module will mainly focus on the physics behind photo-shooting, the chemistry behind film development and the method of taking photos using film cameras. Finally, the film will be developed using instant coffee powder and vitamin C.

In this module, chemical reactions such as acid-base reactions, redox reactions, and photoreactions involved in film development will be illustrated. The physics of light such as reflection, refraction, colour and wave and particle dual natures of light will also be introduced. Materials that film is made of and photographic knowledge, such as film speed, ISO, exposure time and f-stop, will also be included. At the end of the module, students would have experience in photo-shooting and film development.

1.2 Participants Recommended for this Module

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

1.3 Module Aims

The module "*Photos in a Coffee Can*" aims to:

- Introduce the knowledge of physics and chemistry behind photography and film development
- Raise students' awareness of the scientific knowledge and working principles of film photography
- Introduce photographic knowledge, such as film speed, ISO, exposure time and f-stop to students
- Provide an opportunity for students to do film development
- Advance students' application of subject knowledge and skills learned in the school curriculum of senior secondary (SS) Chemistry and SS Physics

1.4 Module Learning Outcomes

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

- Understand the physics of light, such as reflection, refraction and nature of light
- Comprehend chemical theories such as acid-base, redox reactions and functional groups of organic compounds
- Explain the working principles of photography by applying the physical theories learnt
- List out the chemical compounds used for film development
- Explain the working principles of film development by applying the chemical theories learnt
- Develop a film

1.5 Learning & Teaching Approach / Practice

By taking out your cell phone from your pocket, switching it to the camera mode and simply touching the display, a perfect image can be captured instantaneously, and it can be visioned whenever and wherever you want nowadays. However, about twenty years ago, people were taking photos using a bag-sized single-lens reflex camera and film, a transparent strip coated with different chemicals. The image was captured by the film, and the film was developed to form a photograph through a series of chemical reactions, and you could only obtain the photo after several days. Although many photographers are still using the single-lens reflex camera, the film is phasing out. However, from a scientific point of view, it is still a fun experience by using and developing film from scratch, which involves many different interesting scientific principles, especially in physics and chemistry. This module will adopt both problem-based learning and experimental approaches to explain different observations.

After introducing all necessary knowledge in Units 1 to 3, students would have a chance to apply their knowledge in film development by using instant coffee powder and vitamin C in Unit 4.

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	Light reflection, refraction, dual nature properties, chemical reactions, acid-base, redox reactions, organic compounds and photoreactions	✪✪✪✪✪
Technology	Camera, capture of image by film and film development	✪✪✪✪
Engineering	Mechanism of a film camera	✪✪
Arts	Photography skills such as film speed, ISO, exposure and f-stop	✪✪✪✪

Mathematics	Calculation of chemicals used in the film development process	✪✪

1.7 Mapping of Key Learning Areas (KLAs)

Unit	Science Education	Technology Education	Mathematics Education	Arts Education
1	◆ Reflection of light (SP3.2.2) ◆ Refraction of light (SP3.2.3) ◆ Wave nature of light (SP3.2.6) ◆ Particle nature of light	◆ Structure of camera ◆ Image capture by film		
2	◆ Atomic structure (SC2.1) ◆ Ionic and covalent bond (SC2.5) ◆ Reactivity of metal (SC3.2) ◆ Redox reactions (SC7.3) ◆ Typical reactions of various functional groups (SC11.3) ◆ Metals and alloys (SC14.4)	◆ Image capture by film		
3	◆ Introduction to acids and alkalis (SC4.1) ◆ Indicators and pH (SC11.3) ◆ Salt and neutralization (SC4.4)	◆ Film development		◆ Photography skills

	◆ Redox reactions (SC7.3) ◆ Typical reactions of various functional groups (SC11.3)			
4	◆ Laboratory equipment and basic practical skills (SJ1.4) ◆ Dissolving (SJ2.2)	◆ Film development using instant coffee powder	◆ Using percentages (MJ5.1, 5.2) ◆ Rates, ratios and proportions (MJ6.1, 6.2)	◆ Photography skills

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	Assessment*
1	Capturing the light	120 mins	Worksheets, lab reports and presentation
2	The chemistry of image capturing	120 mins	
3	The birth of a photograph	130 mins	
4	I am a film developer	120 mins	
	Total	**8 hours 10 mins**	

1.9 Thematic Area

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

2 Module Design

The developing film involves many chemical reactions and, of course, requires many chemicals, but most are not environmentally friendly. Surprisingly, instant coffee powder and vitamin C can be used as the primary and secondary reducing agents or called developing agents, which are the essential chemicals for film development. These two substances participate in a series of chemical reactions during film development and give good quality of the final photo.

In this module, chemical reactions such as acid-base reactions, redox reactions, and photoreactions involved in film development will be illustrated. The physics of light such as reflection, refraction, colour and wave and particle dual natures of light will also be introduced. Materials that film is made of and photographic knowledge, such as film speed, ISO, exposure time and f-stop, will also be included. At the end of the module, students would have experience in photo-shooting and film development.

Students are expected to have basic knowledge of the physics of light and how a camera can be used for photography. Unit 1 will familiarise students with the physics of light, such as reflection, refraction and dual nature of light. The structure and design of an "old-style" film camera will also be introduced in Unit 1.

In Unit 2, chemical knowledge and working principles of image-capturing by the film will be introduced. The chemical composition of a roll film and chemical reactions that happen during image-capturing like photoreaction will be explained using knowledge of chemistry.

In Unit 3, the working mechanism and underlying principles of film development will be illustrated. The chemical reactions during film development, such as redox reactions, acid-base reactions and salt dissolving, will be explained. In addition, basic knowledge of photography skills will also be introduced, which can help students to create and design their own photos.

In Unit 4, students can take photos using a film camera or a 3D DIY pinhole camera. Students will then develop their own film using instant coffee powder and vitamin C. Finally, the developed film will be scanned, and the resulting photo with good quality will be given to the students.

2.1 Unit 1: Capturing the Light

Although cameras such as single-lens reflex types can be very delicate and expensive, the working principle of photography, is not difficult. The most important part of a film camera is the lens. Light from the object will pass through the lenses and is reflected and refracted. It is then focused on the roll film and initiates a series of reactions on it in order to record the object.

In this unit, the simple structure of a film camera will be introduced. Different lenses used in a film camera and how light from the object is reflected and refracted to the eye and the film will be introduced and illustrated.

This unit would familiarise students with the physics of light and the simple mechanism of photo-taking which are necessary for students to understand Unit 2.

2.1.1 Objectives

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

- Understand the concepts of light reflection and refraction
- Identify the dual nature properties of light
- List out different parts in a simple film camera
- Explain the usage of different parts in a simple film camera
- Explain part of the working mechanism of photography

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 structure of a simple film camera: ◆ To introduce different lenses used in the camera ◆ To introduce roll film	15 mins	◆ PowerPoint slides
(3) The physics of light ◆ Reflection of light ◆ Refraction of light by convex lens ◆ To introduce the dual nature (wave/particle) properties of light	55 mins	◆ PowerPoint slides
(4) The pathway of light inside the camera: ◆ To ask students to predict the pathway of light by using the theories introduced ◆ To explain how light from an object can reach the film or the eyepiece ◆ To introduce how light can interact with the film	30 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	**120 mins**	

2.1.4 Assessment (if appropriate)

- Student's knowledge of the structure of a simple film camera will be assessed through polling and multiple-choice questions
- Student's knowledge of the physics of light such as reflection, refraction and dual nature will be assessed through multiple-choice and short questions
- Overall students' participation would be reviewed

2.2 Unit 2: The Chemistry of Image Capturing

After introducing how light from the object can be directed to the film inside the camera, the chemical process of how the light reacts with the film and is recorded will be explained. A photographic film consisting of different layers of materials which are necessary for it to function properly will also be introduced. Since a series of chemical reactions are involved in image capturing by film, basic chemical knowledge will be first illustrated with examples.

In Unit 2, chemical knowledge and working principles of image capturing by the film will be explained. The different materials used, their chemical structures and the chemical composition of a roll film will be introduced. The chemical reactions during image capturing, such as photoreaction and redox reaction, will be illustrated with real examples. Students are expected to understand the process of capturing images by film, and this unit paves the road for understanding Unit 3 and Unit 4.

2.2.1 Objectives

Upon completion of *Unit 2,* students should be able to:

- Understand the working principles of image capturing by film
- List out the main chemical compounds of a film
- Describe the chemical properties of the chemical compounds used in image capturing
- Explain the chemical interactions between the light from an object and the film

2.2.2 Pre-requisite (if appropriate)

Nil.

2.2.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction: ◆ To recap major ideas from the previous lesson ◆ To assess students' prior knowledge ◆ To explain the learning objectives of this lesson	10 mins	◆ PowerPoint slides

Description	Duration (hr/min)	Resources
(2) Brief introduction of a film: ◆ To introduce the functions of a film ◆ To introduce the structure of a film ◆ To list out the chemical compositions of a film ◆ To show a film to students	20 mins	◆ PowerPoint slides ◆ A roll film
(3) The chemistry of the image capturing process: ◆ To introduce the working principles of image capturing ◆ To explain the image capturing functions of different chemical compounds used one by one ◆ To relate the functions to different chemical theories such as photoreaction and redox reaction ◆ To ask students why a darkroom is usually used for film development	80 mins	◆ PowerPoint slides
(4) Debriefing: ◆ To review the knowledge covered in this lesson ◆ To briefly introduce the next lesson	10 mins	◆ PowerPoint slides ◆ Notes
Total	**120 mins**	

2.2.4 Assessment (if appropriate)

- Student's knowledge and understanding of the working principles, scientific explanations and chemical theories of the image capturing process by the film will be assessed through polling and multiple-choice questions
- Overall students' participation would be reviewed

2.3 Unit 3: The Birth of a Photograph

In Units 1 and 2, students have been familiarised with different physical and chemical knowledge of light and image capturing. These are all essential elements for understanding the science of film development. The working mechanism and underlying principles of film development involve different chemical reactions between different chemical reagents, such as redox reactions, acid-base reactions, and salt dissolving. In addition, basic knowledge of photography skills will also be introduced, which can help the students to create, design and develop their own photos in Unit 4.

Different chemical reagents used for film development will be introduced in this unit. In addition, the science behind the film development process will be explained based on different chemical theories in the SS syllabus.

2.3.1 Objectives

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

- List out the chemical reagents used for film development
- Describe the process of film development
- Explain how the reagents used interact with the chemicals on the film during the development process
- Understand some photography skills

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	10 mins	◆ PowerPoint slides
(2) Chemical reagents used for film development: ◆ To list out the chemical reagents used ◆ To introduce the chemical properties of the reagents ◆ To list out the safety issues of the chemical reagents used	30 mins	◆ PowerPoint slides
(3) Film development process: ◆ To briefly introduce the whole process of film development ◆ To explain each step of film development by using different chemical theories ◆ To show a developed film to students	50 mins	◆ PowerPoint slides ◆ Online videos ◆ Developed film
(4) Photography skills: ◆ To introduce different photography skills ◆ To explain how the skills can affect the process of light, image capturing and film development ◆ To explain how the skills can affect the quality of a photograph ◆ To encourage students to design a photo which the film will be developed in Unit 4	30 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	**130 mins**	

2.3.4 Assessment (if appropriate)

- Student's knowledge and understanding of the working principles of film development and the functions of chemical reagents used will be assessed through polling and multiple-choice questions
- Student's knowledge and understanding of photography skills and their effects will be assessed through the pre-lab report
- Overall students' participation would be reviewed

2.4 Unit 4: I Am a Film Developer

In order to have a comprehensive understanding of the science of photography, including light, image capturing, and film development, students are provided with a chance to experience all three processes in this unit. Students who have been equipped with scientific knowledge introduced in Units 1, 2 and 3 should be able to handle and master them.

In Unit 4, students can take a photo using a film camera or a 3D DIY pinhole camera. They will then develop their own film using instant coffee powder and vitamin C. The chemical properties and reactions during the film development of coffee powder and vitamin C will be introduced. Finally, the developed film will be scanned, and the resulting photo with good quality will be given to the students. Students will be encouraged to share their ideas and think about their own artwork.

2.4.1 Objectives

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

- Take a photograph by using a film camera or 3D DIY pinhole camera
- Develop the film by using instant coffee powder and vitamin C
- Explain the chemistry of the film development process
- Appreciate other students' photos from an artistic and a scientific point of view

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) Safety instruction: ◆ To mention the safety issue of using different chemical reagents	10 min	◆ PowerPoint slides

Description	Duration (hr/min)	Resources
(3) Experiment section: ◆ To take a photo by using a roll ◆ To brief students on the procedures of the experiment ◆ To guide students to finish the experiment	60 min	◆ PowerPoint slides ◆ Activity 3
(4) Presentation: ◆ To present the photograph ◆ Students and the teacher comment on and appreciate other's works from an artistic and a scientific point of view	20 min	◆ PowerPoint slides ◆ Notes
(5) Debriefing: ◆ To review the knowledge covered in all units	20 min	◆ PowerPoint slides ◆ Notes
Total	**120 min**	

2.4.4 Assessment (if appropriate)

- Student's scientific knowledge and understanding of the experiment will be assessed through polling and multiple-choice questions
- Student's laboratory performance will be assessed through the laboratory session
- 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

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