Jockey Club STEAM Education Resources Sharing Scheme

CUBrodic Table

Teachers' Guide

Second Edition August 2020

School of Science and Technology
Hong Kong Metropolitan University

Ho Man Tin, Kowloon, Hong Kong

Table of 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 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: CUBrodic Table

CUBrodic Table (扭轉新元素) is one of the core modules in the scheme to enhance students' interest in learning STEAM integrating key learning areas (KLAs) from different subjects. This module consists of a 27-hour learning module for making a Rubik's cube.

In this module, students will build their customised Rubik's cube decorated with chemical element stickers, the so-called CUBrodic Table. Through this process, students will learn the operations of the image-editing software, 3D modelling software, colour printers and 3D printers. With the support of learning activities and tools, students will also relate chemical elements, their functions and applications in daily life. Furthermore, students will learn and apply mathematics and logic for solving a Rubik's cube.

This module covers five units of topics related to chemistry and mathematics suitable for junior secondary students:

- Unit 1 – Engineering: Mechanism and Design of a Rubik's Cube
- Unit 2 – Technology: 3D Modelling and Printing a Rubik's Cube
- Unit 3 – Science: Elements, Atoms and Periodic Table
- Unit 4 – Art: Design Stickers for Decorating a Rubik's Cube
- Unit 5 – Mathematics: Rubik's Cube Solver

In *Unit 1*, *Mechanism and Design of a Rubik's Cube*, the internal structure of a Rubik's cube will be presented to help students explore the actual outlook of the pieces and the internal pivot mechanism of a Rubik's cube. *Unit 2*, *3D Modelling and Printing a Rubik's Cube*, has a series of step-by-step video clips guiding students to build 3D models of Rubik's Cube components and pieces. The students will also try to operate a 3D printer to output the components and pieces for assembling a Rubik's cube. In *Unit 3*, *Elements, Atoms and Periodic Table*, a fundamental topic in chemistry, will be presented. Activities utilising some learning tools have been designed and incorporated in this unit to help students relate elements to their properties and applications in daily life. Based on the knowledge gained in *Unit 3*, the students will then be asked to select chemical elements and design stickers for decorating the assembled Rubik's cube in *Unit 4*. In the last unit, *Unit 5*, skills for solving a Rubik's cube will be presented to students.

Teachers may present the whole module to students or just pick parts of the contents for incorporating into their standard curriculum depending on teaching and learning needs. If you have any questions and/or comments about the module, please do not hesitate to contact the Project Team.

1.2. Participants Recommended for this Module

☑ Junior Secondary School Students
☐ Senior Secondary School Students
☐ Others (please specify: _____)

1.3. Module Aims

The module *CUBrodic Table* aims to:

- *Arise* students' *interest* in STEAM elements by building a Rubik's cube with chemical element stickers
- *Appreciate* the principles of Chemistry and Mathematics related to a Rubik's cube

1.4. Module Learning Outcomes

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

- *Describe* the internal pivot mechanism of a Rubik's cube
- *Build* the 3D structure of a Rubik's cube with the assistance of a computer software
- *Manipulate* the operation of a 3D printer to produce components of a Rubik's cube
- *Assemble* a Rubik's cube according to the assembly manual
- *Identify* the atomic structures of different classes of elements
- *Relate* the classes and position of different elements in the periodic table
- *Design* and *decorate* a Rubik's cube with chemical element stickers
- *Apply* simple algorithms to solve a Rubik's cube

1.5. Nature of STEAM Activity

Element	Description	Composition
Science	• Elements, Atoms and Periodic Table	✪✪
Technology	• 3D Modelling and Printing a Rubik's Cube	✪✪✪
Engineering	• Mechanism and Design of a Rubik's Cube	✪
Arts	• Design Stickers for Decorating a Rubik's Cube	✪
Mathematics	• Rubik's Cube Solver	✪✪

1.6. Mapping of Key Learning Areas (KLAs)

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others
1		TK1.1 Hardware and software TK5.10 Appropriate choice and use of tools, equipment and machines for the realisation of design solution			
2		TK1.1 Hardware and software TK6.3 The production process in various fields TK16.3 Information processing and information processing tools TE7.4 Computer-aided manufacturing			
3	SJ13.1 Atoms and elements SJ13.2 Periodic Table				
4				computer-aided design, colour, font, composition and the structure of graphs, decoration, creativity	

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others
5					MS15.1 – MS 15.5 Permutations and combinations

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	Engineering: Mechanism and Design of a Rubik's Cube	1
2	Technology: 3D Modelling and Printing a Rubik's Cube	20
3	Science: Elements, Atoms and Periodic Table	3
4	Art: Design Stickers for Decorating a Rubik's Cube	2
5	Mathematics: Rubik's Cube Solver	2
	Total	**28 hours**

*Remark: A total of **20** non-contact hours of the module is recommended*

1.8. Thematic Area

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

2. Module Design

2.1. Unit 1: Engineering: Mechanism and Design of a Rubik's Cube

To build a 3D model of a Rubik's cube, it is necessary to learn about the design and structure of a Rubik's cube. To begin with, an overview of the whole module will be introduced followed by presenting the history of Rubik's cube. A reference video on the internal structure of a 2x2 Rubik's cube will then be shown to students. After watching the video, teachers will be supposed to open a real Rubik's cube and show the outlook of different components and pieces, and the internal pivot mechanism to the students.

The original Rubik's cube is 3x3 (also known as 3x3x3). However, the teaching material of this module is based on a 2x2 Rubik's cube, which is less common in the market so as to produce a special customised item (as the outcome) at the end of the module. Furthermore, the solver for a 2x2 Rubik's cube is less complex and is more suitable for junior students who have no experience in solving a Rubik's cube. Teachers may adopt a 3x3 Rubik's cube in their classes if needed. References and teaching materials on 3x3 Rubik's Cube are also provided in the teaching material kit for easy preparation.

2.1.1. Objectives

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

- *Recognise* the design, structure, components and pieces of a Rubik's Cube
- *Describe* the internal pivot mechanism of a Rubik's cube

2.1.2. Description of Activity

Topic	Teaching Hours	Activities Hours
Module Introduction • Outline of the module • History of Rubik's cube	20 mins	
Mechanism and Design of a Rubik's Cube • Reference video watching • Demo of opening a real Rubik's Cube		 5 mins 25 mins
Study unit summary	10 mins	
Total	**60 mins**	

2.1.3. Assessment (if appropriate)

Nil

2.2. Unit 2: Technology: 3D Modelling and Printing a Rubik's Cube

In this unit, the students will learn how to build 3D models of the components and pieces in a 2x2 Rubik's cube using SOLIDWORKS, a popular 3D modelling software. The

design of a 3D model will be output as the specific file format called “STL”, which will be loaded in another software FLASHPRINT. It controls a 3D printer to 3D print individual components and pieces. The printed components will then be assembled to produce a Rubik’s cube.

In the first part of this unit, students will learn the basic functions of SOLIDWORKS through a task, building a 3D model of a Rubik’s cube stand, to get familiar with the interface and common operations of the software. Teachers are recommended to demonstrate the basic functions and controls of SOLIDWORKS one by one and build the stand together. The design of the 3D model will be saved in the STL format and then it will be opened in FLASHPRINT. The basic functions of FLASHPRINT will be demonstrated followed by 3D printing. In the second part, the students will be allowed to build and 3D print 3D models of components and pieces of a 2x2 Rubik’s cube with limited guidance from their teachers and/or technicians. In the last part of this unit, an instruction manual for assembling a 2x2 Rubik’s cube will be distributed to the students. Students will assemble their 3D-printed components and pieces to give a 3D-printed 2x2 Rubik’s cube.

Step-by-step video clips of drawing the 3D models and operating FLASHPRINT, and instruction manuals for assembling 2x2 and 3x3 Rubik’s cubes are available in the teaching material kit. Teachers may consider distributing the video clips to the students so that students can follow the video clips and draw 3D models on their own with limited guidance. 3D models of 2x2 and 3x3 Rubik’s cubes, and STL files are also available in the teaching material kit.

The software programs used in this module are popular for 3D modelling and printing. However, this does not limit teachers from using other similar programs for fulfilling their teaching and learning needs. Indeed, there are many free 3D modelling and printing programs readily available.

Many 3D printers have limited precisions (usually at mm level). Limited precision leads to a rough surface of the artefact. Furthermore, the dimension variation of 3D printed components increases with decreasing size. High variation may lead to difficulty in assembling the components and affect the turning smoothness of the Rubik’s cube. The edge length is recommended to be 5 to 7 cm for guaranteed output results. A saw file might be used to fine-tune the sizes and polish the edges of the printed individual components. Teachers may also consider applying lubricants to ensure the smooth turning of the assembled Rubik’s cube.

The designs of the components are complex and are of irregular shapes. The orientation of the individual components has to be carefully set for 3D printing to increase the success rate of printing. An imbalanced orientation will lead to a collapse of the partially printed structure in the middle of the output process. Teachers are welcome to contact us for technical support in 3D printing.

3D printing is a long process. Printing all the components and pieces for composing a Rubik’s cube may take several days. If the preparation time is limited or a 3D printer is not available, teachers may consider requesting 3D printing service which is

commercially available. In general, the printing quality is good, and the delivery time is relatively short.

Figure 2.1 Rough surface of printed components due to the limited precision of the 3D printer

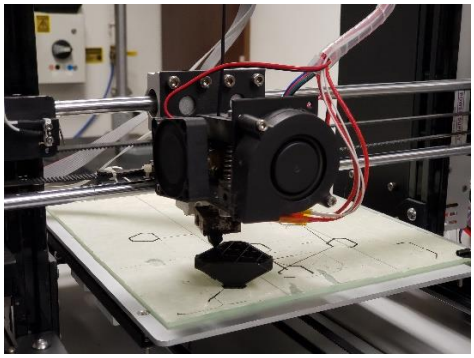

Figure 2.2 An appropriate orientation of the components has to be set to avoid the collapse of the partially printed component during 3D printing

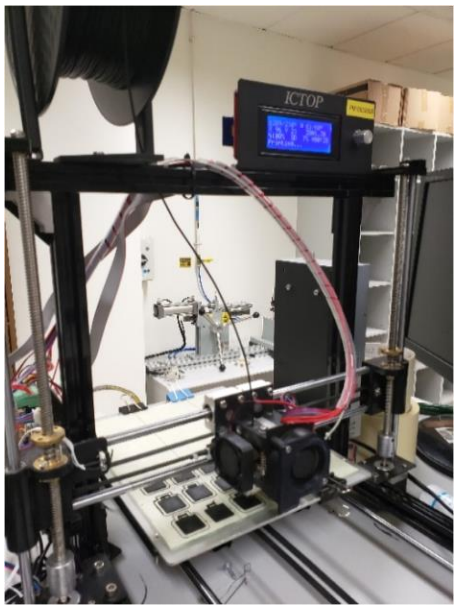

Figure 2.3 Several individual components can be printed at the same time to compress the total printing time

2.2.1. Objectives

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

- *Design* the components of a Rubik's cube by using a 3D modelling software
- *Operate* a 3D printer to produce the components of a Rubik's cube

2.2.2. Description of Activity

Topic	Teaching Hours	Activities Hours
Introduction	10 mins	
SolidWorks – The Basic • Drawing a 3D model of a Rubik's cube stand		60 mins
SolidWorks – Build the 3D Models of Pieces • Drawing 3D models of components and pieces of a Rubik's cube		17 hours
FlashPrint and 3D Printing • Operation of FlashPrint • Setting up a 3D printer		30 mins 10 mins
Assemble the 3D printed Rubik's cube		60 mins
Study unit summary	10 mins	
Total	**20 hours**	

2.2.3. Assessment (if appropriate)

Nil

2.3. Unit 3: Science: Elements, Atoms and Periodic Table

In this unit, students learn about the nature of the elements. There is a Microsoft PowerPoint file in the teaching material kit. Teachers may directly use the file for the presentation of this unit. Explanations and/or instructions for teachers can be found in the notes of the file. Teachers may amend, enhance and/or remove the contents for suiting their teaching and learning needs.

In the first topic, the general concepts of matters, elements and their properties will be discussed. Students' learning will be further consolidated by small group activities. In the first activity, students will be asked to observe and describe the appearance of several elements with the assistance of a periodic table display with real elements (see Figure 2.4). With the help of teachers, students will recognise that the appearances of metals, metalloids and non-metals are different. In the second activity, students' understanding of the properties of elements will be further enhanced. Students will be encouraged to identify three elements in the classroom. Teachers may consider putting some "answers" around the classroom. With the guidance of teachers, students will relate the properties, functions and daily-life applications of the identified elements.

In the second topic, the simple atomic model will be introduced. The components (sub-atomic particles) in an atom including neutrons, protons and electrons will be explained. Explanations on atomic numbers, mass numbers and isotopes will also be presented to the students. In the third activity, students will be asked to "build" the

atomic structures of several elements through the atomic model kit (see Figure 2.5). In the round-up by the teacher, the gradual change of the number of electrons along a row or a group (column) can be highlighted to the students. The relationship between isotopes of an element can also be illustrated easily with the model kit.

Based on the discussions in Topics 1 and 2, further elaborations on groups, periods and blocks in the periodic table will be provided in the last topic of this unit.

Figure 2.4 The outlook of a periodic table display with real elements
(Image credit: Photo / Momotarou2012 / CC BY-SA 3.0)

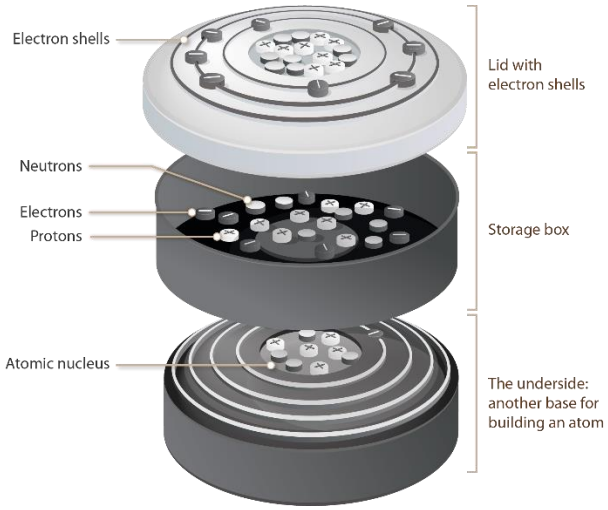

Figure 2.5 The outlook of an atomic model kit

2.3.1. Objectives

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

- *Define* elements and spot elements in real-life applications
- *Illustrate* the structure of a simple atomic model
- *Correlate* the properties of an element with group and period in a periodic table

2.3.2. Description of Activity

Topic	Teaching Hours	Activities Hours
Introduction	5 mins	
Element • Matters, elements and their properties • Periodic table display: Observe the appearance of different elements • Identify three elements in the classroom • Some real-life applications of elements	20 mins 20 mins	 20 mins 20 mins
Atomic model • Neutrons, protons and electrons • Atomic number, Mass number and Isotopes • Atomic model kit: show the atomic structure of the three elements: hydrogen, carbon and chlorine	10 mins 20 mins	20 mins
Periodic table • Classification of elements • Groups of the periodic table	15 mins 20 mins	
Study unit summary	10 mins	
Total	**180 mins**	

2.3.3. Assessment (if appropriate)

Nil

2.4. Unit 4: Art: Design stickers for Decorating a Rubik's Cube

In this unit, students will be asked to propose six themes for grouping chemical elements into the six faces of a Rubik's cube. Students will be encouraged to apply the knowledge learnt in *Unit 3* and think creatively to give unique themes. It is not necessary following the rules forming the periodic table as long as the criteria are logical and scientifically sound. Students may design chemical element stickers based on the sticker template provided in the teaching material kit or use any image editing software to produce their customised stickers. Finally, the design will be printed out on label papers for decorating the 3D printed Rubik's cube produced in *Unit 2*.

2.4.1. Objectives

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

- *Propose* criteria for grouping chemical elements
- *Design* and *produce* chemical element stickers for decorating a Rubik's cube

2.4.2. Description of Activity

Topic	Teaching Hours	Activities Hours
Introduction	5 mins	
Element Stickers • Decide themes for grouping chemical elements • Design and print out the stickers • Decorate the Rubik's cube with chemical element stickers		20 mins 20 mins 10 mins
Study unit summary	5 mins	
Total	**60 mins**	

2.4.3. Assessment (if appropriate)

Nil

2.5. Unit 5: Mathematics: Rubik's Cube Solver

In this unit, the design of a Rubik's cube will be revisited. The concepts of notations and algorithms will be explained. The teachers will then practice some simple algorithms together followed by doing the steps and applying algorithms to solve a 2x2 Rubik's cube.

There are many ways to solve a Rubik's cube. Online resources on tutorials of solving Rubik's cubes are readily available but the method and algorithms applied can be very different from those in this unit. Reference videos can be found on the last slides of the Microsoft PowerPoint File of this unit. A guide for solving a 3x3 Rubik's cube is also available in the teaching material kit.

2.5.1. Objectives

Upon completion of *Unit 5*, students should be able to:

- *Relate* notations with moves of a Rubik's cube
- *Apply* simple algorithms to solve a Rubik's cube

2.5.2. Description of Activity

Topic	Teaching Hours	Activities Hours
Introduction	10 mins	
Notations and algorithms		40 mins
Solving a Rubik's cube		60 mins
Study unit summary	10 mins	
Total	**120 mins**	

2.5.3. Assessment (if appropriate)

Nil

3. Resources

3.1. Resources for Unit 1: Engineering: Mechanism and Design of a Rubik's Cube

Materials & Equipment	Remarks
Normal classroom setting	A computer with a projector for teaching using Microsoft PowerPoint
PowerPoint file for teaching & learning material for students	Available in module teaching material kit
2x2 and 3x3 Rubik's cubes	For demonstration

3.2. Resources for Unit 2: Technology: 3D Modelling and Printing a Rubik's Cube

Materials & Equipment	Remarks
Computer	For running SOLIDWORKS, a 3D modelling software
3D printer	NA
Screws (M3 x 16 mm with spring)	For assembly of 3D printed individual components of Rubik's cube
A PowerPoint file as the introduction to the project	Available in module teaching material kit
A set of template files of Rubik's cube 3D individual components	Available in module teaching material kit
A screwdriver, a saw file, lubricant	For assembly of 3D printed Rubik's cube
Reference videos of SOLIDWORKS tutorials	Ultimate SolidWorks Tutorial for Absolute Beginners- Step-By-Step by Solidworks Tutorials https://youtu.be/qtgmGkEPXs8 SolidWorks 2014 Tutorial 1: Interface, Add-ins, New Part, Options, Units by Tutorials Engineer https://youtu.be/dN1Ub864wks
A reference video showing the structure, mechanism and assembly of a 2x2 Rubik's cube	ANY 2x2 Rubik's Cube Disassembly and Assembly Tutorial by Z3Cubing: https://youtu.be/WonakLnT-Tw
A reference online resources of files printing individual components of 2x2 Rubik's cube (not editable)	2x2 Rubik's Cube 3D print files by mrvanes: https://www.thingiverse.com/thing:2030212

3.3. Resources for Unit 3: Science: Elements, Atoms and Periodic Table

Materials & Equipment	Remarks
Normal classroom setting	• A computer with a projector for teaching using Microsoft PowerPoint • Allow students to form small groups and sit together to do activities
PowerPoint file for teaching & learning material for students	Available in module teaching material kit
Periodic table display with some real elements	• Learning tool for activity • The quantity needed depends on class size. Two to four students sharing one item is recommended. • Available for borrowing
Magnifier	• Learning tool for activity • The quantity needed depends on class size. Two to four students sharing one item is recommended. • This item is for easy observation of elements of the periodic table display.
Products/tools/items made by elements in daily life	Optional learning tools for activity
Atomic model kit	• Learning tool for activity • The quantity needed depends on class size. Two to four students sharing one item is recommended. • Available for borrowing

3.4. Resources for Unit 4: Art: Design Stickers for Decorating a Rubik's Cube

Materials & Equipment	Remarks
Computer	For running photo-editing software
PowerPoint file for teaching & learning material for students	Available in module teaching material kit
Photo-editing software	Free label printing software • LabelJoy • Avery Design and Print • Papilio Label Helper • Inkscape
Sticker – printing paper	Equipment: colour printer Label of size a x a cm CAUTION: The label design should also include bleed and crop marks. For 2x2 Rubik's Cube, need 24 stickers. For 3x3 Rubik's Cube, need 54 stickers.

3.5. Resources for Unit 5: Mathematics: Rubik's Cube Solver

Materials & Equipment	Remarks
Normal classroom setting	A computer with projector for teaching using Microsoft PowerPoint
PowerPoint file for teaching & learning material for students	Available in module teaching material kit
A pdf file of an instruction manual showing Rubik's cube solver step by step	Available in module teaching material kit

4. References

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007). Science Education Key Learning Area: Mathematics - Curriculum and Assessment Guide (Secondary 4-6). Hong Kong: Government Logistics Department. Retrieved December, 2017, from https://334.edb.hkedcity.net/new/doc/eng/curriculum2017/Math%20C%26A%20Guide_2017_e.pdf

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007). Science Education Key Learning Area: Combined Science - Curriculum and Assessment Guide (Secondary 4 - 6). Hong Kong: Government Logistics Department. Retrieved June, 2018, from https://334.edb.hkedcity.net/new/doc/eng/curriculum2018/CS_C&A_Guide_updated_Eng_22082018.pdf

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007). Science Education Key Learning Area: Integrated Science - New Senior Secondary Curriculum and Assessment Guide (Secondary 4-6). Hong Kong: Government Logistics Department. Retrieved November , 2015, from https://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/IS_C_and_A_Guide_updated_e_151126.pdf

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007). Science Education Key Learning Area: Physics - Curriculum and Assessment Guide (Secondary 4 - 6). Hong Kong: Government Logistics Department. Retrieved November, 2015, from https://334.edb.hkedcity.net/new/doc/chi/curriculum2015/Phy_CAGuide_c_2015.pdf

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007). Science Education Key Learning Area: Biology - Curriculum and Assessment Guide (Secondary 4 - 6). Hong Kong: Government Logistics Department. Retrieved June, 2018, from https://334.edb.hkedcity.net/new/doc/chi/curriculum2015/Bio_CAGuide_e_2015.pdf

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007). Science Education Key Learning Area: Chemistry - Curriculum and Assessment Guide (Secondary 4 - 6). Hong Kong: Government Logistics Department. Retrieved June, 2018, from https://334.edb.hkedcity.net/new/doc/eng/curriculum2018/Chem_C&A_Guide_updated_Eng_22082018.pdf

5. Acknowledgement

Ms LAU Si Nam, Kit Sam Lam Bing Yim Secondary School

Mr Alex LAI, School of Science and Technology, Hong Kong Metropolitan University

Dr Douglas NG, School of Science and Technology, Hong Kong Metropolitan University

Ms Bernadette KWOK, Jockey Club STEAM Education Resources Sharing Scheme,
Hong Kong Metropolitan University

6. Project Team

Dr Sidney CHAN, School of Science and Technology,
Hong Kong Metropolitan University

Mr Justin CHAN, Jockey Club STEAM Education Resources Sharing Scheme,
Hong Kong Metropolitan University