Jockey Club STEAM Education Resources Sharing Scheme

Confusing the Wind

Teachers' Guide

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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: Confusing the Wind

The engineering design process is a very important concept in STEAM education, especially in the "Engineering" element. It encourages students to learn from trial-and-error, and allows them to reflect on their understanding of their design works and improvement processes.

"*Confusing the Wind*" aims to provide an opportunity for students to explore their future study/career in the field of engineering. Students would be engaged to think like engineers by going through the basic engineering design process in the context of applying aerodynamics to a moving object.

The module is compiled with the following 3 units,

- Unit 1 – Paper Airplane Design;
- Unit 2 – Go against the Wind; and
- Unit 3 – Pitching Day.

1.2 Participants Recommended for this Module

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

1.3 Module Aims

The module "*Confusing the Wind*" aims to:

- Provide students with authentic experiences in designing and making engineering prototypes following the basic engineering design process;
- Explore with students the science behind any engineering problems, such as the concept of aerodynamics and the application and integration of Science, Mathematics and Technology subject knowledge and skills;
- Provide students with analytical, technical, theoretical and practical knowledge in aspects of testing science;
- Arouse students' curiosity in the field of engineering through creative design & make activities.

1.4 Module Learning Outcomes

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

- Practice the concept of the basic engineering design process;

- Integrate the concept of aerodynamics, basic geometry, force, motion, etc. to solve engineering problems;
- Design and make paper airplanes and rocket car prototypes to run engineering tests;
- Apply basic techniques and tools in testing science and certification.

1.5 Learning & Teaching Approach / Practice

The basic engineering design process has three major parts, including
- define a problem and brainstorm alternative solutions,
- design and test the selected solution, and
- communicate the result.

The module uses context-based learning and teaching approach to engage students to solve a real-life problem by going through the basic engineering design process.

By incorporating the 'Arts' in the module, students would be able to thoroughly report and effectively communicate the results with Professional Engineers in the real world.

1.6 Nature of STEAM Activity

Element	Description	Composition
Science	• Apply new concepts of aerodynamics and prior knowledge of force and motion	✪✪
Technology	• Conduct drag force testing using Wind Tunnel Testing System; and • Use MS Excel graphics and MS PowerPoint slideshows for presentation	✪✪
Engineering	• Practice the basic engineering design process; • Design paper airplane and rocket car prototypes and inquire the science behind them; and • Practice recording data, conducting data analyses, and reporting testing results	✪✪✪
Arts	• Practice presentation skills	✪
Mathematics	• Integrate basic geometry with various science subject knowledge to solve engineering problems	✪✪

1.7 Mapping of Key Learning Areas (KLAs)

Unit	Science Education	Technology Education	Mathematics Education	Arts Education	Others
Unit 1	SJ11.2 Force SJ11.4 Friction and Air Resistance	TK4.1 Materials and Structures	MJ19.1 Angles and parallel lines MJ21 Congruent Triangle MJ22 Similar Triangle MJ25.1 & MJ25.4 Pythagoras' theorem		
Unit 2	SJ11.1 Motion	TK4.1 Materials and Structures	MJ13.2 & MJ13.3 Formulae MJ7.1 & MJ7.2 Algebraic expressions MJ8.1 & MJ8.3 Linear equations in one unknown		
Unit 3	SJ11.5 Action and reaction	TK16.3 & TK16.4 Information Processing and Information Processing Tools	MJ28.1-3 Data Handling Strand	Presentation 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
1	Paper Airplane Design	2.5
2	Go against the Wind	2.5
3	Pitching Day	2.5
	Total	**7.5 hours**

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

1.9 Thematic Area

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

2 Module Design

In the first two units, students would have a glance at the basic engineering design process through hands-on activities to apply the concept of aerodynamics to the design of a paper airplane and a rocket car. In the last unit, students would also be required to conduct data analysis and present their results using Microsoft Excel and Microsoft PowerPoint slideshow.

2.1 Unit 1: Paper Airplane Design

In this first unit, students will act as engineers working on designing a solution that can transport a small package of medical supplies under any weather conditions safely and reliably. Before they start the production of the solution, the company is now asking them to design a paper airplane to test out the aerodynamics matters.

As with the practice of Professional Engineers, the teacher will allow students to practise the following basic engineering design process in their design of a paper airplane,

- define a problem and brainstorm alternative solutions,
- design and test the selected solution, and
- communicate the result.

One of the key factors when designing an airplane is Aerodynamics.

Aerodynamics is the study of how air interacts with objects. This is an important subject. Some public transportations rely heavily on aerodynamic principles, such as airplanes. Much of the design of airplanes focuses on the aerodynamics of their wings and noses to keep them moving quickly through the air.

By watching an online video with the students, the teacher will help students to recognise that the wind force can lift an entire airplane or change the direction of the airplane. The wind seems to be intangible and weak in normal weather. However, when people use wind wisely with the knowledge of aerodynamics, any object can be lifted to the sky.

A game on designing a paper airplane is set for students. Students will design a paper airplane, conduct the flying test, inquire about possible factors that may affect the flying results and determine key parameters for designing a good paper airplane, such as launching angle, launching force (i.e. drag force, lifting force, and gravity force), the height of the launching point, mass and shape of the plane, etc.

As Professional Engineers, students also learn to have a proper tracking system to record, interpret and evaluate the flying test results. Fine-tuning or redesigning the paper airplane design using the analyzed test results will yield a better solution.

Last but not least, students would have the opportunities to compare the results and draw conclusions / make recommendations on their findings as real engineers.

2.1.1 Objectives

By bringing in the basic concept of the engineering design process, the new concept of aerodynamics and students' prior knowledge of the basic geometry and types of force, this unit would let students design a paper airplane, record the data from testing & redesigning, identify important design criteria & constraints and communicate the result effectively.

2.1.2 Pre-requisite (if appropriate)

- Scientific concepts such as force, speed and acceleration
- Basic geometry

2.1.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction • Arouse students' interest by introducing the context background and the basic engineering design process • Teacher briefs about STEAM education, objectives, assessment criteria, group arrangement, lab safety, etc.	15 min	• Learning Portfolio (Teacher Version) • PPT (P1-5) • Learning Portfolio (P1-2)
(2) Engineering design process – Defining the problem and brainstorming alternate solutions • Teacher briefs about the requirements of making a paper airplane • A student as a volunteer first tries his/her best effort to fly off the paper airplane sample while other students observe and inquire about possible design factors that may affect the results • Students watch an online video on Aerodynamics and summarise the relevant concept in airplane design with the teacher • Students define the engineering problem • Three students as volunteers fly off three paper airplane samples while others observe and set hypotheses by recording down measurements based on new knowledge learned • The teacher reviews the prior knowledge on basic geometry and type of force with students	45 min	• PPT (P6-18) • Paper airplane samples (x3) • Video • Learning Portfolio (P3-5)

Description	Duration (hr/min)	Resources
(3) Engineering design process – Making, testing and redesigning the paper airplane • Each student draw up his/her paper airplane based on the set of selected design parameters and draw a free-body diagram of the design • Students create their own paper airplanes and measure/calculate the design parameters • Using the paper airplane launcher and force sensors, students run the flying test in groups and record the landing results • Students analyse the data and redesign or fine-tune their design to yield a better result • A maximum of 3 trials is allowed for each student	1 hr	• Learning Portfolio (P5-9) • Equipment
(4) Engineering design process – Evaluating and presenting the testing result • The teacher facilitates students to review the results, conclude any important design criteria and constraints, and present the result or recommendations in class • The teacher debriefs the whole class about their work done and consolidates the basic engineering design process with the student	30 min	• PPT (P19) • Learning Portfolio (P10)
Total	**2 hr 30 min**	

2.1.4 Assessment (if appropriate)

Students' work in the learning portfolio and the best flying test result will be reviewed during and after the class.

2.2 Unit 2: Go against the Wind

In the previous unit, students have already had a glaze of the basic engineering design process and the concept of aerodynamics. By applying these given pieces of new knowledge and skills and integrating the prior knowledge in Science and Mathematics, students have designed their own paper airplanes that aimed to travel a long distance.

In this unit, students will continue their engineers' status in the company. Recently, the boss is not happy about the design of a vehicle and asks them to develop a better one that will reduce the effect of the wing force.

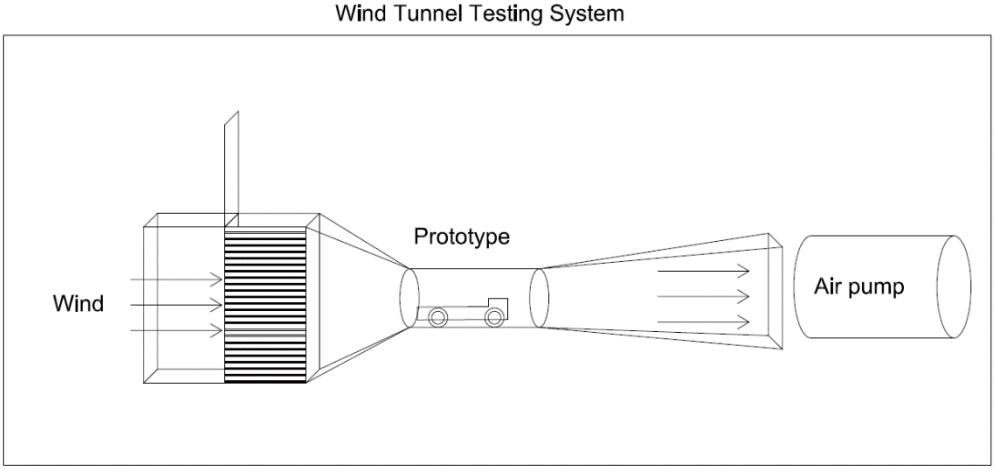
The basic engineering design process will again be used in this unit. As professional engineers, students will build a prototype of the solution to test their ideas before building the actual work. Students need to go through the engineering design process. Each student will be given a rocket car prototype made of foam block and they need to conduct drag force testing using the wind tunnel testing system. They will interpret the result and modify the rocket car prototype.

As learned from the concept of Aerodynamics, drag force is the force caused by the movement of air. By watching an online video, teachers will facilitate students to realise how the components of the bodywork and shape of a vehicle influence fuel consumption.

That is, wind force can cause a lot of financial costs to our society. By minimizing the drag force with an appropriate shape of a vehicle, the wind force will be catered and the consumable expense (e.g. fuel consumption, mechanics damage) will be reduced. Ultimately, it will bring better selling of the vehicle.

To design a rocket car with a low drag force, students must first understand the concept of streamlining. Many studies have found that an object can reach a very low drag coefficient and thus yields a low drag force if the traveling fluid has minimized detour (streamline) as it runs over an object. It also shows that a droplet-like shape of an object will lead to a minimum drag coefficient.

As such, the teacher may first introduce the wind tunnel testing system, e.g.



and the following drag force formula to students,

$$F_D = C_D A \frac{\rho V^2}{2}$$

where

F_D is the drag force

C_D is the drag coefficient

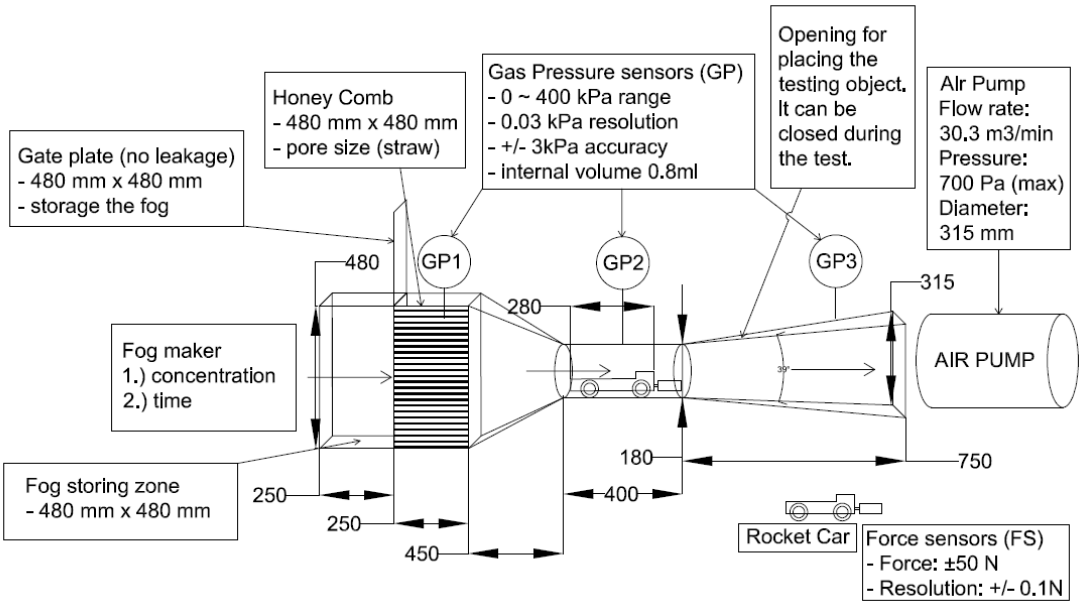
A is the reference area

ρ is the density of the fluid

V is the flow velocity relative to the object

To be able to understand the equation, students need to attend senior years Physics classes. In this unit, the teacher may simply review some basic substitution methods students learned in Secondary 2 Mathematics classes and assist them to plug in the number for each variable to find the unknown.

After students complete the prototype, the prototype will be tested using the wind tunnel testing system. In brief, the diagram shown below indicates that the air pump located on the right draws the wind from the left into the wind tunnel (the middle). The wind will go through the honeycomb which uniforms the airflow. That airflow will pass the testing zone where the artefact will be placed.



Students will record the results and fine-tune their design until a low drag coefficient can be reached. Again, they will make up their conclusion and/or recommendation to their boss at the end.

2.2.1 Objectives

By applying the concept of the engineering design process and the concept of aerodynamics, this unit introduces students to building a prototype of a rocket car with considerations on the effect of drag force on the rocket car and guides students to test their prototype designs using the wind tunnel testing system.

2.2.2 Pre-requisite (if appropriate)

- Mathematical formulae, algebraic expressions, and Linear equations in one unknown
- Scientific concepts in motion and force
- Basic engineering design process
- Data plotting using MS Excel

2.2.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction • Arouse students' interest by introducing the new task from their boss. • The eacher reviews the learning of the previous unit, brief the lab safety and the challenge for this unit, etc.	15 min	• Learning Portfolio (Teacher version) • PPT (P1-6)
(2) Demonstration on drag force and wind tunnel testing system • The teacher makes use of videos to illustrate the effects of wind force in real world • Students as volunteers using the rocket car samples to demonstrate the drag force effect • The teacher goes through the components of the wind tunnel testing system and briefs the science behind • After introducing the formula of drag force and its variables, the teacher reviews prior knowledge on some basic arithmetic skills such as substitution, calculating area and wind speed • The teacher demonstrates how to estimate the drag coefficient of the rocket car using the wind tunnel testing system and how to make the rocket car that yields a low drag coefficient	45 min	• PPT (P7-14) • Rocket car samples (x3) • Video
(3) Hands-on learning activity • Without much help from the teacher, students would work in groups following the basic Engineering Design Process, e.g. i. Set an engineering design process plan for the activity for the group ii. Design and fabricate the rocket cars for wind tunnel testing by individual student iii. Measure, calculate and record the design parameters of the rocket cars iv. Estimate the drag coefficient using the wind tunnel testing system v. Evaluate the rocket cars and test results vi. Fine-tune and re-test the designs	60 min	• Learning Portfolio (P11-15)

Description	Duration (hr/min)	Resources
(4) Conclusion • The teacher uses questioning to debrief what students have done and reviews the engineering design process in this activity • The teacher briefly introduces the next unit and reviews how to use MS Excel for plotting statistical graph	30 min	• PPT (P15 -22)
(5) Take-home Assignment for Unit 3 • Students will organise all their testing results, photos, reports, etc. of these 2 units • Students will plot data graphs of these 2 units testing results using MS Excel • Students will study the MS PowerPoint presentation's development tips and notes in the learning portfolio for Unit 3	(*)	• Learning Portfolio (P16-22)
Total	**2 hours 30 min**	

Remark: *(*) Around **TWO** non-contact hours are expected*

2.2.4 Assessment (if appropriate)

Student's work in the learning portfolio and the best testing result will be reviewed during and after the class.

2.3 Unit 3: Pitching Day

In the previous two units, students should have completed their design and testing of a paper airplane and a rocket car with sets of data recorded. The final stage of the basic engineering design process is communicating the result. Students need to be able to present their engineering designs clearly because typical engineering design does involve several stakeholders. Those stakeholders can be investors, researchers, or suppliers. Therefore, students shall learn how to present a technical design concisely so that others can understand and contribute to the design.

In this last unit, students will continue their engineers' roles in the company. The customer has finally scheduled to come for a meeting with your boss for giving a big deal on the production of the vehicle. Students are assigned to do a 10 minutes presentation at the meeting to brief the customer on what has been tested and make recommendations as Professional Engineers.

To prepare students for this, they shall learn several strategies for making effective presentations. Students have already been asked to plot various statistical graphs using MS Excel as homework. In this unit, they shall prepare a presentation to summarise their design works and testing results using MS PowerPoint. They will present their slides in class.

For effective PowerPoint presentations, one must consider the following items,

- Define the target audience
- Plan and organise presentation content
- Put the message in point form, precisely and concisely
- Maintain consistency, including font type, color tone, background, etc.
- Keep it simple. Use key phrases and keywords
- Easy to read. Use graphics, charts and tables to illustrate your ideas when necessary; do not overly use special effects and animations

Teachers may use the design and testing of a paper airplane for illustration, i.e. first brief the customer about how we define the problem, set the hypotheses, select the solution for testing and fine-tune until we get the best result. Last but not least, conclusions and/or recommendations would be given.

2.3.1 Objectives

This unit emphasises the last part of the basic engineering design process, "Communicate the Result" where students would learn how to effectively use MS PowerPoint and MS Excel to communicate the work and data.

2.3.2 Pre-requisite (if appropriate)

- Basic Engineering Design Process
- Data plotting using MS Excel

2.3.3 Description of Activity

Description	Duration (hr/min)	Resources
(1) Introduction • Arouse students' interest by introducing the meeting arrangement with the customer • The teacher reviews the learning of the previous units, briefs the lab safety, if any, and the objective for this unit, etc.	15 min	• Learning Portfolio (Teacher version) • Computer Lab • PPT (P1-4)
(2) Brainstorm Effective Use of Presentation Tools • Use questioning to allow students to brainstorm their steps to deliver an effective PowerPoint presentation • The teacher briefly goes through the MS PowerPoint notes in the learning portfolio and	15 min	• PPT (P5-11) • Learning Portfolio (P16-22)

uses testing data from Unit 1 to illustrate the kind of technical presentation for engineering product		
(3) Hands-on Activities • Each student creates his/her own MS PowerPoint slideshow to present their work and data from Units 1 & 2 with MS Excel statistical graphs from the take-home assignment	1 hr	• Statistical Graphs from take-home assignments by individual students
(4) Presentation and Conclusion • One student will be randomly selected to present his/her MS PowerPoint slideshow in class • To extend this activity and appreciate students' learning contribution, the teacher together with the whole class may select one best performer at the end • The teacher makes a final remark by going through the module learning outcomes with students	1 hr	• PPT (P12-14)
Total	**2 hr 30 min**	

2.3.4 Assessment (if appropriate)

Student's PowerPoint Slideshow and class presentation, if appropriate will be reviewed during and after the class.

3 Resources

3.1 Resources for Unit 1 – Paper Airplane Design

- PPT (Unit 1);
- Learning Portfolio; and
- Learning Portfolio (Teacher Version).

3.2 Resources for Unit 2 – Go against the Wind

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

3.3 Resources for Unit 3 – Pitching Day

- PPT (Unit 3);
- Learning Portfolio; and
- Learning Portfolio (Teacher Version).

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6 Project Team

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