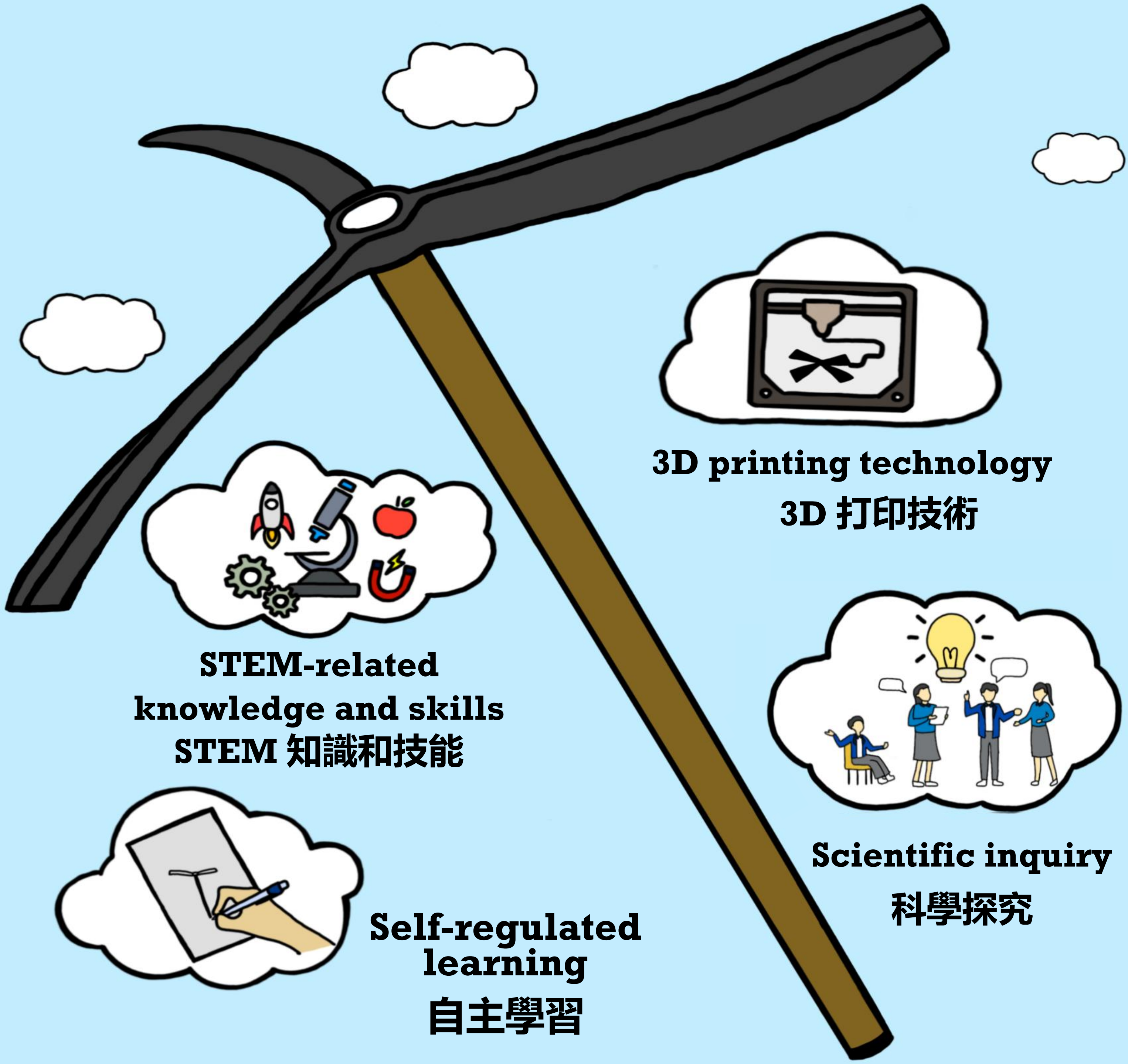
Hopping into the Learning of Forces: 3D-printed Hopter

使用 3D 打印：捕「竹」蜻蜓力學原理



優質教育基金
Quality Education Fund

Faculty of Education
The University of Hong Kong
香港大學教育學院

Table of Contents

目錄

Teacher's Manual

Hopping into the Learning of Forces: 3D-printed Hopter

<u>Topic</u>

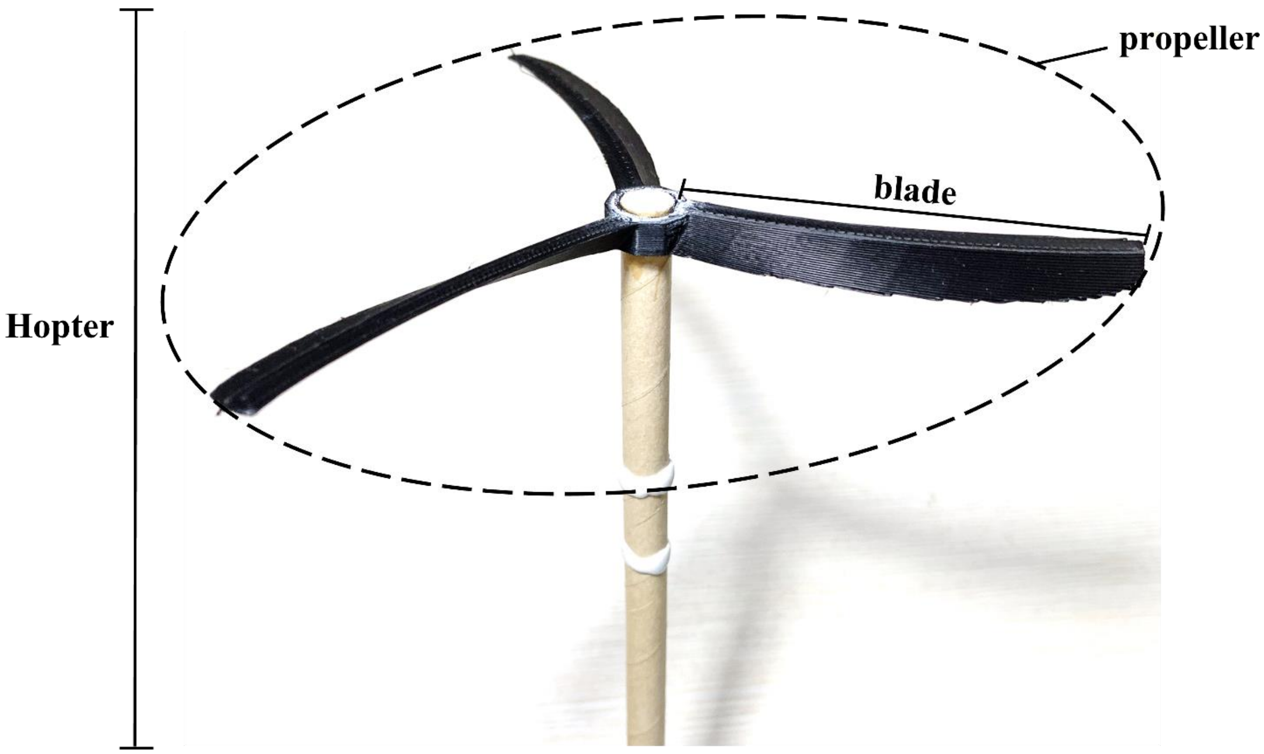
Force and Motion

<u>Target learners</u>

KS3 (Secondary Two students)

<u>Introduction</u>

In response to the call for STEM education, this project aims to develop students' understanding of the principles of flying (e.g., action-reaction force pairs) and identify the factors (e.g., the radius of propeller) affecting the flying time of a 3D-printed Hopter.



Project Learning Objectives[1] (Appendix A: Project Learning Objectives for further details)

Regarding the CDC document, this project aims to achieve three learning outcomes: Knowledge and Understanding (K), Skills and Process (S), and Values and Attitudes (A).

Knowledge and Understanding (K)	● 11.1 Motion: "uniform and non-uniform motion" ● 11.2 Force: "effect of force" and "balanced and unbalanced forces" ● 11.3-11.4 Gravity, Friction and Air Friction: "weight and mass" and "effect of air resistance" ● 11.5 Action and Reaction: "action and reaction force pairs"
Skills and Process (S)	● observe and investigate the flying process of students' Hopters ● investigate the characteristics of the Hopter designs with precise measurements and records ● design a fair investigation by asking the correct scientific questions and identifying the variables in the experiment ● handle the apparatus and take the precautions carefully in the experiment ● classify the data collected to compare the similarities and differences of the Hopter designs ● deduce the relationship of the variables as used in the design. ● infer from the data to construct scientific explanations and conclusions ● communicate within their group effectively throughout the project
Values and Attitudes (A)	● develop curiosity in daily phenomena and an interest in science

Aim of the project

This project encourages students to design and build a Hopter that flies in the air for the longest time. (Or any other aims that teachers prefer).

[1] Supplement to the Science Education Key Learning Area Curriculum Guide: Science (Secondary 1-3). Page 6-11, Education Bureau, HKSARG, Retrieved from: https://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/Science(S1-3)_supp_e_2017.pdf

Outline of the Project

There are three stages in this project:

<table>
<tr><td colspan="2">Time</td><td>Proposed teaching and learning activity</td></tr>
<tr><td rowspan="2">Stage 1</td><td>Lessons 1 - 2</td><td>● Interest promoting and project introduction

Students are expected to
● justify the principle of Hopter flying by studying the blades design of the propeller;
● conduct internet research to formulate their theory; and
● devise a project plan on investigating the factors affecting the flying time of Hopter.

(Appendix B: Suggested variations for the Hopters' design)</td></tr>
<tr><td>Post-Lesson</td><td>Devise a project plan for a scientific investigation
→ remind students about different factors affecting the Hopter flight</td></tr>
<tr><td rowspan="2">Stage 2</td><td>Lessons 3 - 4</td><td>Students are expected to
● execute their project plan on studying the factors affecting the flying time of Hopter;
● amend their design while building and testing their prototype; and
● record their results and discuss the findings with their team members</td></tr>
<tr><td>Post-Lesson</td><td>Gather findings and write report drafts</td></tr>
<tr><td rowspan="2">Stage 3</td><td>Lesson 5 - 6</td><td>Students are expected to
● present their findings to classmates and demonstrate their inquiry process;
● justify their theories on hypothesis; and
● discuss their experimental results using accurate scientific terminologies.</td></tr>
<tr><td>Post-Lesson</td><td>Submit the reports</td></tr>
</table>

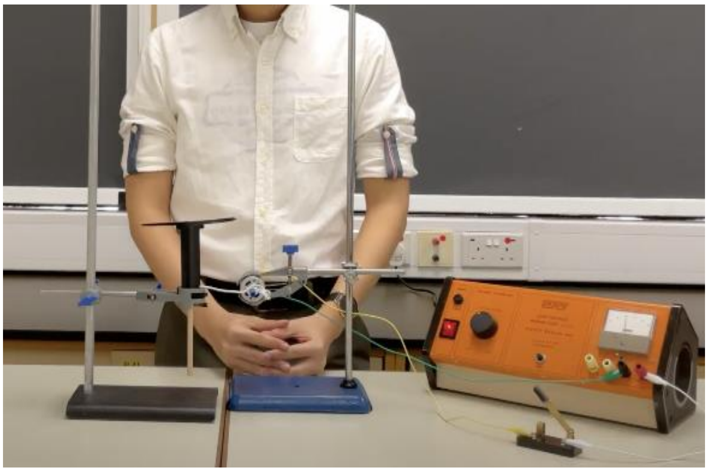
Worksheet Exemplars

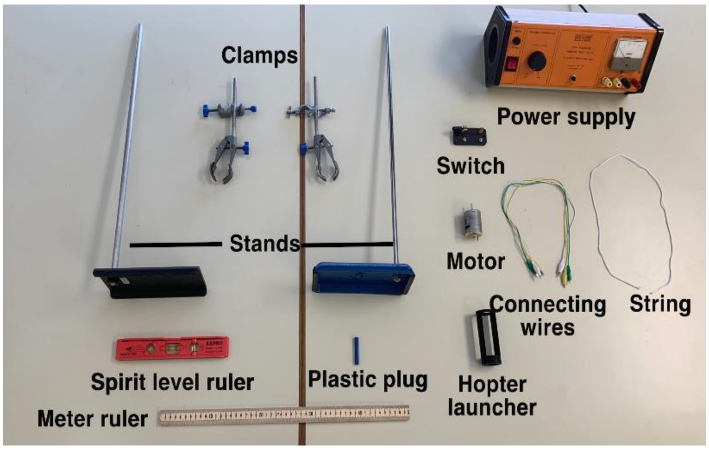
To cater to the learners' diversity, templates for student reports for 'Guided-Open Inquiry' and 'Guided Inquiry' exemplars are provided. Teachers may design the level of inquiry in different sections of the project. (Appendix C: Variations in inquiry level)

Hopter launcher set-up

Link to the set-up video:

https://bit.ly/3BbNTGH





Materials

Meter ruler	1
Spirit level ruler	1
Plastic plug	1
Stand and clamp	2
String	1
Hopter launcher (3D print)	1
Low-voltage power supply	1
Switch	1
Electronic motor	1
Connecting wires	1

Preparation

1. Push the wall plug to the motor at its full length and swirled by a string.
2. Put the stands side by side, as shown in the figure. Hold the Hopter launcher and the motor by the clamps, respectively.
3. Connect the motor in series with a switch and a power supply, as shown in the figure.
4. Adjust the two stands to fix the distance between the launcher and motor.
5. Using the spirit level ruler, adjust the position of the clamp, so that the launcher and motor stay at the same horizontal level.

Safety and precaution

- Wear safety goggles when necessary.
- Ensure that students' hands are away from the spinning motor as the string may accidentally hit their hands.
- Be aware that the string may get stuck in the motor while spinning. Make sure to turn off the motor before removing the string.

Appendix A: Project Learning Objectives[2]

Regarding the CDC document, this project aims to achieve three learning outcomes: Knowledge and Understanding (K), Skills and Process (S), and Values and Attitudes (A).

Knowledge and Understanding (K)	● 11.1 Motion: Students may describe the motion of the Hopters with accurate scientific wordings such as “uniform and non-uniform motion.” ● 11.2 Force: The motion of the Hopter can be described and explained by the concepts of “effect of force” and “balanced and unbalanced forces”. Students first have to recognise there is a non-uniform motion, then deduce there is an unbalanced force acting on the Hopter. Students may also differentiate between contact and non-contact forces in the project. ● 11.3-11.4 Gravity, Friction and Air Friction: Some of the concepts in these topics can be used to explain the Hopter motion in students’ testing, such as ideas of “weight and mass” and the effect of air resistance. ● 11.5 Action and Reaction: The motion of the Hopter can be described and explained by the concepts of “action and reaction force pairs”, students have first to recognise there is an action force acting on the Hopter, then to discover the reaction force pair and deduce the force pair is acting on which two bodies. It could be a great way to elicit and assess students' understanding of these concepts.
Skills and Process (S)	● Students have to observe and investigate the flying process of their Hopters, hence, to investigate the characteristics of the Hopter designs with precise measurements and records. ● Students have to design a fair investigation by asking the correct scientific questions and identifying the variables in the experiment. ● Henceforth, students have to handle the apparatus and take precautions carefully during the experiment. ● Afterwards, students have to classify the data collected to compare the similarities and differences of the Hopter designs, hence deducing the relationship of the variables as used in the design. Students may also have to infer from the data to construct scientific explanations and conclusions. ● Students have to communicate within their group effectively throughout the project.

[2] Supplement to the Science Education Key Learning Area Curriculum Guide: Science (Secondary 1-3). Page 6-11, Education Bureau, HKSARG, Retrieved from: https://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/Science(S1-3)_supp_e_2017.pdf

Values and Attitudes (A)	This project allows students to develop curiosity about daily phenomena, such as wondering how things fly instead of simply accepting the fact that they fly. It also fosters students' interest in science and appreciates the wonder of the technological world, such as explaining the flying principle of drones using scientific knowledge. Besides, this project is developed to be an excellent alternative learning and teaching activity. One of the popular activities suggested in the curriculum is using water rockets to demonstrate the action and reaction force pair. While the visual effect of the water rocket is strong, it is often troublesome to prepare the relevant materials on such a large scale. Also, the mechanism of water rockets could be more difficult to understand as it involves complex concepts such as pressure. On the other hand, Hopter is a popular childhood toy, so it is more familiar to students and it is easier for them to comprehend how a fan blade spins to create wind.

Appendix B: Suggested variations for the Hopters design

Throughout the project, students are expected to create the .stl files containing their 3D Hopter designs. Students may use popular 3D software editing apps such as "Tinkercad" and "Vectary" to draw their 3D models. For differentiated learners, we also provide some drawn 3D blades (See, "3D printing files" folder) for easier assembling after drawing the central core connecting all the blades.

As students can design their own Hopters, there could be many variations. For example,

- Radius of the propeller
- Number of blades
- Tilted angle
- Printing density of the Hopter
- Dimensions of the central core
- Types and dimensions of the straws

Based on the 3D blades provided to teachers as a reference, 3 variables, "Radius of the propeller" (60-80 mm), "Number of blades" (2-4 blades) and "Tilted angle" (15-35 degrees) are chosen. The naming of the .stl files and folders is as follows:

Files	Instruction of naming
Folders	Hopter_(Radius of propeller)mm_T(Tilted angle) E.g., "Hopter_70mm_T15" indicates this folder stores Hopter .stl files for 2-4 blades of length 70mm in the tilted angle of 15 degrees.
Hopter .stl files	Hopter_W(Number of blades)_(Radius of propeller)mm_T(Tilted angle) E.g., "Hopter_W3_80mm_T35" indicates it is the .stl file for Hopter of 3 blades, radius of 80 mm in the tilted angle of 35 degrees.
Blade .stil files	(Radius of propeller)mm_T(Tilted angle) E.g., "60mm_T15" indicates it is the .stl file for a propeller in the radius of 60 mm in the tilted angle of 15 degrees.

Possible variations of the propeller	The radius of the propeller	Number of blades	Tilted angle of the blades
Best performance at	80 mm	3	15°

Appendix C: Variations in inquiry level

In fact, there are numerous variations in inquiry levels based on the design of the project template:

<table>
<tr><th colspan="2"></th><th colspan="4">Level of Inquiry</th></tr>
<tr><th colspan="2">Features</th><th>Open</th><th>Guided</th><th>Driven</th><th>Closed</th></tr>
<tr><td colspan="2">Introduction</td><td>Students search for other resources to gather extra information</td><td>Students are guided with scaffolding questions concerning specific areas and sources of information</td><td>Students are provided with directed connections to specific information</td><td>(Students are not required to search for external information)</td></tr>
<tr><td rowspan="2">Project Plan</td><td>Posing project aims</td><td>Students pose a scientific question(s) to be answered in this project

Students may formulate the aims of the project</td><td>Students choose the question(s) from sample questions or pose new questions

Students may formulate the aims of the project</td><td>Students may attempt and clarify the sample questions

The aim of the project is suggested to be the Hopters flying for the longest time</td><td>Students engage in teacher-selected questions

The aim of the project is suggested to be the Hopters flying for the longest time</td></tr>
<tr><td>Posing procedure</td><td>Students determine and design the scientific procedures to collect evidence</td><td>Students are guided with scaffolding questions to design the procedures so as to collect specific data</td><td>Students are provided with detailed steps of the experiment</td><td>Students are provided with detailed steps of the experiment</td></tr>
<tr><td colspan="2">Result</td><td>Students record and summarise the results effectively</td><td>Students record and are guided with questions on summarising the data

A concise table with blanks will be provided</td><td>Students record data and are asked to summarise

A concise table with blanks will be provided</td><td>Students record data and are told how to summarise

A concise table with blanks will be provided</td></tr>
</table>

Discussion and Reflection	Students formulate the scientific explanation and answer the questions they posed, by inferring from the data they collected Students articulate sound and scientific arguments by summarising and analysing the results and explanation More open-ended questions are introduced for students to share their thinking throughout the project	Students are guided with scaffolding questions in the data analysis process to formulate a scientific explanation Students are guided with scaffolding questions concerning the content of the discussion, and articulate their views effectively More open-ended questions are introduced for students to share their thinking throughout the project	Students are provided with concrete examples of inferring and interpreting the data to draw a scientific explanation Students are provided with guiding questions and formulate their discussion by answering the questions directly Recalling questions will be provided for students to describe their scientific discovery	Students are provided with concrete data with scientific interpretation to draw a conclusion Students are scaffolded with steps and procedures to communicate with the audience effectively Recalling questions will be provided for students to describe their scientific discovery

使用 3D 打印：捕「竹」蜻蜓力學原理

探究報告 (引導式探究)

甲.　簡介

無人機日趨盛行，撇除複雜的電路，它與多啦 A 夢的法寶「竹蜻蜓」無異。透過本活動，你要設計並製作能停留空中最長時間的竹蜻蜓，探究影響竹蜻蜓運動的因素。

乙.　探究計劃

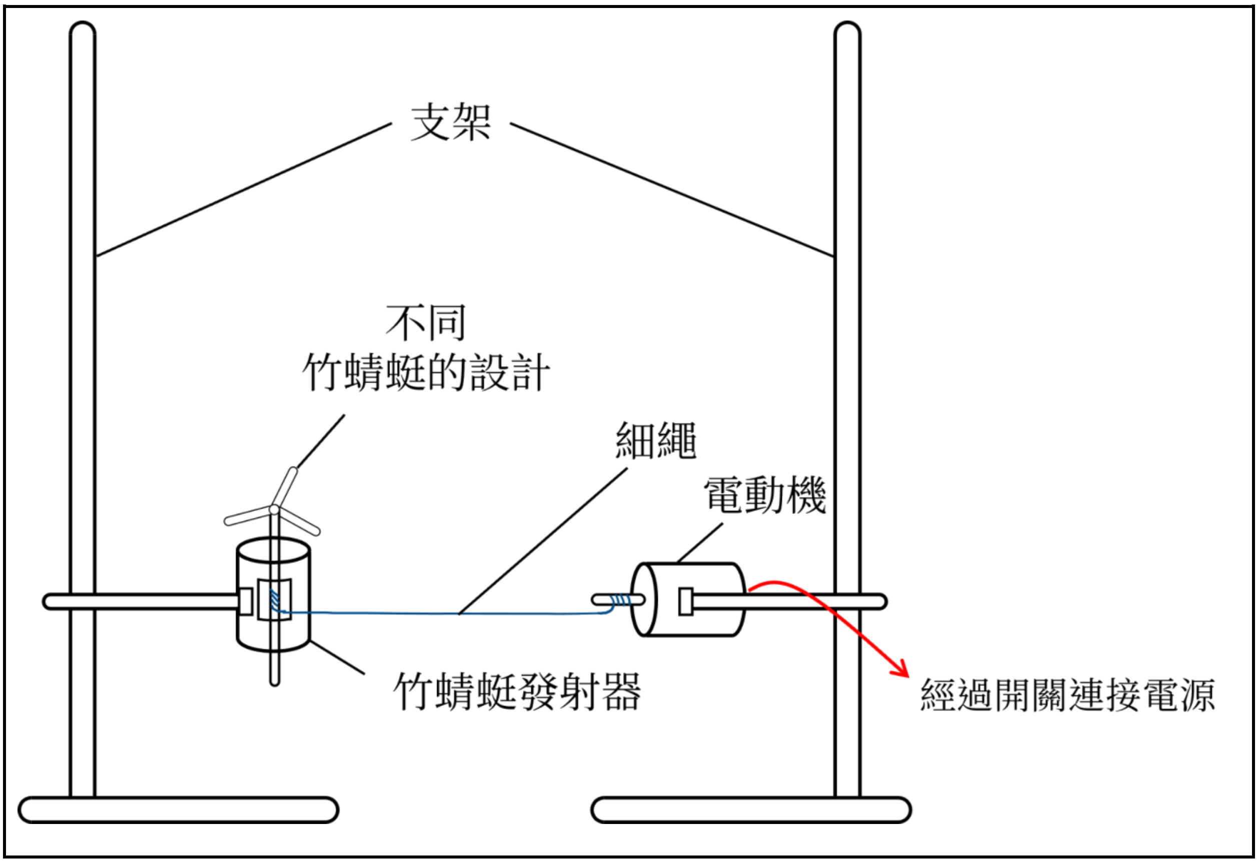
I.　假設

一個扇葉較長的竹蜻蜓能停留在空中較長時間。

II.　變項表

<u>因變項</u> (要量度的變項)	<u>獨立變項</u> (唯一改變的變項)	<u>對照變項</u> (保持不變的變項)
竹蜻蜓在空中的飛行______	螺旋槳的__________／ 扇葉的____________	在適當空格內加上「✔」 螺旋槳的半徑 ☐ 竹蜻蜓扇葉的數目 ☐ 扇葉的傾斜角度 ☐ 竹蜻蜓的製作物料 ☐

III.　步驟



1. 依照上圖裝置儀器。
2. 把細繩穿過竹蜻蜓發射器。
3. 把細繩束在竹蜻蜓上並放置於竹蜻蜓發射器內。
4. 關閉電路並記錄竹蜻蜓的飛行時間。
5. 利用不同竹蜻蜓的設計重複第 2 至第 4 步。

丙. 實驗結果及分析

	竹蜻蜓的飛行時間			
	第一次	第二次	第三次	平均

根據試驗結果，哪一個竹蜻蜓的設計表現最好？

____

丁. 實驗結果的討論及最終成品

討論

1. 描述你所設計的竹蜻蜓的表現。試驗結果支持你的實驗假設嗎？

____

____

2. 進行三次試驗的目的是什麼？試討論本實驗中一個主要的誤差來源及改善方法。

____

____

____

戊. 總結

試總結是次探究活動。

己. 個人反思

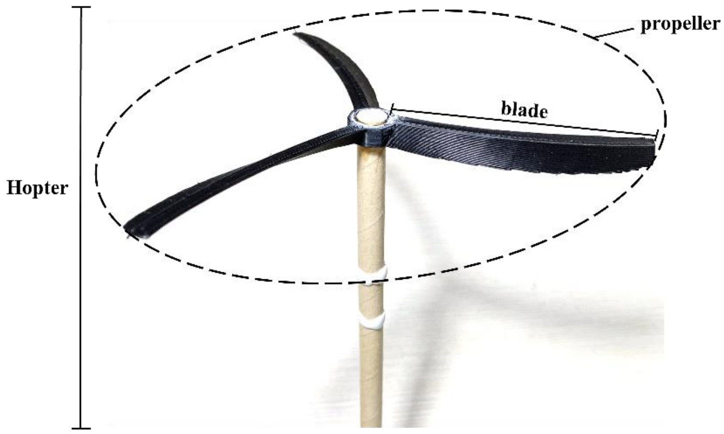
試用下表總結你的學習進程。

我已知道的 **(探究活動前)**	我在探究活動中 想知道的	我在探究活動中 新學到的

Hopping into the Learning of Forces: 3D-printed Hopter

Project report (Guided Inquiry)

A. Introduction



Drones are becoming increasingly popular these days and they resemble a simplified version of 'Hopter', a gadget from the comic Doraemon. This project will identify some factors that affect the flying time of a Hopter.

B. Project Plan

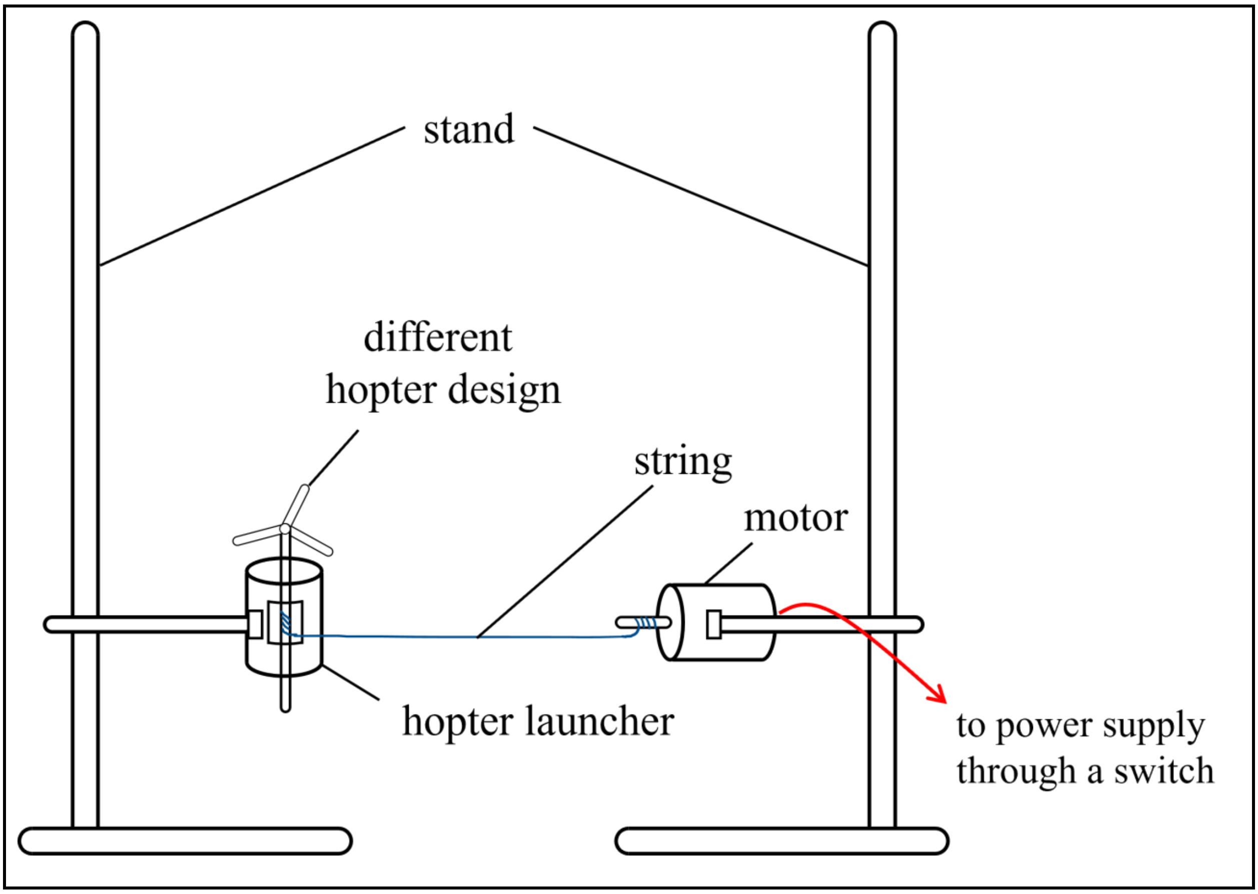
I. Hypothesis

A Hopter with a larger radius of propellers will fly longer in the air.

II. Identifying variables

Dependent variable (What you should measure)	Independent variable (What you should change)	Controlled variable(s) (What you should keep the same)
The __________ of the Hopter	__________ of the propeller	Put a '✔' in the appropriate box Radius of propeller ☐ Number of Hopter blade ☐ Tilted angle of the blade ☐ Materials used for the Hopter ☐

III. Procedures



1. Set up the apparatus as shown in the figure above.
2. Guide the string into the Hopter launcher.
3. Swirl the string on the Hopter and place it in the Hopter launcher.
4. Close the switch and record the flying time of the Hopter.
5. Repeat steps 2 to 4 with different radiuses of the propellers.

D. Results analysis

	Flying time of the Hopter			
	Trial 1	Trial 2	Trial 3	Average

Based on the experimental results, which Hopter performs the best?

____

E. Discussion of the experimental result and the final product

Experimental Discussion

1. Describe the performance of the Hopter with various propellers' radii. Do the results support the hypothesis?

____

____

2. What is the purpose of taking three trials? Discuss one possible source of error and suggest one improvement to reduce the error.

____

____

____

F. Conclusion

What is the conclusion of this experiment?

____

G. Self-reflection

You may use the following KWL template to summarise your learning.

What I *Know* before the activity	**What I *Want to Know* during the activity**	**What I *Learned* after the activity**

使用 3D 打印：捕「竹」蜻蜓力學原理

探究報告 (引導式 - 開放式探究)

甲.　簡介

無人機日趨盛行，撇除複雜的電路，它與多啦A夢的法寶「竹蜻蜓」無異。透過本活動，你要設計並製作能停留空中最長時間的竹蜻蜓，探究影響竹蜻蜓運動的因素。

資料搜集：飛行的原理

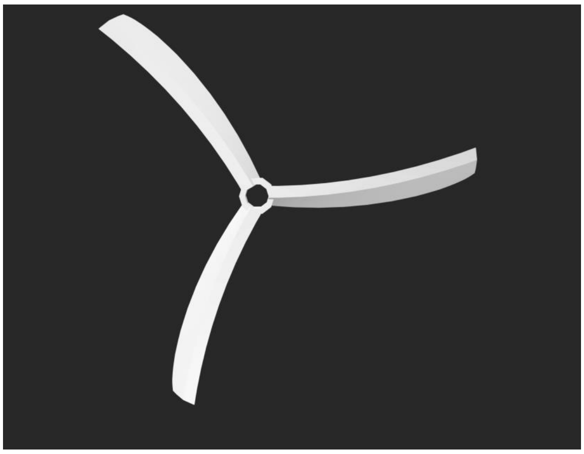
（根據互聯網搜尋結果以及就你所知，試解釋飛行的原理並舉例能影響飛行時間的因素，並加以論述。）

乙. 探究計劃

I. 假設

影響竹蜻蜓飛行的因素是甚麼？由此，制定你的實驗假設並畫出你的竹蜻蜓立體設計圖。

下列為一竹蜻蜓 3D 模型（.stl 檔案）範例，你將會以 3D 打印技術設計你的竹蜻蜓。老師將會提供竹蜻蜓發射器以作試驗。（請於日期前提交.stl 檔案）



II. 變項表

因變項 (要量度的變項)	獨立變項 (唯一改變的變項)	對照變項 (保持不變的變項)
		在適當空格內加上「✔」 螺旋槳的半徑 ☐ 竹蜻蜓扇葉的數目 ☐ 扇葉的傾斜角度 ☐ 竹蜻蜓的製作物料 ☐

III. 步驟

你將如何設計並進行實驗？在下方繪畫並**標示**你的實驗裝置，及描述能驗證假設的實驗步驟。

（小提示：在重覆實驗時，有什麼需要改變？試在繪圖中標示）

丙. 實驗結果及分析

	竹蜻蜓的飛行時間			
	第一次	第二次	第三次	平均

根據試驗結果，哪一個竹蜻蜓的設計表現最好？

丁.　實驗結果的討論及最終成品

討論

1.　描述你所設計的竹蜻蜓的表現。試驗結果支持你的實驗假設嗎？

2.　實驗結果如何影響最後的竹蜻蜓設計？

3.　進行三次試驗的目的是什麼？試討論本實驗中一個主要的誤差來源及改善方法。

4.　根據實驗結果或你搜集的資料，你可如何完善你的竹蜻蜓設計或是實驗方法，以達到所求目的？

戊. 總結

試總結是次探究活動。

己. 個人反思

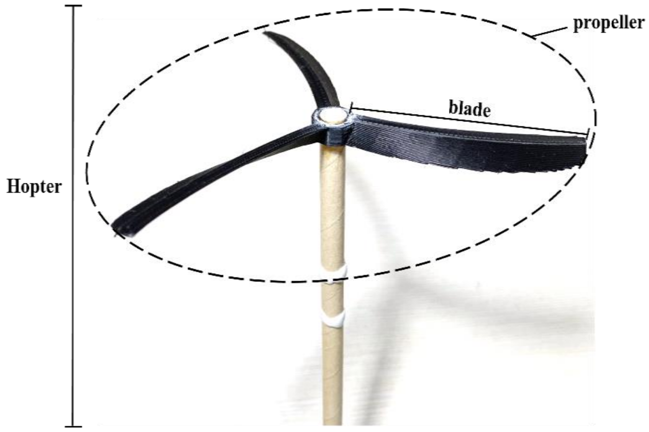
1. 於活動中，你學懂了什麼？你享受設計和測試竹蜻蜓的過程嗎？

2. 你還有想繼續探究的其他問題/現象嗎？

Hopping into the Learning of Forces: 3D-printed Hopter Project report (Guided-Open Inquiry)

A. Introduction

Drones are becoming increasingly popular these days and they resemble a simplified version of 'Hopter', a gadget from the comic Doraemon. This project will identify some factors that affect the Hopter's motion. Moreover, you will build your own Hopter that flies for the longest time.



Background Information Research: Principle of Flying

(Based on your research findings, what are the concepts and principles of flying? Can you identify the factors affecting the flying time?)

B. Project Plan

I. Hypothesis

What are the factors affecting how a Hopter flies? Formulate a hypothesis and draw your Hopter design with labels and dimensions.

Reference: A Hopter sample is shown below. You will be provided with a Hopter launcher to test your designed Hopters made with a 3D printer. (Please submit the .stl file by DATE).

II. Identifying variables

Dependent variable (What you should measure)	Independent variable (What you should change)	Controlled variable(s) (What you should keep the same)
		Put a '✔' in the appropriate box Radius of propeller ☐ Number of Hopter blade ☐ Tilted angle of the blade ☐ Materials used for the Hopter ☐

III. Procedures

How will you carry out the experiment? Draw a **labelled** diagram for apparatus set-up and describe the experimental procedures to test your hypothesis.

(Hint: What needs to be changed in each trial? Label as well the change in your diagram.)

C. Results analysis

	Flying time of the Hopter			
	Trial 1	Trial 2	Trial 3	Average

Based on the experimental results, which Hopter performs the best?

____

D. Discussion of the experimental result and the final product

Experimental Discussion

After designing and testing your final product, we may discuss the following:

1. Describe the performance of the Hopter in your design. Do the results support the hypothesis?

____

____

____

2. How do the experimental results inform your final design of the Hopter?

____

____

3. What is the purpose of taking three trials? Discuss one possible source of error and suggest one improvement to reduce the error.

____

____

____

4. Based on your findings or further research, how would you modify your Hopter structure or testing procedure to achieve your goal?

____

____

E. Conclusion

What is the conclusion of this experiment?

____

____

F. Self-reflection

1. What have you learnt throughout this project? Do you enjoy the building and testing of the Hopter?

____

____

____

2. Is there anything you want to continue exploring in the future?

____

____

____

使用 3D 打印：捕「竹」蜻蜓力學原理

探究報告 (引導式探究)

甲. 簡介

無人機日趨盛行，撇除複雜的電路，它與多啦 A 夢的法寶「竹蜻蜓」無異。透過本活動，你要設計並製作能停留空中最長時間的竹蜻蜓，探究影響竹蜻蜓運動的因素。

乙. 探究計劃

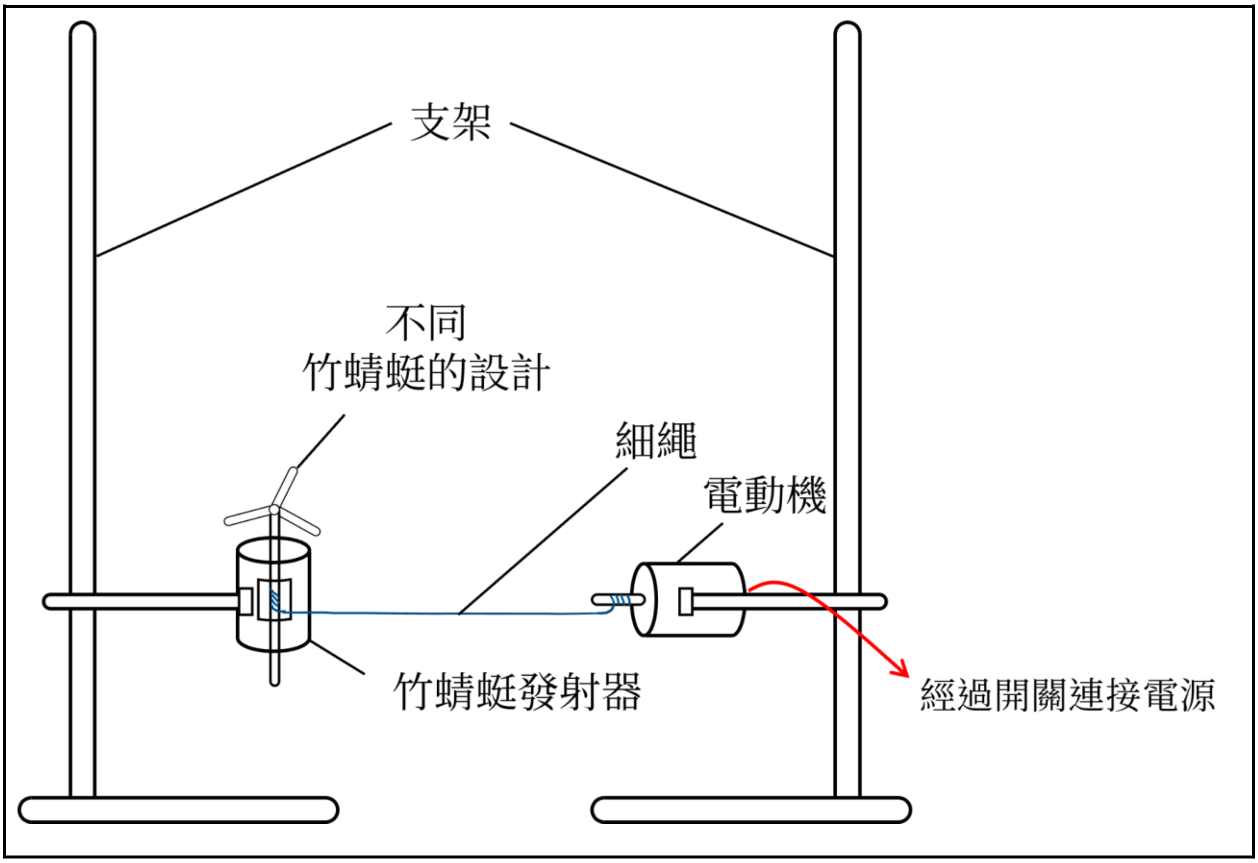
I. 假設

一個扇葉較長的竹蜻蜓能停留在空中較長時間。

II. 變項表

因變項 (要量度的變項)	獨立變項 (唯一改變的變項)	對照變項 (保持不變的變項)
竹蜻蜓在空中的飛行＿時間＿	螺旋槳的＿＿半徑＿＿／ 扇葉的＿＿＿長度＿＿	在適當空格內加上「✔」 螺旋槳的半徑 ☐ 竹蜻蜓扇葉的數目 ☑ 扇葉的傾斜角度 ☑ 竹蜻蜓的製作物料 ☑

III. 步驟



1. 依照上圖裝置儀器。
2. 把細繩穿過竹蜻蜓發射器。
3. 把細繩束在竹蜻蜓上並放置於竹蜻蜓發射器內。
4. 關閉電路並記錄竹蜻蜓的飛行時間。
5. 利用不同竹蜻蜓的設計重複第二至第四步。

丙.　實驗結果及分析

螺旋槳的半徑／扇葉的長度	竹蜻蜓的飛行時間			
	第一次	第二次	第三次	平均

根據試驗結果，哪一個竹蜻蜓的設計表現最好？

(視乎學生實驗結果)

丁.　實驗結果的討論及最終成品

討論

1.　描述你所設計的竹蜻蜓的表現。試驗結果支持你的實驗假設嗎？

(學生應描述並總結他們的實驗結果)

(需與學生與乙部的探究計劃相連貫)

(根據學生所選變項的任何合理答案)

2.　進行三次試驗的目的是什麼？試討論本實驗中一個主要的誤差來源及改善方法。

（任何合理答案，如：）

- 系統誤差，如竹蜻蜓並非平放於發射器上。
- 人為誤差，如使用秒錶時讀數誤差。

戊. 總結

試就是次探究活動作出總結

（學生可總結實驗結果及額外資料以得出實驗總結）

己. 個人反思

試用下表總結你的學習進程。

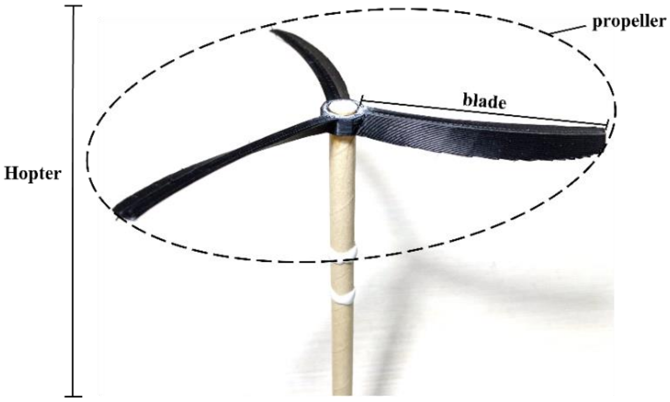
我已知道的 **(探究活動前)**	我在探究活動中 想知道的	我在探究活動中 新學到的

Hopping into the Learning of Forces: 3D-printed Hopter

Project report (Guided Inquiry)

A. Introduction

Drones are becoming increasingly popular these days and they resemble a simplified version of 'Hopter', a gadget from the comic Doraemon. This project will identify some factors that affect the flying time of a Hopter.



B. Project Plan

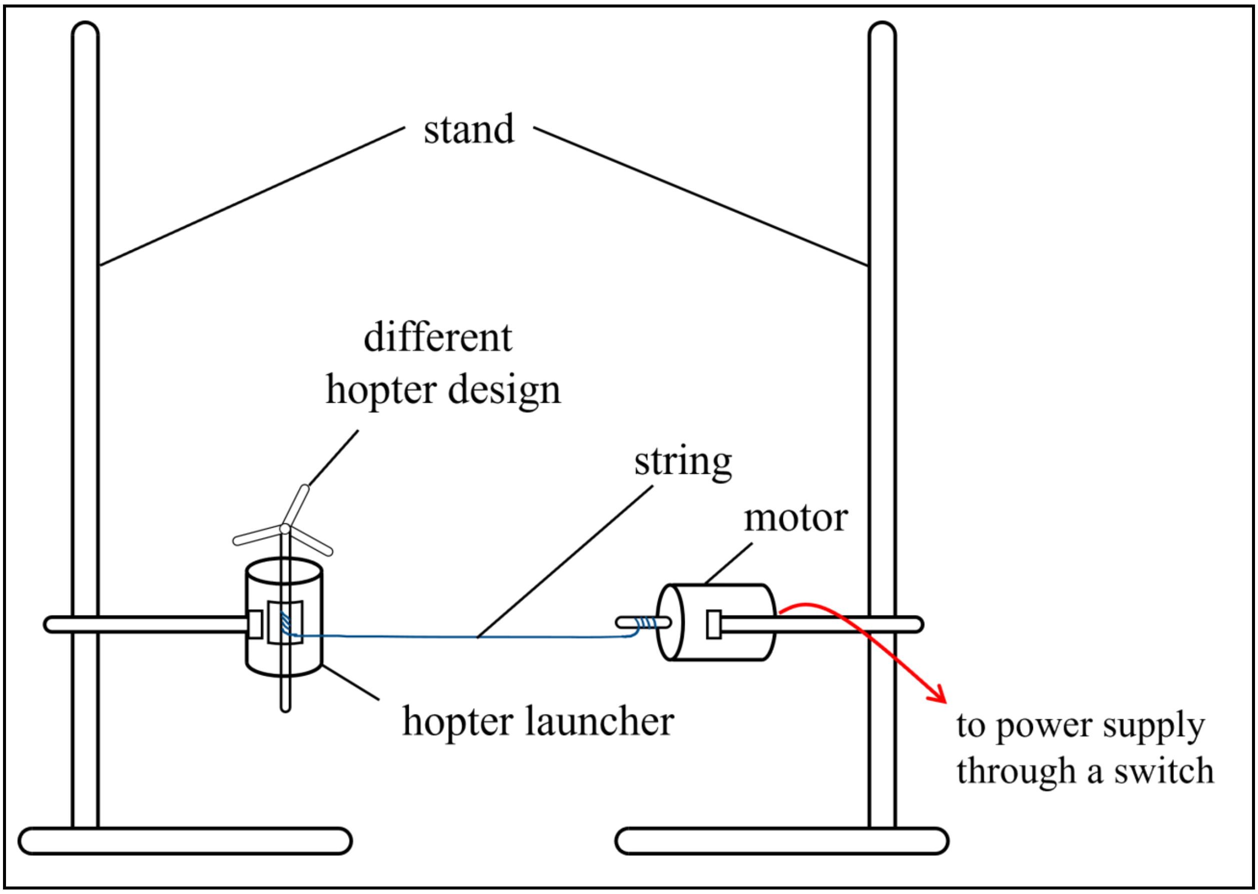
I. Hypothesis

A Hopter with a larger radius of propellers will fly longer in the air.

II. Identifying variables

Dependent variable (What you should measure)	Independent variable (What you should change)	Controlled variable(s) (What you should keep the same)
The flying time of the Hopter	Radius of the propeller	Put a '✔' in the appropriate box Radius of propeller ☐ Number of Hopter blade ☑ Tilted angle of the blade ☑ Materials used for the Hopters ☑

III. Procedures



1. Set up the apparatus as shown in the figure above.
2. Guide the string into the Hopter launcher.
3. Swirl the string on the Hopter and place it in the Hopter launcher.
4. Close the switch and record the flying time of the Hopter.
5. Repeat steps 2 to 4 with different radius of the propellers.

D. Results analysis

The radius of the propeller	Flying time of the Hopter			
	Trial 1	Trial 2	Trial 3	Average

Based on the experimental results, which Hopter performs the best?

(depends on students' performance)

E. Discussion of the experimental result and the final product

Experimental Discussion

1. Describe the performance of the Hopter with various propellers' radii. Do the results support the hypothesis?

   (students may describe and summarize the experimental results)

2. What is the purpose of taking three trials? Discuss one possible source of error and suggest one improvement to reduce the error.

   (any reasonable answers, include

   - Instrumental errors such as the alignment of the Hopter in the launcher
   - Human errors in measuring the time of flight of Hopters if the stopwatch is used)

F. Conclusion

What is the conclusion of this experiment?

(students may describe and summarise the experimental results)

G. Self-reflection

You may use the following KWL template to summarise your learning.

What I *Know* before the activity	**What I *Want to Know* during the activity**	**What I *Learned* after the activity**

使用 3D 打印：捕「竹」蜻蜓力學原理

探究報告 (引導式 - 開放式探究)

甲. 簡介

無人機日趨盛行，撇除複雜的電路，它與多啦 A 夢的法寶「竹蜻蜓」無異。透過本活動，你要設計並製作能停留空中最長時間的竹蜻蜓，探究影響竹蜻蜓運動的因素。

資料搜集：飛行的原理

（根據互聯網搜尋結果以及就你所知，試解釋飛行的原理並舉例能影響飛行時間的因素，並加以論述之。）

學生可就下列框架回答題目：

1. 物體移動的原因
   - 不平衡力作用在物體上（學生的前置知識）
   - 牛頓第二運動定律 $F_{net} = ma$（互聯網搜尋結果）
2. 作用在竹蜻蜓上的力
   - 繪畫隔離體圖以顯示所有作用在竹蜻蜓上的力（學生的前置知識）
     → 重力（由重心指向下）
     → 升力／推進力
   - 作用在竹蜻蜓上的升力來源（互聯網搜尋結果）
     → 柏努利定律／牛頓第三運動定律／壓強梯度力
3. 其他可能影響飛行的因素
   - 飛機機翼設計的考量

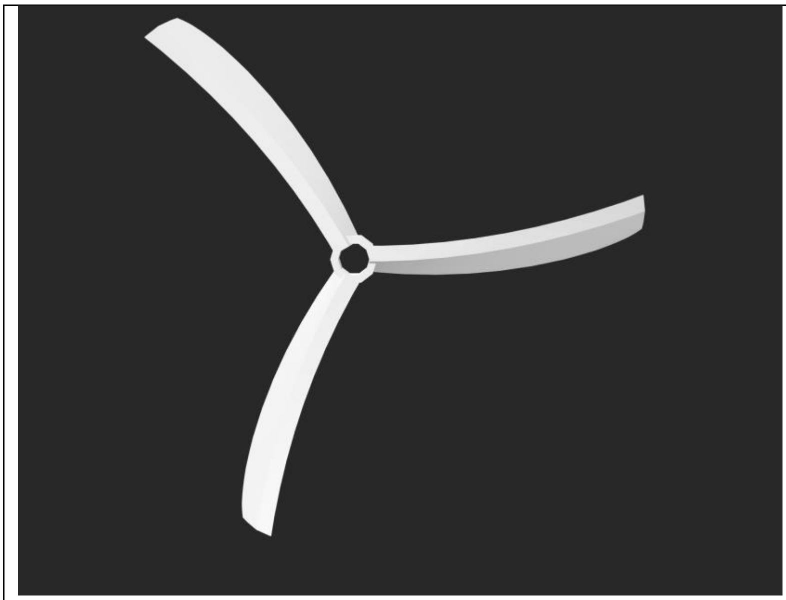
乙. 探究計劃

I. 假設

影響竹蜻蜓飛行的因素是甚麼？由此，制定你的實驗假設並畫出你的竹蜻蜓立體設計圖。

（學生可自由選擇變項，或老師和學生一同選擇變項。請查閱下述教師參考。）

下列為一竹蜻蜓 3D 模型（.stl 檔案）範例，你將會以 3D 打印技術設計你的竹蜻蜓。老師將會提供竹蜻蜓發射器以作試驗。（請於日期前提交.stl 檔案）



教師參考

變項	相關解釋／預期結果
竹蜻蜓扇葉數目	更多的扇葉能令風速更快（皆因更多扇葉拍打空氣粒子），令作用在竹蜻蜓上的升力量值更大。作用在竹蜻蜓上的不平衡力（／向上的淨力）令竹蜻蜓的方向和速度發生變化（／加速）。惟增加扇葉數目將會增加竹蜻蜓的重量。
扇葉的傾斜角度	更大的扇葉角度能吹入更多的空氣（皆因螺旋槳旋轉時接觸更多空氣粒子），令作用在竹蜻蜓上的升力量值更大。作用在竹蜻蜓上的不平衡力（／向上的淨力）令竹蜻蜓的方向和速度發生變化（／加速）。惟風速不均以及風向不定都會影響竹蜻蜓的飛行時間。 或 更大的扇葉角度會令風速下降（皆因空氣粒子並非以垂直於螺旋槳的方向向下移動），令作用在竹蜻蜓上的升力量值更小。作用在竹蜻蜓上的不平衡力（／向上的淨力）令竹蜻蜓的方向和速度發生變化（／加速）。惟風速不均以及風向不定都會影響竹蜻蜓的飛行時間。
螺旋槳半徑	更大的螺旋槳半徑能吹入更多空氣（皆因更多扇葉面積拍打空氣粒子），令作用在竹蜻蜓上的升力量值更大。作用在竹蜻蜓上的不平衡力（／向上的淨力）令竹蜻蜓的方向和速度發生變化（／加速）。惟風速不均以及風向不定都會影響竹蜻蜓的飛行時間。

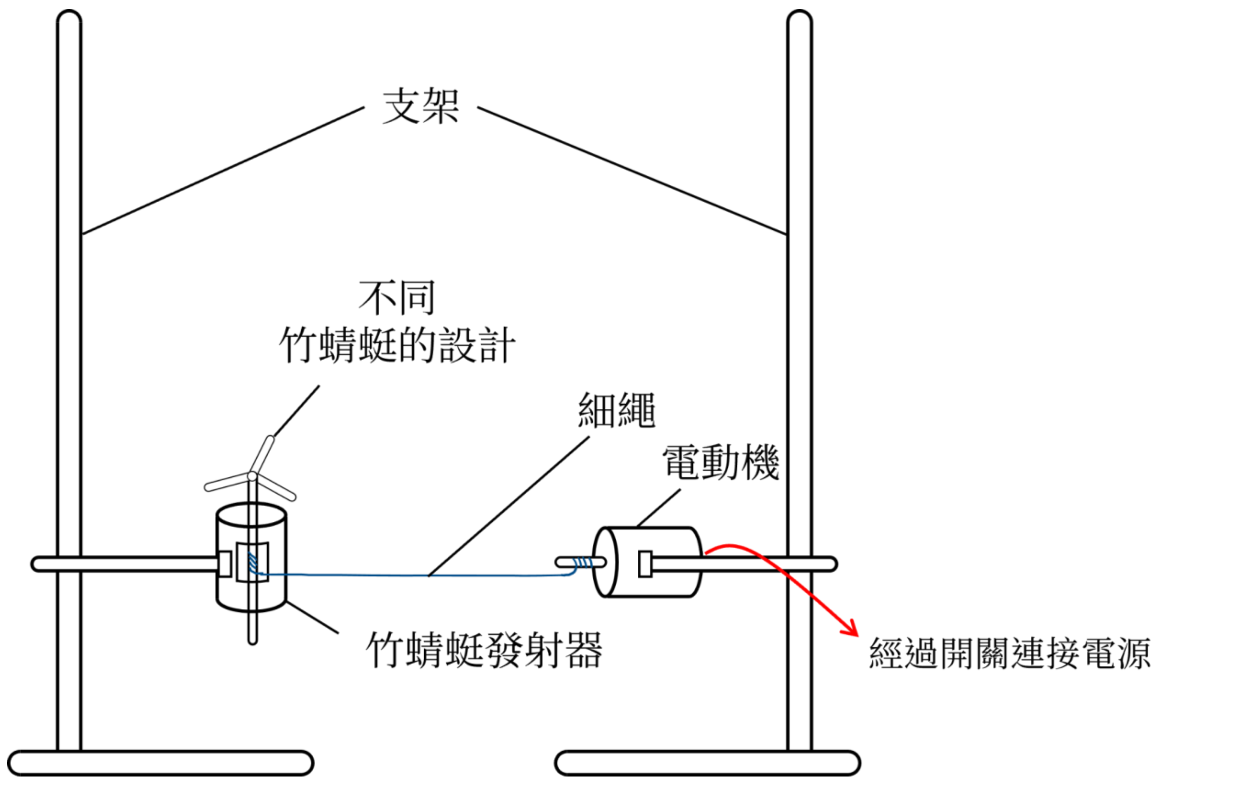
II. 變項表

<u>因變項</u> (要量度的變項)	<u>獨立變項</u> (唯一改變的變項)	<u>對照變項</u> (保持不變的變項)
竹蜻蜓在空中的飛行<u>　時間　</u>	螺旋槳的<u>　半徑　</u>／ 扇葉的<u>　長度　</u>	在適當空格內加上「✔」 螺旋槳的半徑 ☐ 竹蜻蜓扇葉的數目 ☑ 扇葉的傾斜角度 ☑ 竹蜻蜓的製作物料 ☑

III.　步驟

你將如何設計並進行實驗？在下方繪畫並**標示**你的實驗裝置，及描述能驗證假設的實驗步驟。

(小提示：在重覆實驗時，有什麼需要改變？試在繪圖中標示)



1.　依照上圖裝置儀器。
2.　把細繩穿過竹蜻蜓發射器。
3.　把細繩束在竹蜻蜓上並放置於竹蜻蜓發射器內。
4.　關閉電路並記錄竹蜻蜓的飛行時間。
5.　利用不同竹蜻蜓的設計重複第 2 至第 4 步。

丙. 實驗結果及分析

螺旋槳的半徑／扇葉的長度	竹蜻蜓的飛行時間			
	第一次	第二次	第三次	平均

根據試驗結果，哪一個竹蜻蜓的設計表現最好？

(視乎學生實驗結果)

丁. 實驗結果的討論及最終成品

討論

1. 描述你所設計的竹蜻蜓的表現。試驗結果有支持你的實驗假設嗎？

   (學生應描述並總結他們的實驗結果)

   (需與學生與乙部的探究計劃相連貫)

   (根據學生所選變項的任何合理答案)

2. 實驗結果如何影響竹蜻蜓的最後設計？

   (整合各組的最佳設計並改善竹蜻蜓的表現)

3. 進行三次試驗的目的是什麼？試討論本實驗中一個主要的誤差來源及改善的方法。

   （任何合理答案，如：）

   - 系統誤差，如竹蜻蜓並非平放於發射器上。
   - 人為誤差，如使用秒錶時讀數誤差。

4. 根據實驗結果或你搜集的資料，你可如何完善你的竹蜻蜓設計或是實驗方法以達到你所求目的？

   （答案視乎同學實驗結果）

戊. 總結

試就是次探究活動作出總結

（學生可總結實驗結果及額外資料以得出實驗總結）

己. 個人反思

1. 於活動中，你學懂了什麼？你享受設計和測試竹蜻蜓的過程嗎？

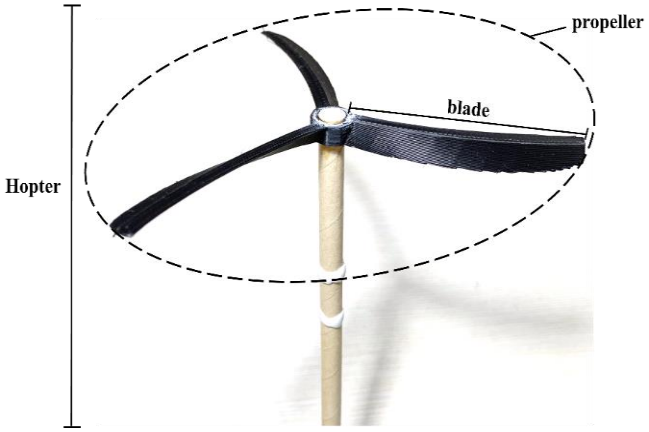
2. 你還有其他問題/現象你想繼續探究嗎？

Hopping into the Learning of Forces: 3D-printed Hopter

Project report (Guided-Open Inquiry)

A. Introduction

Drones are becoming increasingly popular these days and they resemble a simplified version of 'Hopter', a gadget from the comic Doraemon. This project will identify some factors that affect the Hopter's motion. Moreover, you will build your own Hopter that flies for the longest time.



Background Information Research: Principle of Flying

(Based on your research findings, what are the concepts and principles of flying? Can you identify the factors affecting the flying time?)

Students may start presenting their understandings of the principle of flying using the following guidance:

1. Why objects move
   - An unbalanced force acting on the moving object (students' prior knowledge)
   - Use the concept of Newton's Second Law $F_{net} = ma$ (internet research)
2. The forces acting on the Hopter
   - Draw a simple free-body diagram (students' prior knowledge)
     → weight/force of gravity (pointing downward from c.g. of the object)
     → upthrust / upward force
   - identify the source of upward force acting on the Hoper (internet research)
     → Bernoulli Principle / Newton's Third Law / Pressure Gradient Forces
3. Possible factors affecting flying (internet research)
   - Example of wings design in airplane

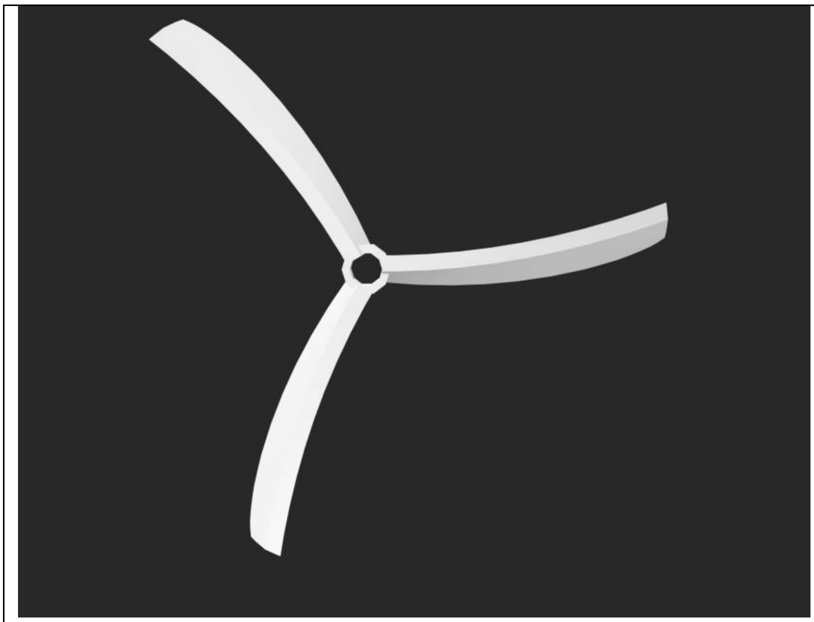
B. Project Plan

I. Hypothesis

What are the factors that affect a Hopter fly? Please formulate a hypothesis and draw your Hopter design with labels and dimensions.

(Depends on students' preference, or teachers may select the variables for students. Check "Teacher's reference" on the next page for more details)

Reference: A Hopter sample is enclosed below. You will be provided with a Hopter launcher to test your designed Hopters made with a 3D printer. (please submit the .stl file by DATE).



Teacher's reference

Variables	Explanation / Prediction
Number of blades of the Hopter	More blades will drive air moving faster (as more blades hitting the air molecules) which gives the Hopter a greater (upward) force. Therefore, a greater unbalanced force (/upward net force) causes the Hopter to change in speed and direction (/accelerate). However, it may increase the weight of the Hopter.
Tilted angle of the blades	The larger tilted angle of the blades will bring in more air (greater surface area of blades hitting the air molecules) which gives the Hopter a greater (upward) force. Therefore, a greater unbalanced force (/upward net force) causes the Hopter to change in speed and direction (/accelerate). If the speed of air flow is uneven and the flow direction changes with time and location, it may cause an air disturbance which affects the flying time of the Hopter. OR The larger tilted angle of the blades will decrease the airspeed (the air molecules are not moving vertically downward) which gives the Hopter a smaller (upward) force. Therefore, a smaller unbalanced force (/upward net force) causes the Hopter to change in speed and direction (/accelerate). If the speed of air flow is uneven and the flow direction changes with time and location, it may cause an air disturbance which affects the flying time of the Hopter.
Radius of the propellers	The larger radius of the propeller will bring in more air (greater surface area of blades hitting the air molecules) which gives the Hopter a greater (upward) force (/smaller force). Therefore, a greater unbalanced force (/upward net force) causes the Hopter to change in speed and direction (/accelerate). If the speed of airflow is uneven and the flow direction changes with time and location, it may cause an air disturbance which affects the flying time of the Hopter.

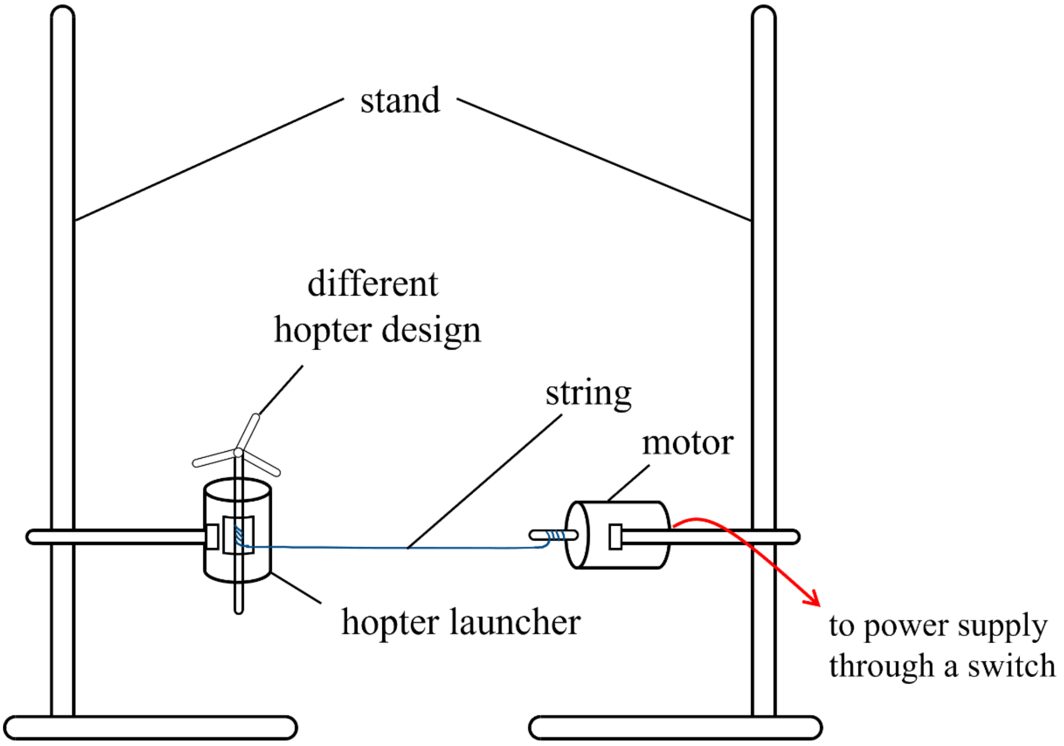
II. Identifying variables

<u>Dependent variable</u> (What you should measure)	<u>Independent variable</u> (What you should change)	<u>Controlled variable(s)</u> (What you should keep the same)
The <u>flying time</u> of the Hopter	<u>Radius</u> of the propeller	Put a '✔' in the appropriate box Radius of propeller ☐ Number of Hopter blade ☑ Tilted angle of the blade ☑ Materials used for the Hopter ☑

III. Procedures

How will you carry out the experiment? Draw a **labelled** diagram for apparatus set-up and describe the experimental procedures to test your hypothesis.

(Hint: What needs to be changed in each trial? Label as well the change in your diagram.)



1. Set up the apparatus as shown in the figure above.
2. Guide the string into the Hopter launcher.
3. Swirl the string on the Hopter and place it in the Hopter launcher.
4. Close the switch and record the flying time of the Hopter.
5. Repeat steps 2 to 4 with different radiuses of the propeller.

C. Results analysis

The radius of the propeller	Flying time of the Hopter			
	Trial 1	Trial 2	Trial 3	Average

Based on the experimental results, which Hopter performs the best?

(depends on students' performance)

D. Discussion of the experimental result and the final product

Experimental Discussion

After designing and testing your final product, we may discuss the following:

1. Describe the performance of the Hopter in your design. Do the results support the hypothesis?
   (students may describe and summarise the experimental results)
   (refer to students' independent variables presented in Section B of the project plan)
   (any reasonable answers for the selected variables)

2. How do the experimental results inform your final design of the Hopter?
   (infusing the modifications from the best results of each trial design to optimise the Hopter's performance)

3. What is the purpose of taking three trials? Discuss one possible source of error and suggest one improvement to reduce the error.
   (any reasonable answers, include)
   - Instrumental errors such as the alignment of the Hopter in the launcher
   - Human errors in measuring the time of flight of Hopter if a stopwatch is used

4. Based on your findings or further research, how would you modify your Hopter structure or testing procedure to achieve your goal?
   (depends on students' experimental results)
   (quantitative results (depends on students' choice of dependent variable): flying time record of the Hopter / greatest height of the flying Hopter)

E. Conclusion

What is the conclusion of this experiment?

(students may describe and summarise the experimental results)

F. Self-reflection

1. What have you learnt throughout this project? Do you enjoy the building and testing of the Hopter?

2. Is there anything you want to continue exploring in the future?

Hopping into the Learning of Forces: 3D-printed Hopter

使用 3D 打印：捕「竹」蜻蜓力學原理

Production 製作

Kwok Kai Yin 郭啟賢

Lo Chun Yip 羅駿業

Bachelor of Education and Bachelor of Science, Faculty of Education, HKU

香港大學教育學院

教育學士及理學士

Consultant 顧問

Leung Kin Yi Promail 梁健儀

Senior Lecturer,
Faculty of Education, HKU

香港大學教育學院

高級講師

Design 設計

Wong Tak Wing 黃德潁

Bachelor of Education and Bachelor of Science, Faculty of Education, HKU

香港大學教育學院

教育學士及理學士

This project is supported by Quality Education Fund (Project No. 2019/0640)

此計劃由優質教育基金贊助

(計劃編號 2019/0640)