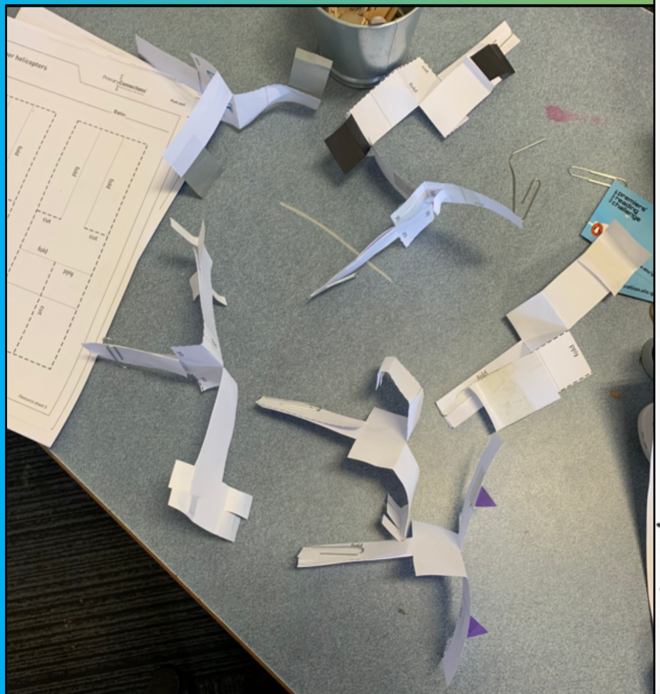
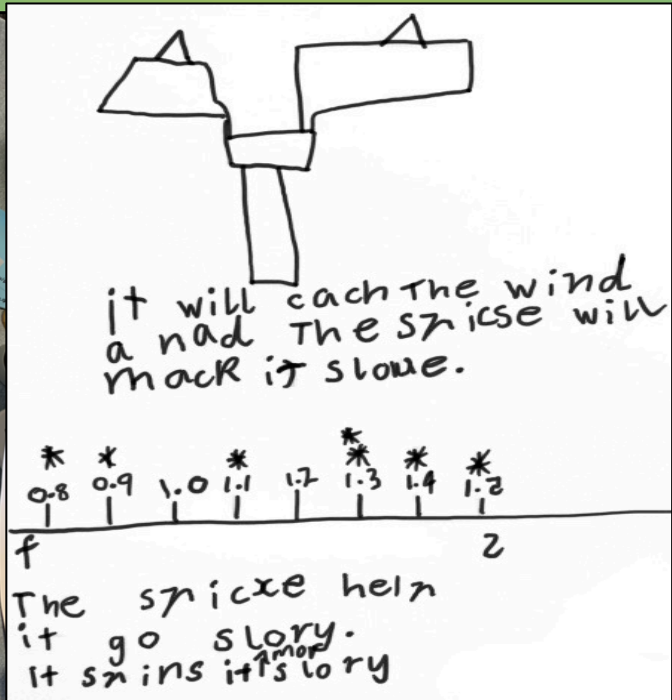
Push and Pull- Paper Helicopters
Year 2





Students explore the flight of paper helicopters, the impact of weight and wing design. Students collect data about their helicopter design, test flights and the importance of generating formal measures to compare results. The data is analysed as class data with possible exploration of number lines, median, and/or mode measures.

INTERDISCIPLINARY MATHEMATICS AND SCIENCE (IMS) LEARNING

DEAKIN UNIVERSITY
MACQUARIE University
VANDERBILT UNIVERSITY
Australian Government
Australian Research Council

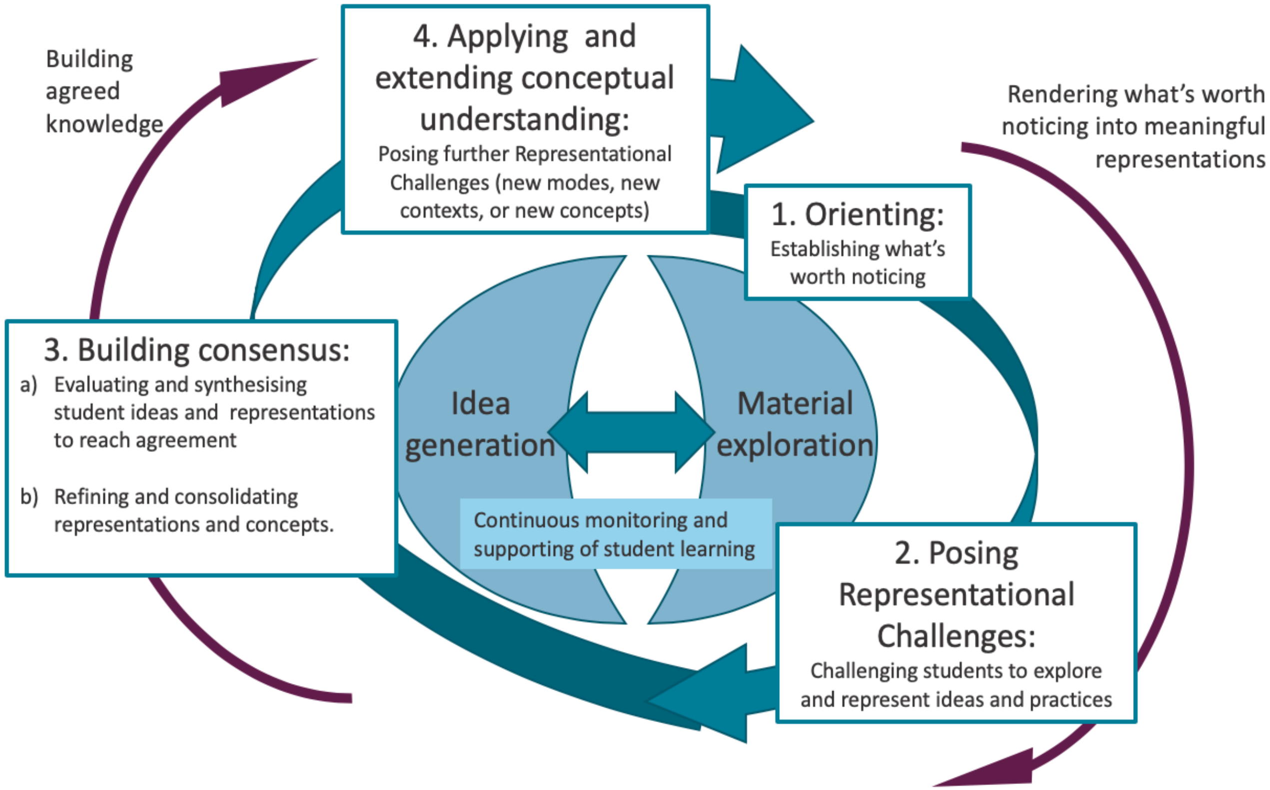
This teaching and learning sequence is one of a number that are designed to productively integrate mathematics with science, using a guided inquiry approach in which students construct, share, evaluate and revise multimodal representations to establish conceptual understanding. See website https://imslearning.org/

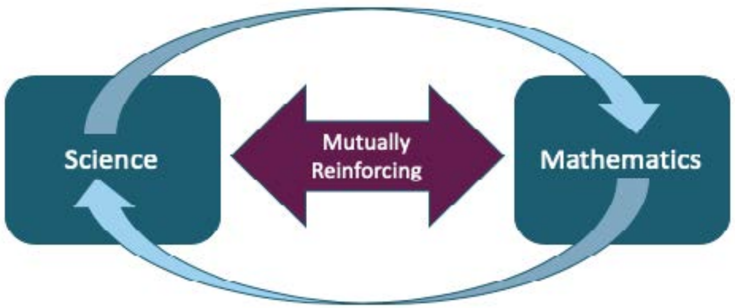
Interdisciplinary Mathematics and Science (IMS) Learning

IMS aims to enrich learning through two interconnected principles, which are key to the nature of the unit design and the pedagogy. The first principle concerns a focus on students constructing, evaluating, and refining multimodal representations, enacted through a four-stage IMS pedagogical model. The second principle concerns interdisciplinarity: the relation between science and mathematics. The project can be found at https://imslearning.org/
Below we describe the key features of the approach.

Student constructed representations

The teaching and learning sequences follow a guided inquiry pedagogy that focuses on students constructing, evaluating, refining, and extending multimodal representations. This is a literacy focus built on the insight that learning in both science and mathematics involves students being inducted into the representational practices that underpin explanation and problem solving. Representations can include diagrams, models, equations, graphs and tables, and symbols as well as written text. The approach involves a number of stages through which the teacher guides student learning. These stages, although distinct, often cycle and repeat within and across lessons. The model (to the right) showing these stages has been developed as an outcome of the IMS research.





Interdisciplinarity

In the teaching and learning sequences, the mathematics and science activities are built around 'concepts in common', with the principle that the learning in each subject enriches learning in the other. For instance, measuring, graphical work and data modelling generally are freshly developed in science contexts in ways that raise questions and promote deeper knowledge in science, and the science context raises questions that can be further explored mathematically.

Stages of the IMS Pedagogical Model

Orienting: Teachers pose questions, explore students' ideas and orient them to the learning focus by a variety of means such as asking for predictions, questioning what they have noticed, asking for ideas about what could be measured, and eliciting prior knowledge. This provides a way to focus students' attention on what is worth noticing about the school environment, or about data sets for instance, and could be interesting to explore.

Posing representational challenges: Students are challenged to explore and represent their ideas and practices, for instance they may be challenged to represent the movement of their shadow over a day, involving decisions about what to measure and how to represent patterns in length, and angle, or to use particle representations to predict, investigate and explain why a saucer of water evaporates more quickly in warm, or windy places.

Building consensus: This involves two stages. First, using the student ideas and representations to compare, evaluate and then synthesise these to reach agreement about which aspects of these effectively show patterns in data, or suggest explanations. Second, these ideas are refined by students, and consolidated to establish a shared understanding of the concept and associated representations. In this process students develop knowledge of the role of representational work in learning.

Applying and extending conceptual understanding: Students are given new representational challenges to extend their new knowledge and practices in related situations, or further concepts are introduced through representational tasks, to repeat the cycle.

In these stages the teacher is constantly monitoring and responding to students' representations and ideas. The approach can be seen as 'assessment as learning'. The focus on student production has been found to allow the teacher significant insights into student thinking. The art of teaching in this way involves setting appropriate tasks, preparing students strategically through questioning and challenges, and guiding their work to reach consensus about the key ideas and their representations. The sequences all involve a close association of material exploration, and the generation of ideas.

These stages have much in common with the 5Es that underpin Primary Connections (PC). The stages line up as Orienting = Engage, Posing Representational Challenges = Explore, Building Consensus = Explain; and Applying and Extending Conceptual Understanding = Elaborate. The 'Evaluate' stage appears in the IMS pedagogy as a continuous process of monitoring and formative assessment (assessment 'for' and 'as' learning) throughout the stages. Most sequences have a summative evaluative task, but this sits outside the cycle. Distinct from the 5Es, the IMS stages are explicitly focused on representations as central to learning (consistent with the PC focus on literacy) and structured to lead from noticing what is of interest to investigate, through the generation of representations, to generating class agreement on key concepts as systems of representations and representational practices.

The teaching and learning sequences follow these stages explicitly, but they cycle in different ways, in different lessons and in different topics. In some lessons there are more than one cycle, or even interweaving cycles for science and mathematics. In other cases, a cycle is spread over a number of lessons. Sometimes, activities have more than one role, such as an extension representational challenge acting as an orientation into a further concept. Nevertheless, we believe the movement from opening up what is noticed, to exploration and representation construction, to evaluating and building consensus, is a fundamental and powerful aspect of effective teaching and learning. Tasks in the sequences are designed to be approachable at a range of levels. This, together with teacher open questioning and targeted scaffolding, enables differentiation of the learning.

Supporting differentiation of learning in the IMS learning design

In the IMS learning sequences the student- guided inquiry design enables diverse student learning needs to be responded to within the regular classroom. The open learning tasks are designed flexibly to enable students to work at their own level, and at their own pace, to develop their understanding and skills in a variety of ways. Variation in student responses offers a resource for promoting, encouraging and refining learning as students demonstrate, in different ways, what they know and understand. With teacher support, students learn from each other's ideas and productions. The focus on student-constructed representations, and open questioning and discussion, enables the teacher to monitor individual students' understandings and cater for their learning needs over time.

Features of the learning sequences that enable embedded and teacher-supported differentiation

There are three distinct aspects of the IMS pedagogy that enable differentiation.

Open questioning, guided inquiry and open tasks provide the teacher with insight into individual student learning and understanding that:

a) enables teacher decisions for on-the-spot feedback, and individualised monitoring and support of student learning through targeted learning adjustments, scaffolding, and extension challenges.

> *"Giving them (students) more freedom is a good approach because they're more capable than I thought they would be, but they still needed the support as well. So, giving students the initial freedom to do whatever they thought they could do and then helping them from that…"*

b) enables support for students to navigate tasks with multiple entry points, solution pathways and outcome possibilities, whilst negating possible student stigmatisation from the withdrawal from their peer group, or students assigned a different task.

> *"the fact that they are open-ended so they (the students) can come to a solution in a variety of different ways. There was not one student where I had to really modify an activity for, they could participate in the activity, they could all have success in the activity but they all got something from it and because it was open-ended…"*

c) enables the development of creative and critical thinking skills, and higher-order thinking, as student responses are not limited

> *"…I always found everything was just deeper level thinking."*

Peer learning, collaborative learning and student voice increases student engagement as students learn from and with their peer group.

Students learn collaboratively as a whole class and in mixed ability peer groups. Student are encouraged to share ideas, co-construct investigations, designs, data and representations. Through purposeful guided reflection, targeted scaffolding, prompts and extension challenges, students engage in comparative discussions and review of peer representations (e.g. graphical representations) to build their understandings.

> *"…we were able to cater for everyone without making it obvious to them that we had to modify the activities, which I think is really important for their confidence and self-esteem and learning too."*
>
> *"…coming from their peers and it's quite interesting because when they actually get feedback from their peers as well I find that they really do put it into practice a lot quicker, it's quite interesting, as opposed to coming from the teacher all the time, it's coming from someone different. That has been a really interesting pick up that we have found..."*

Multimodal representational challenges cater for diverse learner needs and provide differentiated insight into students' conceptions.

Teachers have identified that a focus on multimodal representation enhances learning for students with language difficulties, who are English Second Language (ESL), and/or have literacy support needs, since they are not so constrained by their language skills. Access to multiple modes reduces the effects of language demands as barriers to learning. Students' multimodal representations provide teachers with insight into individual students' knowledge, skills and learning needs.

> *"…this has been really interesting, seeing children that don't speak up as often really come up with some really insightful representations. I mean, they're a lot further ahead than what I thought."*
>
> *"show me what you know through your drawings' and often that speaks volumes because children find it difficult to articulate at the time. They might understand more than what they are conveying… But they are actually showing me so much of their knowledge through their diagrams."*

Push and Pull - Paper Helicopter (year 2): Sequence Overview

In this **teaching and learning sequence** students collect data about their helicopter design test flights and the importance of generating formal measures to compare results. The data is analysed as class data with possible exploration of number lines, median, and/or mode measures. A key focus is the development of measure. Activities are designed so that measuring arises naturally out of the need to describe, identify patterns and compare. For example, the need to devise a consistent measure to record, compare and contrast the test flights. The further mathematics coming from this concerns variation in measure, and data entry, data modelling. Students use their senses to explore the world around them and record informal measurements to make and compare observations. They record, sort, represent their observations, and communicate their ideas to others.

Lesson Sequence - Outline

Lesson 1: Helicopter test flights 1 – Exploring, measuring, and representing the rates of fall of standard paper helicopters

Lesson 2: Helicopter test flights 2 – Exploring, measuring, and representing the effect of weight changes on the rate of fall

Lesson 3: Helicopter test flights 3 – Exploring, measuring, and representing the effect of wingspan changes on the rate of fall

Post Sequence Assessment Task

Note: This sequence draws on the Primary Connections unit "Push and Pull" for some activities. https://www.primaryconnections.org.au/resources-and-pedagogies/curriculum-units/push-pull These lessons 1-3 expand on PC Lesson 7 from Primary Connections unit Push and Pull. This sequence will enriched student learning by situating it at the end of Lessons 1-6 of the PC unit. The sequence explores the effect of weight on the helicopter flight, and wingspan in generating upthrust and slowing down the fall and supports students to develop an understanding of the ways science and mathematics use modelling processes to understand natural systems and mathematical patterns.

Curriculum Focus: Science and Mathematics Learning

Learning Focus	Key Curriculum Outcomes (Victoria Curriculum)
Science ideas and practices • Students explore what influences the rate of fall or flight of a paper helicopter • Students identify force and gravity, push and pull as influencing the flight of the helicopter • Students identify that weight impacts the rate of fall, making it faster • Students plan and conduct investigations considering elements of a fair test (i.e. one variable, multiple tests). • Students explore how changes to the helicopter make the fall faster or slower, i.e. weight and wing length. • Students use representations - annotated drawings and text - to demonstrate the effects of fall, push and pull forces, uplift and gravity.	**Science** **Science as a human endeavor:** People use science in their daily lives (VCSSU041) **Chemical sciences:** Everyday materials can be physically changed or combined with other materials in a variety of ways for particular purposes (VCSSU045) The way objects move depends on a variety of factors including their size and shape: a push or a pull affects how an object moves or changes shape (VCSSU048) **Science Inquiry Skills** ***Questioning and predicting:*** With guidance, identify questions in familiar contexts that can be investigated scientifically and predict what might happen based on prior knowledge (VCSIS065) ***Planning and conducting:*** Participate in guided investigations, including making observations using the senses to explore and answer questions (VCSIS051) ***Recording and processing:*** Use a range of methods, including drawings and provided tables, to sort information (VCSIS053) ***Analysing and evaluating:*** Compare observations and predictions with those of others (VCSIS054) Reflect on an investigation, including whether a test was fair or not (VCSIS071) ***Communicating***: Represent and communicate observations and ideas about changes in objects and events in a variety of ways (VCSIS055)
Mathematics ideas and practices • Reading times in seconds, to one decimal place. • Structuring and interpreting data in controlled experiments – involving spatial patterns and time. • Ordering times from slowest to fastest, reading in seconds to one decimal place. • Constructing visual and tabular representations of time recordings • Ordering and representing times on a timeline	**Mathematics** ***Number and place value:*** Recognise, model, represent and order numbers (to at least 1000) (VCMNA104) Describe patterns with numbers and identify missing elements (VCMNA112) ***Using units of measurement:*** Measure, order and compare objects using familiar metric units of length, area, mass and capacity (VCMMG140) ***Statistics and Probability*** ***Chance:*** Conduct chance experiments, identify and describe possible outcomes and recognise variation in results (VCMSP147) ***Data representation and interpretation:*** Identify a question of interest based on one categorical variable. Gather data relevant to the question (VCMSP126) Collect, check and classify data (VCMSP127) Create displays of data using lists, tables and picture graphs and interpret them (VCMSP128)

Push and Pull – Paper Helicopters (Year 2): Equipment/Resources

Lesson		Equipment/Resources
All Lessons		**Students:** Paper helicopter templates (Appendix 3 or PC unit Push and Pull page 46 resource sheet), scissors, paperclips (same size), student workbooks (unlined), pencils, colours and rulers iPad/stopwatches (or teacher online stopwatch only) **Teachers:** Stopwatch timer (IWB/Computer) iPad stopwatch &/Or Stopwatches for students (if independently measuring and recording) Board (IWB/whiteboard) and or butchers' paper for shared recording and pens HudlTechnique App (available via Apple Store)(optional) Paper helicopter example and templates
1	**Helicopter test flights 1** – Exploring, measuring, and representing the rates of fall of standard paper helicopters	As per all lessons Pre sequence assessment task (handout)
2	**Helicopter test flights 2** – Exploring, measuring, and representing the effect of weight changes on the rate of fall	As per all lessons Large container (100) paperclips – all the same size/weight paperclips
3	**Helicopter test flights 3** – Exploring, measuring, and representing the effect of wingspan changes on the rate of fall	Scrap paper (for lengthening wings) Sticky tape (one per two students)= Post sequence assessment task (handout)

Appendices

1: Teacher Notes
2: References and Resources
3: Paper helicopter templates
4: Pre/Post sequence assessment task (with examples)

LESSON 1– Helicopter test flights 1: Measuring the rate of fall

(Approximate duration 80 minutes)

Curriculum Focus:

Science ideas and practices

- Explore how a push or pull affects how an object moves
- Measure the effect of a push or pull on the movement of an object.
- Explain the effect of a push or pull on the movement of an object by collecting, representing and modelling data

Mathematics ideas and practices

- Collect, check and classify data
- Create displays of data using lists, table and line graphs
- Order numbers, describe patterns and identify 'typical' recordings

Learning Intention:

- Describe and represent the effect of a push or pull on a falling object
- Develop and select appropriate units of measurement for the rate of fall
- Students identify order the data, identifying patterns and deriving appropriate displays (time lines)

Equipment/Resources

Equipment required for all lessons
Students:
Paper helicopter templates (PC unit Push and Pull page 46 resource sheet 5), scissors, paper clips
Student workbooks (unlined), pencils, colours and rulers

Pre sequence assessment task (handout)

Teachers:
Stopwatch timer (IWB/Computer)
iPad stopwatch &/Or Stopwatches for students (if independently measuring and recording)
Board (IWB/whiteboard) and or butchers' paper for shared recording and pens
Paper helicopter example and template
HudlTechnique App (available via Apple Store) (optional)

Lesson at a glance:

Students explore how a standard helicopter falls, the push or pull on a falling object, and derive appropriate ways of measuring (seconds) and recording and display8ing data (tables, timelines).

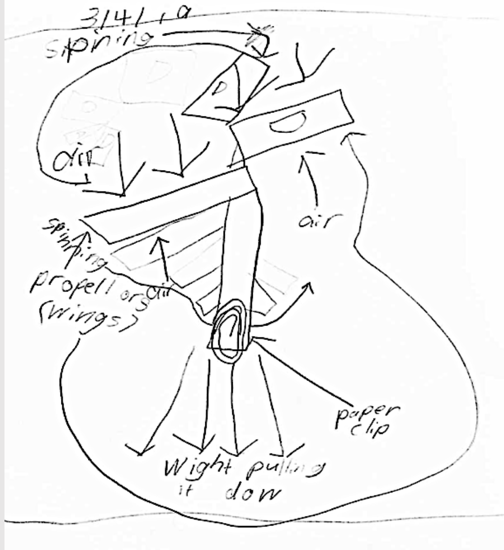
LESSON 1– Helicopter test flights 1: Measuring the rate of fall

(Approximate duration 80 minutes)

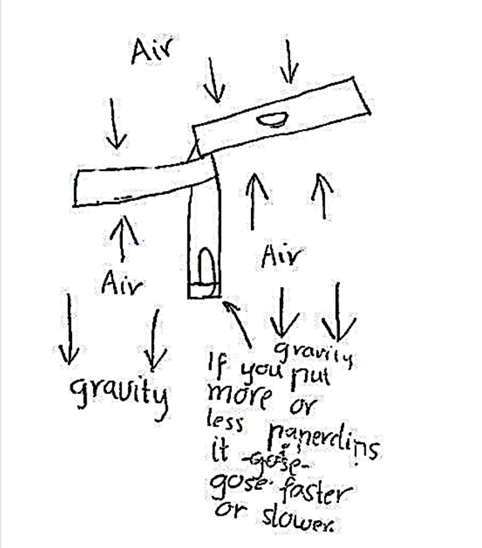
Learning focus	**Pedagogical Stage**	**Lesson Outline** *(NB: time allocations a guide only)*	**Monitor and Support Learning**
Science: Explore the effect of a push or pull on a falling object Explore, measure and explain the rate of fall **Mathematics:** Measure time (seconds) Establish recording system (table)	***Orienting*** Drawing student attention to consider what affects the rate of fall? Students connecting ideas to prior observations, knowledge and experience	**Whole class discussion and investigation preparation** *(20 minutes)* Introduce a paper helicopter that you have made. **Probing Questions:** ❖ *What makes a helicopter fall?* ❖ *What affect how quickly the helicopter falls to the ground?* ❖ *How long will it take for a helicopter to fall when dropping from a certain height?* Ask the students to predict what will happen when you release the helicopter and explain their predictions. Record student ideas on the board. Release the helicopter and discuss how students' observations are compared with their predictions. Discuss: ❖ *What makes a helicopter fall?* ❖ *How it falls?* ❖ *What affects how quickly the helicopter falls to the ground?* Record, List student ideas about what affects the flight on the board probing ❖ *Why will that affect the flight?* ❖ *What questions might we explore about the helicopter flight?* **Investigation preparation** How can we investigate how fast or slow a helicopter falls on the ground? Discuss what students will observe, how they will display their data. NB: Students will need preparation for the timing, and for reading a digital timer with output to 2 decimal places. ❖ *What will need to be considered?* (number of trials/tests, consistency for comparison – fair test e.g. same height, same helicopter etc.) ❖ *How could we measure?* What would we measure in? (seconds – timer/stopwatch NB: Some students may suggest counts – are everybody's count the same?) ❖ *How could we record our data?* (list, table) **Individual Bookwork Preparation** *(5 minutes)* Students Establish a recording system and method	Do students relate this to their prior knowledge of helicopters and other falling objects? Can students identify the forces involved – gravitational pull and air resistance? Can students identify the variables affecting the flight time: wing span, weight, design, height where it drops from, etc.? (fair test) Can students relate this to their experience of speed, in terms of distance and time? Can students appreciate the need for consistency in the dropping process? Can they appreciate the advantage of multiple drops? Can they suggest what might cause variation in times? Can students identify various ways of displaying data based on their previous experience?

		Individual Student Paper Helicopter Making *(5 minutes)* Students to construct a standard paper helicopter using a template (see appendix)	
Science: Explain the effect of a push or pull on a falling object **Mathematics:** Measure, record and order time data	***Posing representation challenges*** Challenge students to explore and represent the flight times of their paper helicopters and how the helicopter falls	**Paper Helicopter Flight Investigation** *(20 minutes)* **Recording flight times: Whole class/small groups** **Teacher Notes & Considerations** Timing & Stopwatch - Consideration of student competency with stop watches/ stop watch app For lower grade students, teacher guidance for using stopwatches is recommended, given the need to control reaction times, possibly whole class recording of group helicopters, guided stopwatch reading (seconds) opportunity. It is best to record the times with one decimal place, to assist with ordering numbers. Draw student attention to the need for multiple tests and a consistent method (fair test – consistent height, recording method, same 'group helicopter') Encourage students to record the flight times accurately and in an easily understood way. **Student Flight Recording & Helicopter Fall Representation** Student record the test times theirs's and others' helicopters, from a standard height, and draw a diagrammatic representation of how the Helicopters fall	Can students record times accurately and arrange the times in order to make sense of the variations? Do students realise that the longest time means the slowest fall? Can students show the effect of gravity and air resistance on the wings of the paper helicopter?

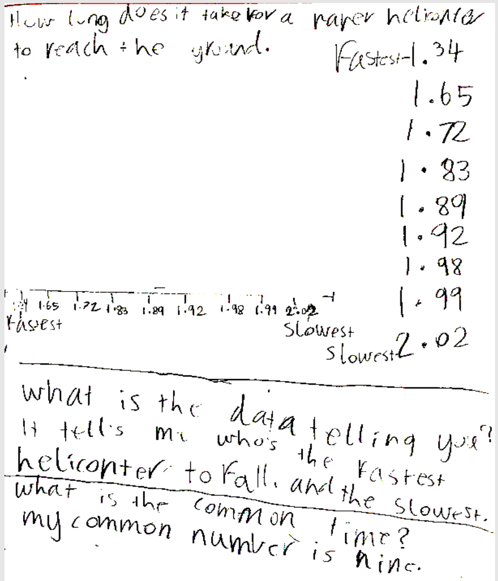
Examples of student work responses



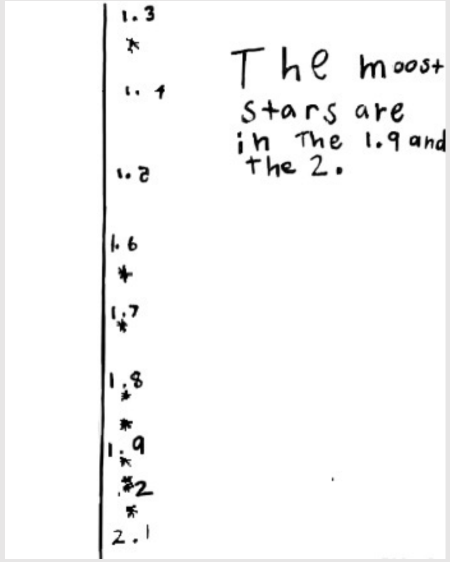
Student uses arrows to demonstrate air forces, and weight 'pushing down



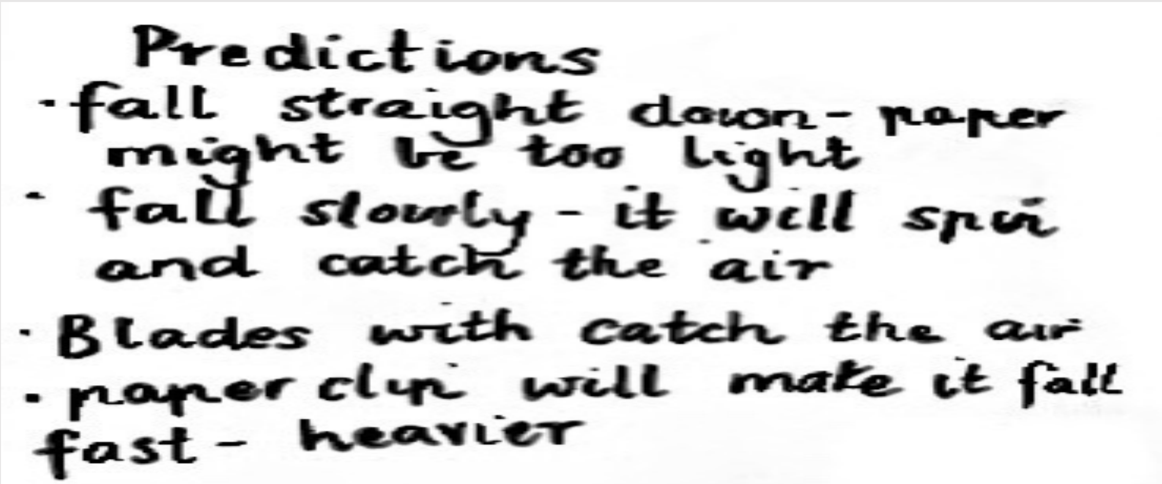
Student uses the term 'gravity' and arrows to show *air* and gravity directionality



Example of student recording of 'tests' and moving towards time-line representation



Student example, from board, of a time line. Student identification of 'the most', frequency of helicopter speeds – 1.9 and 2.0.

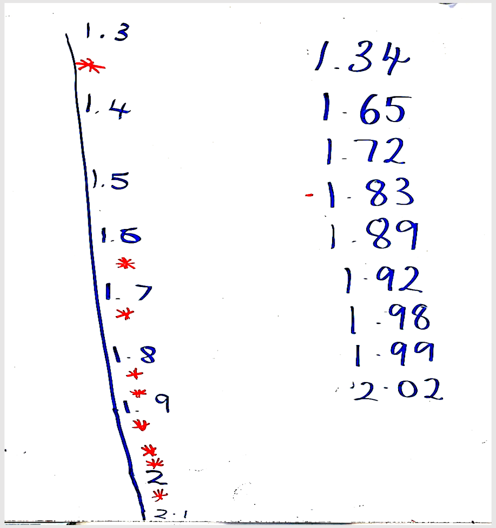


Example of class recorded predictions (whiteboard)

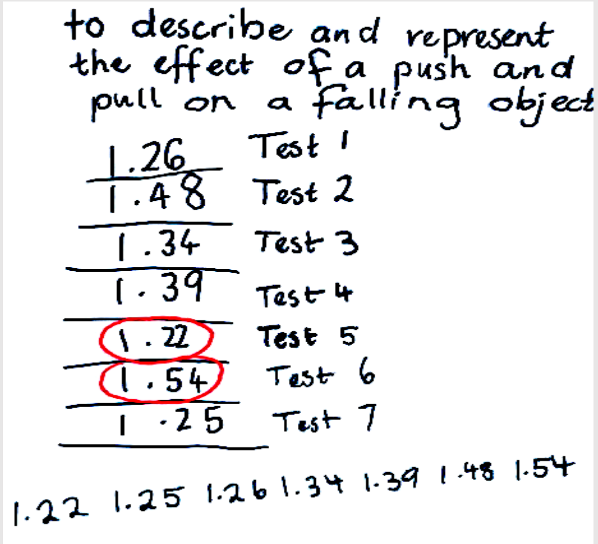
Science: Explain the effect of a push or pull on a falling object Fair Test **Mathematics:** Recording time in seconds Reading one decimal place Ordering – fastest to slowest Time-line Organise and display data to identify mathematics patterns Ordering times, Slowest time – highest number and vice versa. Reading one decimal place. Identifying patterns and frequency Time-line conventions	***Building consensus*** evaluating and synthesising student ideas and representations of the push and pull on a falling object ***Building consensus*** Students develop agreement refining and consolidating ways to represent class data, co-constructing a time-line to represent the data	**Whole Class: Sharing Representations, Observations and Ideas** *(5 minutes)* **Gallery Walk** Students compare and contrast others' representations and ideas Teacher purposefully selects examples (do not remove yet) **PROBING QUESTIONS: during gallery walk for students and guiding questions for following discussion** ❖ *What can you tell from the different representations?* ❖ *How effective are they?* ❖ *What do they show?* ❖ *What don't they show?* **Whole Class Discussion and Review - Helicopter Fall** *(5 minutes)* **Discuss student work examples** (with the above guiding questions) **Review purposefully selected student examples** Encourage students to make meaning from others representations and discuss what makes some representations effective? (labels, arrows Choose a few students to display their drawings and explanations of what affects the flight, and summarise the different ideas on the board with drawings and annotations. Move the class towards an agreed 'model' or 'representation' of the different forces that affect the helicopter. **Whole Class Data – Co-construction & Appraisal** *(20 minutes)* **(moving towards a time-line)** Utilise student examples that are generative towards a time-line, drawing out the features of those examples that make the data clear and easy to understand through questioning ❖ *Which of these ways show the class data clearly?*	Can students identify some patterns in the data, e.g. data clusters, variations, and spread of data? Can students relate the data to their observations of the paper helicopters? Can students order the class results for the standard helicopters to show the variation from largest to smallest times? What does the ordered data show that non-ordered data does not? Can students, with support, suggest and utilise an interval timeline to display their data? Is the interval time-line recognised as an effective way of displaying the data? Can students articulate what it shows that the ordered number set does not? (distribution, outliers, clumping) Can students identify patterns in the data? (spread, clumping, repeats) Do they make reasoned justifications for variation in the results? (variation in design, timing errors, different heights?) (What is the scope of justification?)

		Co-construction - Students with teacher guidance collate and populate the class data, *jointly constructing* an agreed representation of the data that shows the range of times and how the times vary (time-line). **Whole Class: Sharing and evaluation** *(15 minutes)* Discuss the class data recording *Ordering and identifying fastest and slowest times* ❖ *What is the longest time recorded?* ❖ *What is the shortest time?* *Variation* - Draw student attention to variation – and discuss reasons for variation (i.e. measurement/recording accuracy, process accuracy) ❖ *What patterns they can see in the data?* ❖ *What questions can we ask based on this data?* ❖ *What is the 'typical' time for the helicopter to land? How could we decide? How confident are we in this?* *Teacher Note – Language for 'typical' time may need elaboration, e.g. the '**best time** to share with someone for how long the helicopter usually takes'.*	Can students articulate their reasons for what they claim as 'typical' or the 'best' representative time for their/each helicopter? Can they articulate why a number based on the data set is more reliable than any one measure? (Student possible responses - the 'most common time'/'popular time' – (mode), the time in the middle 'not too high or too low' (median))

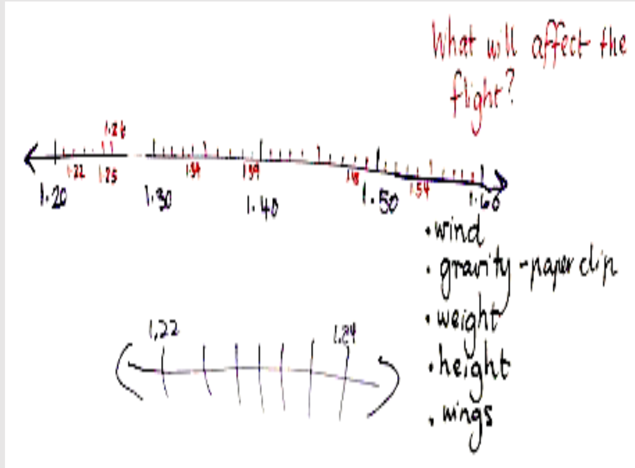
Examples of whole class data and board work



Class Board work – Teacher guided co-construction of data to move towards a time line



Class Board work – Teacher guided co-construction of data with identification of the slowest and fastest time and ordering



Co-constructed number line with times, on board. NB – Data impacted by testing paper helicopters outside. Not consistent data due to 'wind'.

Mathematics: Use data patterns to make predictions	***Applying and extending conceptual understanding*** Posing further representational challenges (to be continued lesson 2)	**Whole Class: Conclusion** *(5 minutes)* **Review question:** ❖ *Can we use this data and our explanations to predict what might happen if we change the weight?* Inform the class that in the next lesson, they will be investigating the effect of weight changes on the time taken for a helicopter to land.	Can students use the patterns identified in the data to make appropriate predictions?

LESSON 2 - Helicopter test flights 2: Effect of weight changes

(Approximate duration 70 minutes)

Curriculum Focus:

Science ideas and practices

- Explore how a push or pull affects how an object moves and the effect of increasing weight
- Measure the effect of a push or pull on the movement of an object.
- Explore and explain the effect of weight, on the movement of an object by collecting, representing and modelling data

Mathematics ideas and practices

- Collect, check and classify data
- Create displays of data using lists, table and line graphs
- Order numbers, describe patterns and identify ‘typical’ recordings

Learning Intention:

- Describe and represent the effect of a push or pull on a falling object
- Generate hypothesis based on data collected in relation to the weight of a helicopter (number of paper clips) and time taken for it to fall to the ground from a fixed height
- Demonstrate understanding that weight effects the rate of fall, increased weight makes the helicopter fall faster.
- Students identify order the data, identifying patterns and deriving appropriate displays (time lines)

Equipment/Resources

Equipment required for all lessons

Students:

Paper helicopter templates (PC unit Push and Pull page 46 resource sheet 5), scissors, paper clips
Student workbooks (unlined), pencils, colours and rulers

Teachers:

Stopwatch timer (IWB/Computer)
iPad stopwatch &/Or Stopwatches for students (if independently measuring and recording)
Board (IWB/whiteboard) and or butchers’ paper for shared recording and pens
Paper helicopter example and template
HudlTechnique App (available via Apple Store - optional)

Lesson at a glance:

Students explore how weight impacts a helicopter falls, and derive appropriate ways of measuring (seconds) and recording and display8ing data (tables, timelines). Students identify patterns in the data and make inferences about the impact of wing length.

LESSON 2 - Helicopter test flights 2: Effect of weight changes

(Approximate duration 70 minutes)

Learning focus	Pedagogical Stage	Lesson Outline (NB: time allocations a guide only)	Monitor and Support Learning
SCIENCE: Explore the effect of air resistance on the helicopter wings. Recognise what constitutes a fair test	***Orienting*** Reviewing understandings of force and models developed from the previous lesson. Drawing attention to 'fair test' and appropriate measuring and recording methods	**Introduction: Whole class** *(10 minutes)* Review class data and representations from Lesson 1. ❖ *What did we learn from the investigation of the time taken for a helicopter to land from a height of 2 metres?* ❖ *What makes the wings of a helicopter spin?* Review the understandings of the forces on the helicopter that affect its flight. Present on the board a diagram that represents the 'model' that explains the helicopter flight. **Introducing Weight Investigation** **How will the number of paper clips (0, 1, 2, 3) effect the rate of fall?** Record students predictions and explanations on the board **Probing questions:** (writing student ideas and predictions on the board) ❖ *Do you think different weight on the helicopter would change the time it takes to fall?* ❖ *How do you think weight will change the time the helicopter takes to fall?* ❖ *How can we record, compare and set up measures to explore the effect of paper clips? (recording tables, timer/stopwatch, seconds)* ❖ *What will we need to keep the same, so the test is fair? (same helicopter, same height, same measuring and recording system)*	Do students identify the forces involved, affecting the helicopter flight? (gravity, uplift) Can students generate explanations for the spinning of the helicopter wings, focusing on the upthrust force of air flow? Can students use the model (force diagram) to make predictions about the effect of weight changes on the flight time? What range of predictions do students make, regarding the effect of weight? Are these predictions justified? Do student make reasoned suggestions and considerations for the investigation (fair test)?

<table>
<tr>
<td>Mathematics:
Measure, record and order times

Organise and display data to identify mathematics patterns

Timeline</td>
<td>Posing Representation Challenge
Students challenged to decide on a way to record their observations and recordings of their group investigation (0/1/2/3 paperclips)</td>
<td>Individual Bookwork - Time Recording Preparation
(5 minutes)
(Individual/groups)
Students set up their recording system in the books

Assign groups to 0/1/2/3 paper clips

Teacher Note & Consideration
As per lesson 1 (small groups, individual or whole class according to level of support and guidance needed for stopwatch time recording)

Whole Class Investigation
(15 minutes)
Review the needs for a ‘fair test’ Investigation
❖ What do we need to consider to make sure our data is a fair comparison

Students drop the helicopter with none, 1, 2, and 3 paper clips from the height of 2 metre.

Teacher &/or groups record the times took for each helicopter to land on the whiteboard. Display the times to the nearest 0.1 on a table.

Teacher Note- Resource: HudlTechnique App (available via Apple Store) can be used to video record each drop which can provide a visual reference of the drops and allow accurate timing. This works best if student drop the paper helicopter against a darker background. Alternatively, use a computer/iPad stopwatch.

<table>
<tr><th rowspan="2">Wing length 70mm</th><th colspan="4">Number of paperclips</th></tr>
<tr><th>0</th><th>1</th><th>2</th><th>3</th></tr>
<tr><td>Test 1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Test 2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Test 3</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Test 4</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Test 5</td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
<td>Do students identify appropriate measure (time - seconds) to compare the effect of weight change?

Can students read and record times accurately?

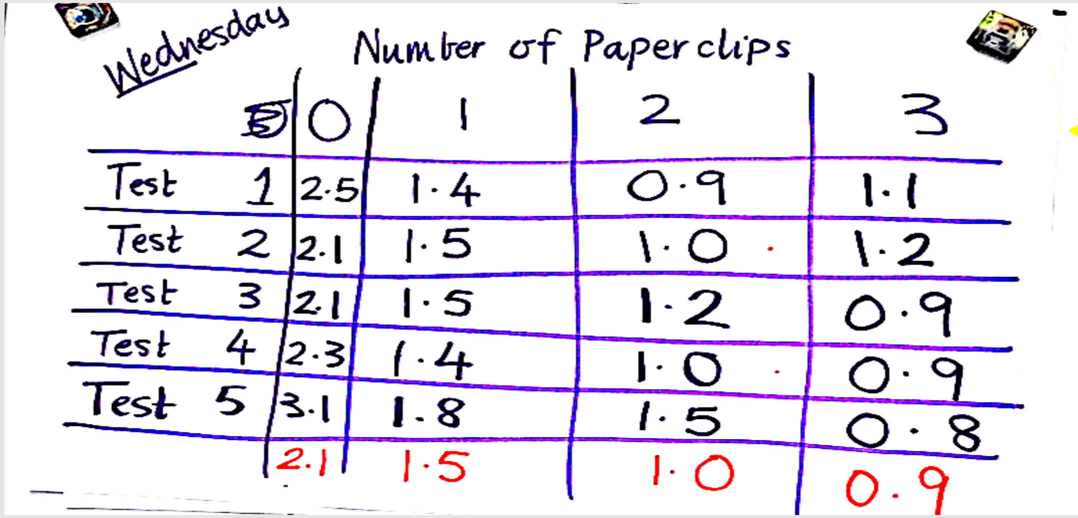
Can students effectively organise and display the data in the table format, recognising the differences between rows and columns and what needs to be placed in each cell?

Do students comment on the accuracy of recordings?

Are students able to notice variation in the results?

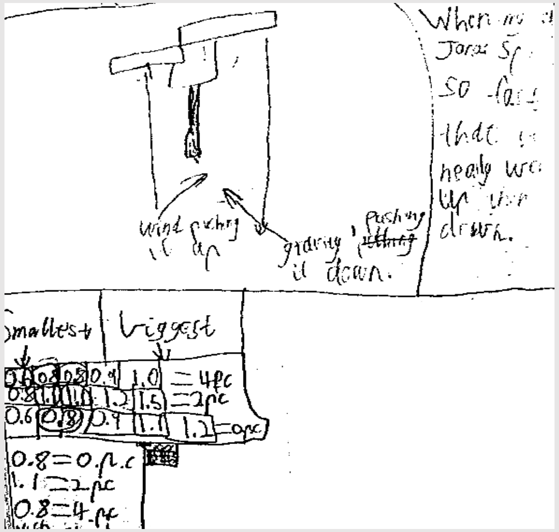
Do students comment on and recognise a pattern in results as they’re recorded?</td>
</tr>
</table>

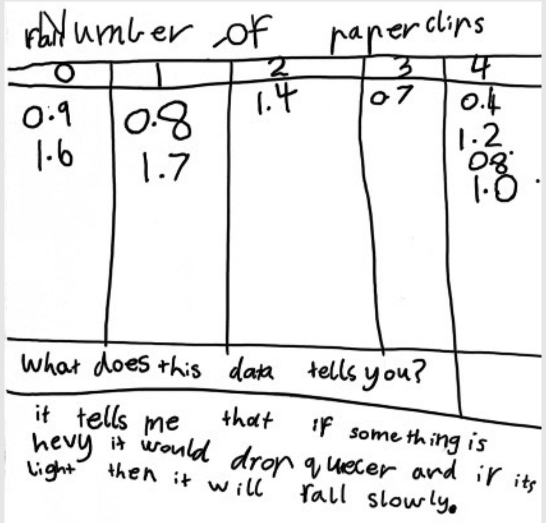
Example of Class board – Flight Test Times with different numbers of paperclips. Note that the median value is used as the typical time.

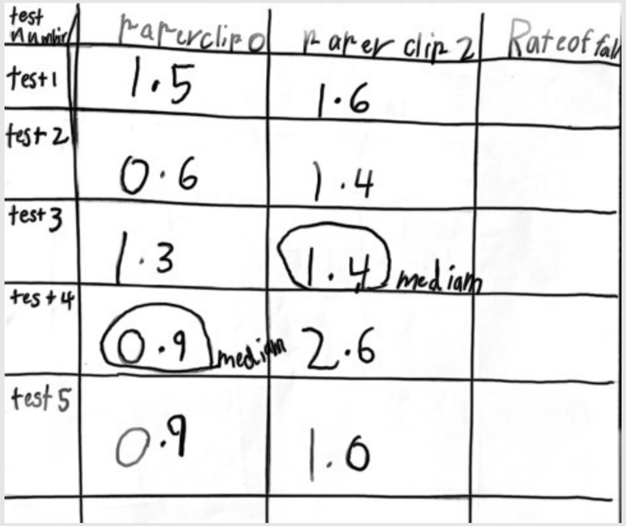


Science: Explore the effect of weight changes on the flight time **Mathematics:** Ordering, recognise mathematics patterns in data. Make generalisations based on mathematics patterns in data	***Posing representation challenges*** Challenging students to explore, interpret and represent the data recorded independently	**Whole Class Data Discussion** *(5 minutes)* Discuss the data display on the whiteboard. ❖ What can you tell from the data? (more weight faster to fall - gravity) ❖ *What questions can we ask based on this data?* ❖ *What is a 'typical' time for a helicopter to land with no paperclip, with 1, 2, or 3 paper clips?* ❖ *What is it important to have more than one measure?* ❖ How could you show the data clearly in a different way? **Individual Book Representation** *(10 – 15 minutes)* **Data Display and What happened?** Student diagrammatically explain how weight effected the Paper helicopters Student represent the data in a display	Can students recognise the variations in the data for each column and suggest ways to deal with the variations, e.g. clusters of similar measures? Can students make reasonable generalisations based on the patterns identified in the data? Can students organise and represent the data in other forms to make sense for themselves and for others? Can students generate explanations for the effect of weight changes on flight time drawing on the data patterns identified?

Examples of student work responses: recording organisation and observations

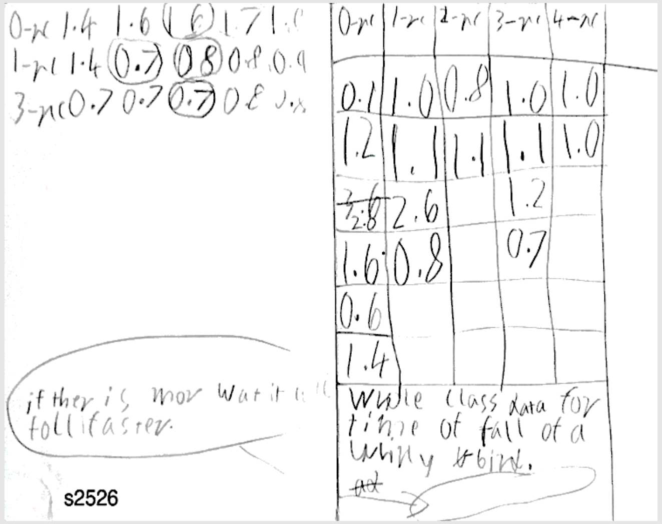


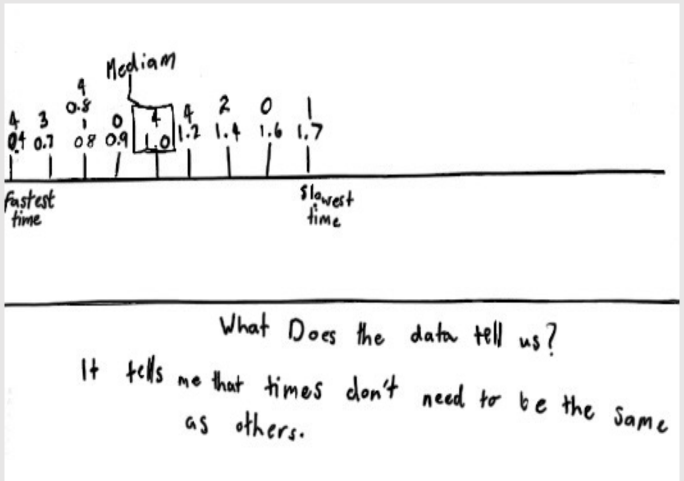


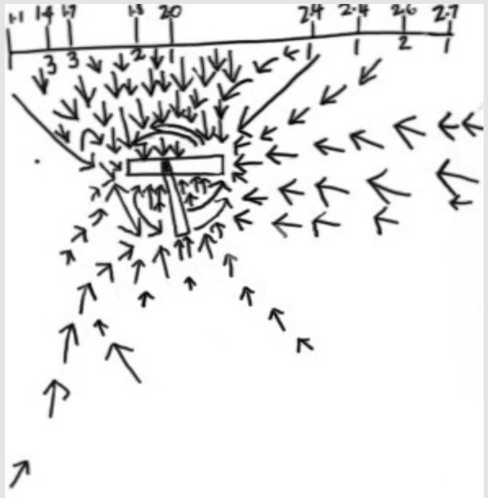


Example of student ordering times Student tabulating their recordings and Example of tabulated recording with recognition of the

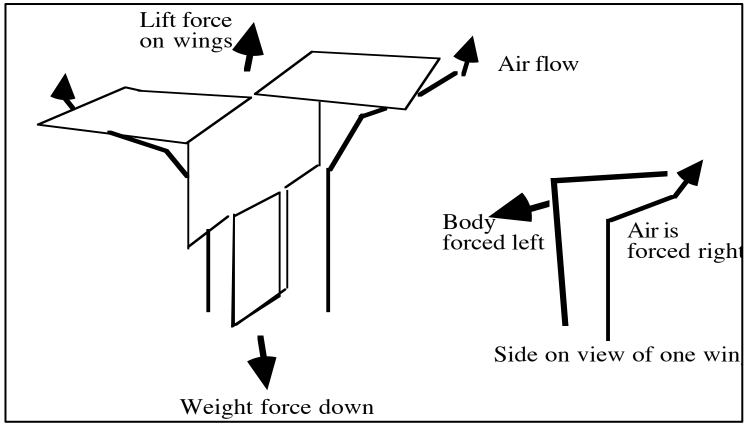
Making observations and inferences median time – (median)







Time-line data and recognising variation Timeline and arrows representing air & gravity Example of weight inferences and tabulated data

	Building consensus Evaluating and synthesising student ideas to reach agreement and a common explanation	**Whole Class: Sharing Representations, Observations and Ideas** *(5 minutes)* **Gallery Walk** Students compare and contrast others' representations and ideas Teacher purposefully selects examples (do not remove yet) **PROBING QUESTIONS: during gallery walk for students and guiding questions for following discussion** ❖ *What can you tell from the different representations?* ❖ *How effective are they?* ❖ *What do they show?* ❖ *What don't they show?* Select and share a few student representations. • *Think about our data, what does each representation show and not show?* • *How can you show the data more clearly?* Discuss the science of weight pulling down versus upthrust from the wings pushing up (see diagram below). • *How does the observation data inform our understanding of the science behind how a paper helicopter works?*  	Can students relate the data to their observations of the paper helicopters? Can students provide reasonable justifications for what they claim as 'typical', e.g. mean, mode? Can students provide evaluative comments about the effectiveness and suitability of each display? Can students relate the data to the scientific explanations about the effect of weight changes, e.g. the gravitational pull?
Mathematics: Make generalisations based on mathematics patterns in data	**Applying and extending conceptual understanding** Posing further representational challenges	**WHOLE CLASS CONCLUSION** *(5 minutes)* **Review Question:** ❖ *Can we use this data and our explanations to predict what might happen if we shorten the wings of a helicopter?* Inform the class that in the next lesson, they will be investigating the effect of changes to the wings on the time taken for a helicopter to land.	Can students use the patterns identified in the data to make predictions about changes to wingspans?

LESSON 3 - Helicopter test flights 3: Effect of changes to the wingspan

(Approximate duration 70 minutes)

Curriculum Focus:

Science ideas and practices

- Design a helicopter with a wing length adaptation that will increase the length of flight
- Explore how a push or pull affects how an object moves
- Measure the effect of a push or pull on the movement of an object.
- Explore and explain the effect of wing length on push or pull on the movement of an object by collecting, representing and modelling data

Mathematics ideas and practices

- Collect, check and classify data
- Create displays of data using lists, table and line graphs
- Order numbers, describe patterns and identify 'typical' recordings

Learning Intention:

- Describe and represent the effect of a push or pull on a falling object
- Generate hypothesis based on data collected in relation to the wingspan of a helicopter (size, length, area etc) and time taken for it to fall to the ground from a fixed height
- Demonstrate understanding of uplift and increased wing length effecting the rate of fall of a helicopter, slowing it down.
- Students identify order the data, identifying patterns and deriving appropriate displays (time lines)

Lesson at a glance:

Students explore how different wing lengths effect the rate of fall of a helicopter. They design their own helicopters (changing only the wings) and test and compare the results. Student derive appropriate ways of measuring (seconds) and recording and displaying data (tables, timelines) for ease of comparison.
Students identify patterns in the data and make inferences about the impact of wing length.

Equipment/Resources

This lesson

Scrap card, scrap paper (for lengthening wings)
Sticky tape (one between two students)

Equipment required for all lessons

Students:

Paper helicopter templates (PC unit Push and Pull page 46 resource sheet 5), scissors, paper clips
Student workbooks (unlined), pencils, colours and rulers

Pre sequence assessment task (handout)

Teachers:

Stopwatch timer (IWB/Computer)
iPad stopwatch &/Or Stopwatches for students (if independently measuring and recording)
Board (IWB/whiteboard) and or butchers' paper for shared recording and pens
Paper helicopter example and template
HudlTechnique App (available via Apple Store)(optional)

LESSON 3 - Helicopter test flights 3: Effect of changes to the wingspan

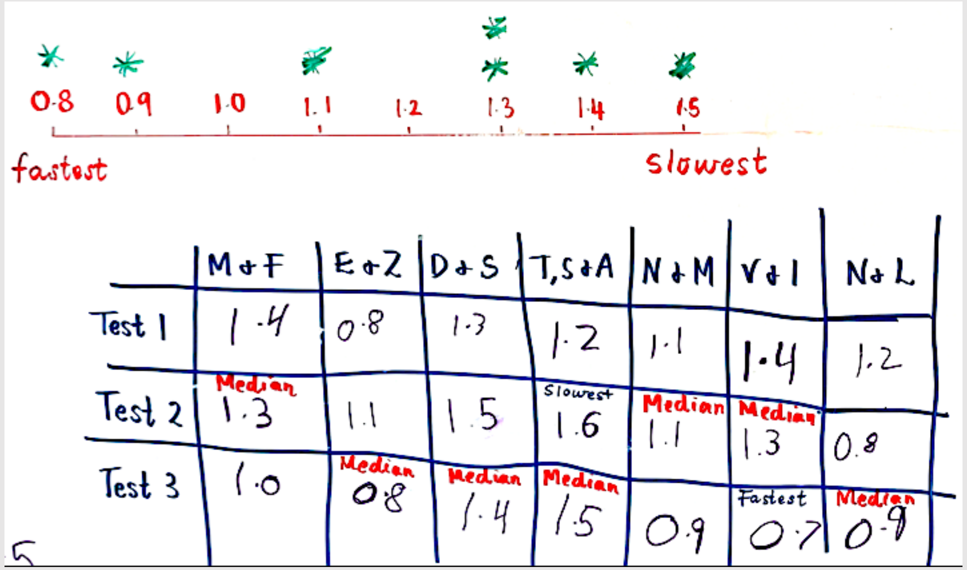
(Approximate duration 70 minutes)

Learning focus	Pedagogical Stage	Lesson Outline (NB: time allocations a guide only)	Monitor and Support Learning
Science: Explore the effect of wingspan changes on flight time	***Orienting*** Reviewing understandings of force and models developed from the previous lesson. Establishing the focus of the lesson	**Whole Class Introduction** *(5 minutes)* **Reviewing & consolidating the impact of weight** Review class data displays and explanations generated from Lesson 8. ❖ *What did we learn from the investigation of helicopters with different number of paper clips?* ❖ *Has that changed our model of the helicopter flight?* Teacher simultaneously drops two paper helicopters one with one paper clip (in one hand) and one with four paperclips (in the other hand) **Probing questions:** ❖ How does the time that the two paper helicopters take to fall compare? ❖ What is the one variable that is different between the two paper helicopters? (weight, number of paperclips) ❖ Why does the number of paper clips affect the fall? Discuss other variables that could be altered and explored **Introduce Investigation and Design Challenge** *(5 minutes)* **** Focus Variable > The wings*** ❖ How might the wings be changed to make the paper helicopter fall slowly? Write down student ideas and suggestions on the board. ❖ What will we need to do to make a fair comparison? Confirm the need for other variables to remain the same e.g. height it is dropped from & number of paperclips constant at one)	Do students recognise that increased weight makes the paper helicopters fall at a faster rate? Can students make predications based on their previous observations and provide reasonable justifications for their predictions? Can students relate the model with the observations to make reasonable links, the air flow under the smaller wings compared with the standard wings?

Science: Air – uplift and gravity Explore the effect of wingspan changes on flight time	***Posing representation challenges*** Challenge students to design a wing alteration that might increase the time it takes for the helicopter to fall, represent and explain their choices through representations ***Building consensus*** Student groups synthesise the trial times of their design helicopter and reach an agreement on the best representative helicopter, based on slowest times	**Wing Design Challenge Investigation** *(20 minutes)* **Pairs or small groups** Students to discuss possible changes to their **wings** to increase the time their helicopters flies. NB: Reinforce to students that they are only to change the wings – for a fair comparison **Wing Design Representation & Data Recording Preparation (Bookwork)** Students to draw and represent their design change in their book with an explanation Students set up their recording system, preparing for investigation NB- Draw student attention to the needs for multiple tests for a fair comparison **Represent & Explain** ❖ How have you changed the wings? ❖ Why do you think that makes the helicopter fall slower? (Draw/Explain your helicopter) **Paper helicopter Making** *(5 minutes)* Each student (in the pairs) makes their agreed design (only changing the wings) helicopter **Pair Helicopter Test – Determining Representative Helicopter** *(5 minutes)* Students select the 'slowest' of their two helicopters to represent their design in the whole class flight trial. Students: One in each hand of one person drops them simultaneously (as per teacher model at the beginning of the lesson) Students identify and agree: Which falls the slowest? NB: both students could trial this, to confirm test and limit bias etc. The slowest in each pair will be tested in the whole class comparison.	Can students decided on and justify the changes they can make to the wings in order to slow down the falling of a helicopter? What are the range of student wing designs? Do they represent a variety of ideas that can be discussed? Do students make reasoned justifications for their wing changes?

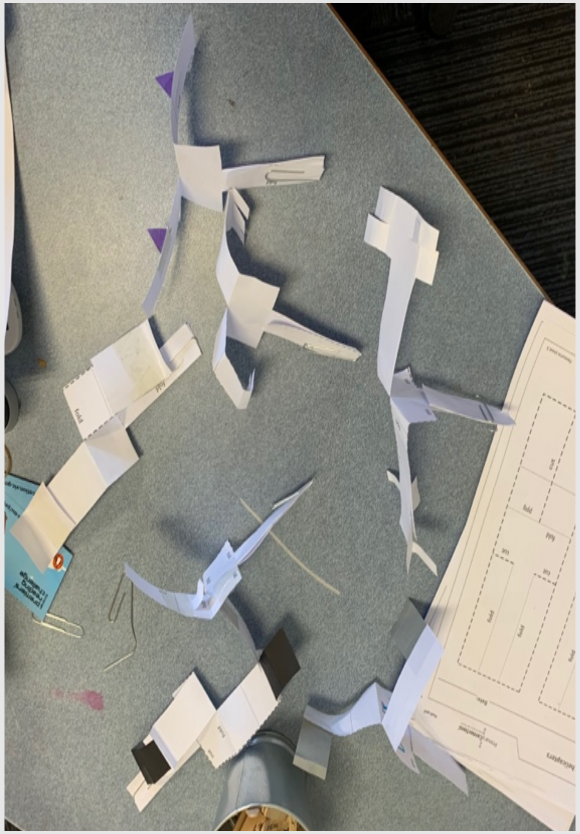
Mathematics: Measure and record time and length Organise and display data to identify mathematics patterns **Tables**	***Building consensus*** Students record and synthesise the data to reach an agreement on the slowest fall helicopters, making inferences about the wing design. (large wings, more resistance and slower fall)	**Whole Class: Recording and Comparing Wing Designs** *(15 minutes)* (using the slowest from each group/pair) ❖ How can we test and record the times and data? (Table/confirming) Students to derive the table on the board (as per previous test trials ❖ How are we to conduct the trials to make sure they're a 'fair test' and fair comparison? (same height, way of timing etc.) RECORD drop time for each paper helicopter (a student recording in the whole class table? teachers dropping & timing) Teacher Note: Use the computer stopwatch and model reading/co-reading one decimal place and seconds together. **Data Discussion – Whole Class** *(5 – 10 minutes)* **What makes these designs fall slower?** ❖ What is the typical time for each wing design? (work out together) ❖ What can you tell from the data? - ❖ Which are the two slowest falling helicopters? Ask students who made these to explain their thinking. ❖ Why are they slower? What is different about their wings? How does the length of the wings effect the time the helicopter takes to fall? ❖ Which is the slowest design? Why? ❖ How could we display the ordered times clearly in a display? (co-construct a scaled timeline) Teacher Note – Co-construct whole time line or set up the scale for students to continue inputting data independently in their own books.	Are students able to identify and agree on the slowest of their helicopters? Do they recognise/reason why there may be variation? Can students, with help, generate plausible reasons for which designs slowed down the helicopters? (Air catching the wings)

Whole Class Board work examples with class determined ‘typical’ and ‘median’ flight time

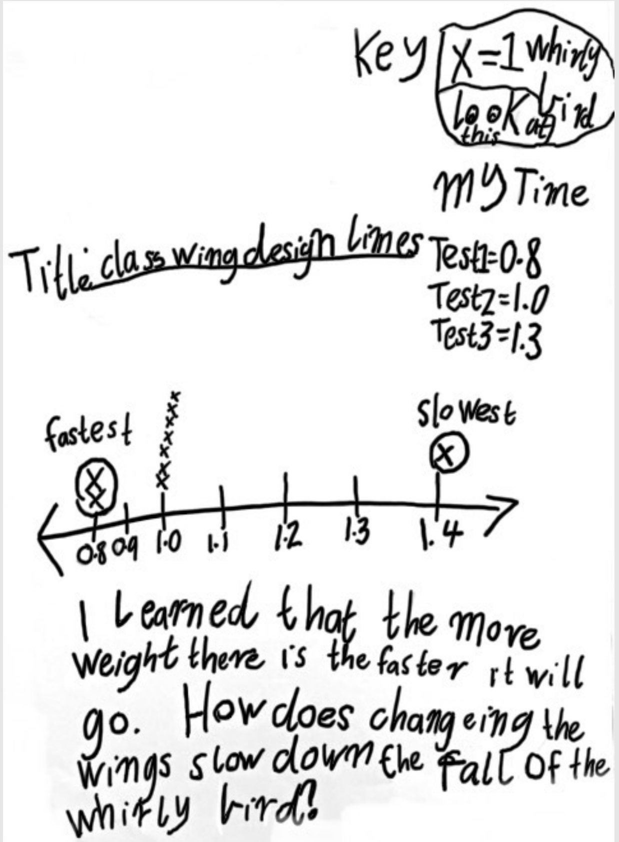


Mathematics: Data ordering and displays (timeline) Data analysis and pattern identification **Science:** Uplift, resistance and the effect of wing length	***Posing representation challenges*** Challenge students to interpret, explain and represent the data recorded independently	**Individual Book Representation** *(10 minutes)* **Data Display and What happened?** Student represent the data in a display (timeline) Student diagrammatically explain how different wing designs and lengths effected the Paper helicopters “How does changing the wings slow down the fall of the helicopter?” “What have I learnt about the helicopter flight?”	

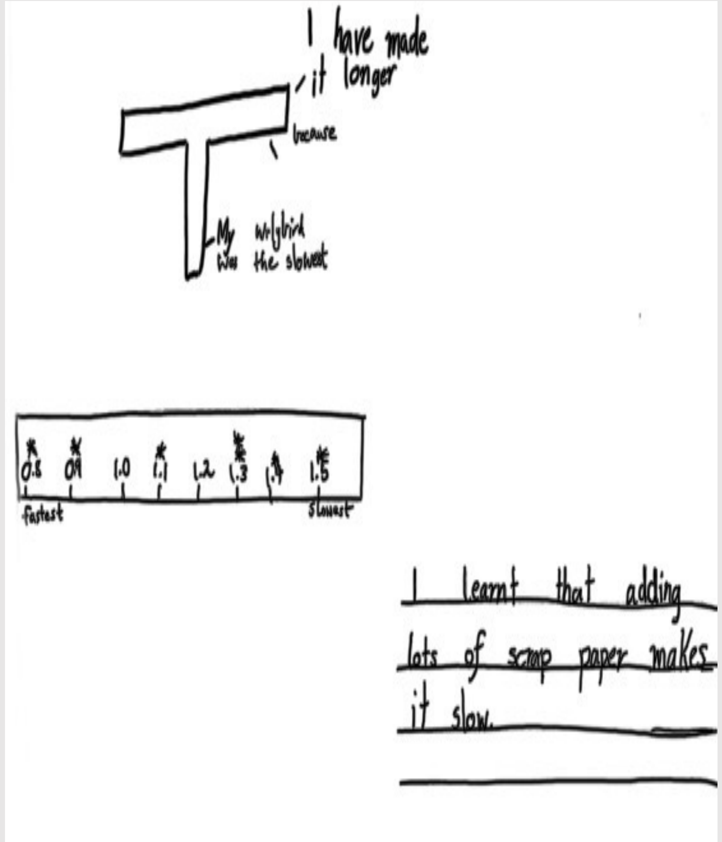
Examples of student responses: Variation in wing design to slow the fall, in a Grade 2 class



Representation of own design flight test trial data



Student bookwork representations of individual and whole class data



Representation of design test times and explanation why it was 'the slowest' design

Science: Explore the effect of wingspan changes on flight time **Mathematics::** Make generalisations based on mathematics patterns in data	***Building consensus*** Evaluating and synthesising student ideas	**Gallery walk** *(20 minutes)* ❖ Students to exchange ideas and ask questions of each other's data display and representations: ❖ *What does each representation show and not show?* ❖ *How can you show the data more clearly?* **Class discussion: What are the effects of the different changes to the wings** ❖ *What are the characteristics of the helicopter that helps to slow down its fall?* ❖ *How definitive are the measures, and how could we be sure?* ❖ *What conclusion can be drawn from the data collected by the different groups? How can we be certain about our conclusions?* ❖ *What further questions do we have?*	Can students provide evaluative comments about the effectiveness and suitability of each representation and data display? Can students relate the data to their observations of the paper helicopters? Can students generate hypotheses based on the mathematics patterns identified in the data?
Science: Explore the relationships between observations, data, and models in science **Mathematics::** Make generalisations based on mathematics patterns in data	***Building consensus*** Refining and consolidating representations and concepts	**Whole Class: Review** *(10 minutes)* Get the students to reflect on the processes of investigation and the accuracy of the data collected. **Review questions:** ❖ *How does the data help us to understand the science?* ❖ *How does our understanding of the science inform what to collect as data?* ❖ *How did our model of helicopter flight help us to predict and explain what will happen?* Ask students what other changes can be made to the paper helicopter to slow it down and get students to explain their thinking. Time permitting – student could refine their representations (bookwork)	Can students make evaluative comments on their investigation process and accuracy of the data collected? Can students relate the data to the observations and to the science model discussed in class? Can students generate further hypotheses based on their understanding of the science model and the mathematics patterns identified in the data?

APPENDIX 1 - Teacher Notes

These three-lesson sequence should be built upon the lessons in the PC unit. Getting students to use words such as push, pull, gravity, upwards push (upthrust), etc. from the word wall. Students should also be encouraged to use force-arrows to represent pushes and pulls in explaining how a paper helicopter works.

When representing the time data from each lesson (times taken for a helicopter to fall), the children could look for number of falls that are the same time and record frequency if this happens. They could draw a simple plot of fall times in order. There may be clusters of same times. Getting them to think of how to represent the clusters could help to stimulate discussions of 'what is a typical time' in relation to mathematics concepts such as mode and median.

APPENDIX 2 - References and Resources

For concepts and activities related to force and motion, see https://blogs.deakin.edu.au/sci-enviro-ed/early-years/force-and-motion/

For further ideas of paper helicopter test flights (paper helicopter), see Russell's article on paper helicopter explorations in Prime Number below.

Whirlybird explorations

Russell Tytler, STEME research group, School of Education, Deakin University.

Tytler, R. (1996). Whirlybirds exploration. *Prime Number, 11*(2), 8-12.

So what is a whirlybird?

I had been teaching whirlybirds for some years now - you know those paper helicopter-like objects that you weight with a paper clip and which spin when they fall. They invariably cause a gasp of delight when first discovered. I've seen so many that I'm now surprised when anyone expresses surprise when they drop them, that they move into that slow, whirling downward motion. So when I decided to write about them, I thought I'd take the opportunity to investigate what actually went on with that disarming flight. This article describes a weekend's exploration.

The science of whirlybirds has to do with air resistance and aerodynamic forces, due to air flow around the wings, that counteract the gravitational force that impels everything downwards. The usual challenge I give to students is to alter the shape or size or weight of the whirlybird to make it descend more slowly, or spin faster. I took as my own challenge the exploration of what affects their speed of descent.

First, a description of how to make a whirlybird. It is made out of a single sheet of paper as shown, cut along the solid lines and folded along the dotted lines in the directions indicated by the arrows. A paper clip is usually used to weight the bottom section. That's it!

I decided that, if I was going to investigate different aspects of whirlybirds, I needed to start with a 'standard' shape and size. To this end, I cut an A4 sheet in four equal parts, and my standard whirlybird ended up with the dimensions shown, one quarter the area of an A4 sheet.

The wings are 70 cm long, and the bottom section, which is usually weighted with a paper clip, is also 70 cm. In other words, I divided the paper into thirds, lengthwise, and thirds or halves crosswise for the bottom section and wings respectively.

You can see the mathematics creeping in!

The science of whirlybirds

As for the science; one question you might ask yourselves or children is this : "Why does the whirlybird spin?"

The easiest way to envisage this is to imagine the air rushing up past the wings as the whirlybird falls. If you simulate this with a finger pushing up on each wing, you will see that in each case the body is forced sideways, but in a different direction, causing a twisting action.

And if you want the whirlybird to spin the other way? Reverse the wing folds.

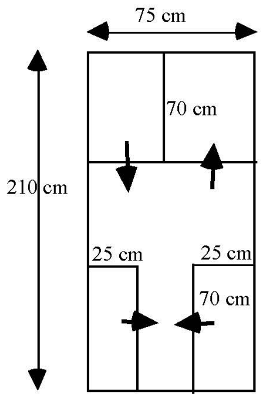


Figure 1: Standard whirlybird

The forces acting on the whirlybird - both the vertical lift force on the wings and the downward gravitational (weight) force, and the sideways kick on parts of the body due to the air flow - are shown in figure 2.

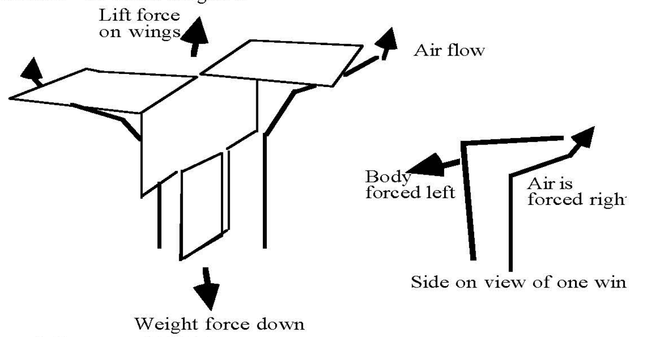


Figure 2: Forces on whirlybirds

What I was interested in investigating was the effect of overall size and shape, and wing size and shape, on the lift force on a whirlybird. The lift force is essentially created by the rapid rotation of the wings, which creates an air flow pattern that must be similar to that on an aeroplane wing, with the air speed above the wing being greater than that below. This causes a net pressure force upwards. I makes sense that the greater the weight (adding paper clips), the faster the fall, and the greater the wing span the slower the fall. I was, however, interested in the details.

I have worked with many students on whirlybirds, challenging them to investigate factors affecting the flight, but have never really been happy with the generality of the conclusions reached. There is lots of language generated (upthrust, air pressure, air flow, weight, vortex, drag, air resistance, gyrate) and good general discussion of the principles, but what really makes a difference to their flight?

I started off by modifying my standard whirlybird in a controlled way, and comparing each alteration with the standard by dropping both together and seeing which hit the ground first. I found I could get a good idea by dropping them from above my head (about 2 m), but ended up clambering onto the kitchen servery and dropping them from rafter height (we have a convenient cathedral ceiling in our family room). It takes a short distance of fall to establish the spinning motion, and the greater height minimizes effects due to this. It was important to drop them two at a time, together. How many times have I seen half a dozen children lined up in class, on chairs, and told "ready, set, go" by the teacher. Do you imagine they let go at the same time? Believe me, there is no chance at all for a fair comparison, particularly if everyone is wanting theirs to win!

Changing the overall size

First I cut whirlybirds with half, and then one quarter of the overall dimensions of the standard, giving them weight, and wing area ratios of 1: 1/4 : 1/16. Doing this with children, or course, could be accompanied by some useful fraction and area work. What I found was that the overall dimension made no difference to the flight time. They hit the ground simultaneously! It seems probable that the weight decrease is counterbalanced by an equivalent decrease in wing area (not wing span, though). The smaller whirlybird spun much faster, though. I thought about this. It seems to me that if we think of a whirlybird making a given number of spirals in a distance proportional to its length as it corkscrews downwards, that would explain this observation.

Then I tried weighting them each with a paper clip. The smaller whirlybirds fell much faster. Clearly the standard whirlybird with its greater wing size is able to support the weight more easily. Then I thought: what if I weight them proportionally? I put 4 paper clips on the standard whirlybird, one on the half size whirlybird, and a quarter of a paperclip (I raided my toolkit) on the quarter size whirlybird. They all fell at exactly the same rate! At this stage I started to believe in the orderly arrangement of the universe.

It was time to get serious. I had brought home a stopwatch (the old mechanical sort), and decided to construct a controlled experiment dropping a variety of whirlybirds out of a small window at the top of our stairs into the driveway below. The distance is about 5 m.

I enlisted my daughter's help in operating the stopwatch from ground level, and gathering the whirlybirds up for reweighting and redropping. We generally timed two drops for each whirlybird, but if we felt there had been any uncertainties in timing, repeated these again. The results presented are averages. Generally, the accuracy was within 0.2-0.3 seconds. I kept a record of the times she relayed up, in a prepared table. She is currently a year 12 physics student, and was quite intrigued by my design. We both had to cope with the bemused glances of the neighbours, but I at least was able to content myself with the thought that eccentricity has a long and honoured tradition in academia. Not so in a secondary college!

Changing the width

I halved the width of the standard whirlybird, and then doubled it, without changing the length. The results, for these whirlybirds with none or one paperclip, are given below.

Wb	Unweighted	One paperclip`
Half width (37 cm)	6.5 s	4.0 s
Standard	3.6 s	3.0 s
Double width (150 cm)	3.0 s	2.8 s

Table 1: Effect of width and weight on flight time from 5m.

Clearly, the narrower whirlybird is gaining more upthrust compared to its weight. It spun much faster than the others (it was in fact the most impressive of any of the whirlybirds) and I believe this is due to it having less opposition to spin because of the narrower body, and that the faster spin increases the aerodynamic upthrust, prolonging the flight. The effect of weight in speeding up the fall can be clearly seen. Thinking to construct an even slower whirlybird, I constructed a quarter width version. It flopped rather than span! There must be a ratio of wing length to width beyond which the flight becomes unstable.

Lengthening the wings

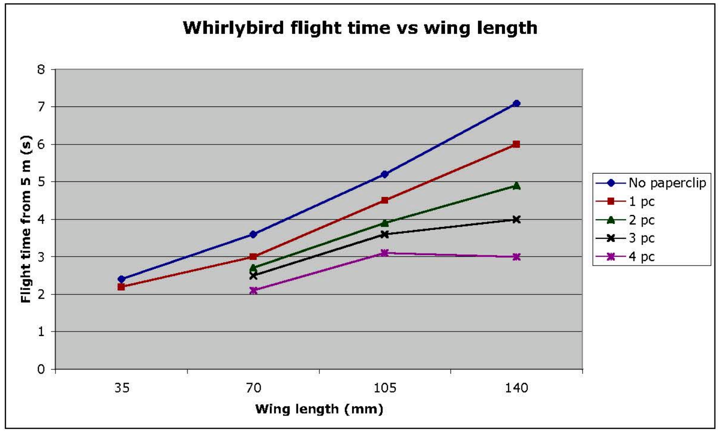
I then systematically changed the wing length on the standard whirlybird by cutting bits of paper 37 cm wide and gluing them to the standard wings, using as little overlap as practicable. I dropped them with 1, 2, 3 and 4 paperclips attached to investigate the effect of weight as well as wing span. The results are shown in Table 2, and graphed in Figures 3 and 4.

Wing length	Number of paperclips				
	0	1	2	3	4
35 mm	2.4	2.2			
70 mm	3.6	3.0	2.7	2.5	2.1
105 mm	5.2	4.5	3.9	3.6	3.1
140 mm	7.1	6.0	4.9	4.0	3.0
174 mm	Unstable				

Table 2: Flight times (in seconds) for different wing lengths and weights, over 5 m.

The effect of greater wingspan in generating upthrust and slowing down the fall can be clearly seen, as can the effect of weighting with paperclips. I didn't have any sensitive scales at my disposal, but by using the kitchen scales to weigh 10 paper clips (8 grams) and 5 sheets of paper (20 standard whirlybirds: 30 grams) I was able to establish that adding two paper clips approximately doubled the whirlybird's weight. Doubling the weight does not halve the flight time. It takes 3 to 4 times the weight to do that.

Figure 3 shows the effect on time of the different wingspans, for different numbers of paper clips. The general trends are quite clear, but there is an interesting reversal when 4 paper clips are added, in that the increasing wing span actually starts to shorten the time. I suspect in this region the heavy weight and fast fall causes the longer wings to flap, thus reducing their effectiveness. The 175 mm wing span was unstable generally, but plummeted with 4 paperclips on. This tendency to instability if the wing length to width



ratio is too great has already been commented on.

Figure 3: Graph of flight time vs. wing length, for different numbers of paperclips.

Figure 4 uses the same figures to show the effect of weight on a whirlybird of given winglength. The results are quite orderly and predictable. The fact that the 105 mm and 140 mm whirlybirds fell at the same rate when weighted with four paperclips shows up on this graph as an intersection.

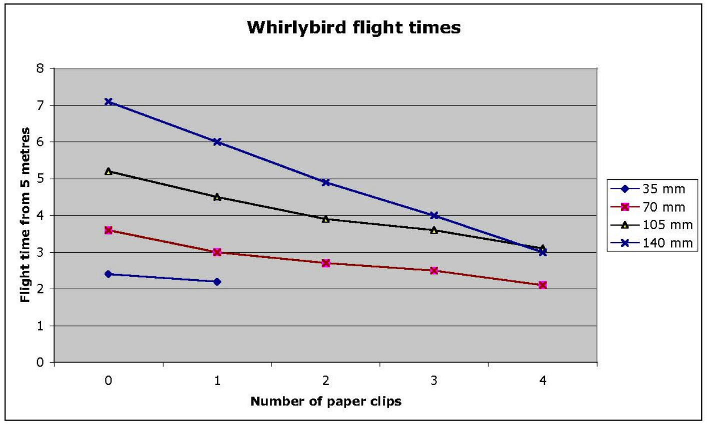


Figure 4: Graph of flight time vs. weight, for different wingspans.

Wing length or area?

I suspected that the important factor in determining the upthrust on the wings was the length of the leading edge, rather than the area, since it is the leading edge that slices through the air and creates the flow pattern. On the other hand, the pressure difference produced will act on the area as a whole. To sort out these factors I used a standard whirlybird with different shaped wings, as shown in Figure 4, and we timed them over the 5 m. Each was weighted with one paper clip. The area is shown compared to the standard (A) in each case. The length of the leading edge is also given in the table.

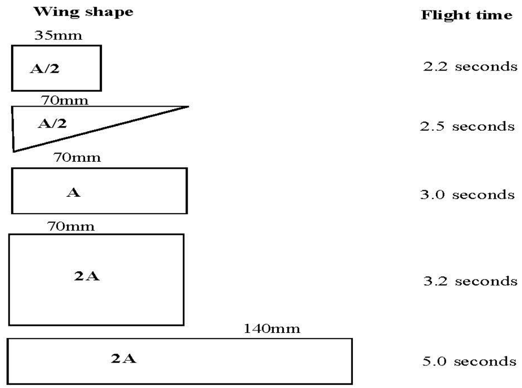


Figure 5: Effect of wing length and wing area on flight time.

Figure 5 shows clearly that the length has more effect on flight time, and hence on the upthrust force, than does area. Comparing the middle three results does show, however, that for the same wing length the area does make a measurable difference.

Some thoughts about scientific method

Tables 1 and 2 represent the classic experimental design in that they involve controlling some variables while varying others. However, when I thought back about my pilgrimage towards understanding over the weekend, it was clear to me that those initial informal trials were critical in identifying what the possible factors were that were worth investigating. I haven't (and here I'm participating in a great scientific tradition) told you anything about all the whirlybirds I threw in the bin, or left out of the final report. It took me a long time, too, to work out how to differentiate between wing length and area, or even that I might want to do that. The process of a science investigation never quite manages to follow that simple observation-hypothesis-experiment-conclude rule.

The other point about science investigations I've been reflecting on is that tables like Table 2 provide a very clear representation of the experimental design. Standard accounts of the investigation process (plan, experiment, record, conclude) represent recording as something you do after an experiment. However, tables like those above can be thought of as the point toward which planning is aimed. Once you've got your table, you know what needs to be done.

So what?

At this point I might feel compelled to explain why I am offering this as a mathematics/science activity for primary schools. Apart from having provided me with an absorbing hobby for one weekend, and intrigued and bemused my family and neighbours by turn (they all thought the sight of these whirlybirds spinning down from our rafters highly amusing, if not educative), what have we to show from these results?

Firstly, to understand the results requires talk of the balancing forces of gravity and upthrust, and the effects of air on wings even if only at the level of wing size, floating, and analogies with helicopter blades. There is a lot of science there. Explaining the spinning is a fruitful activity.

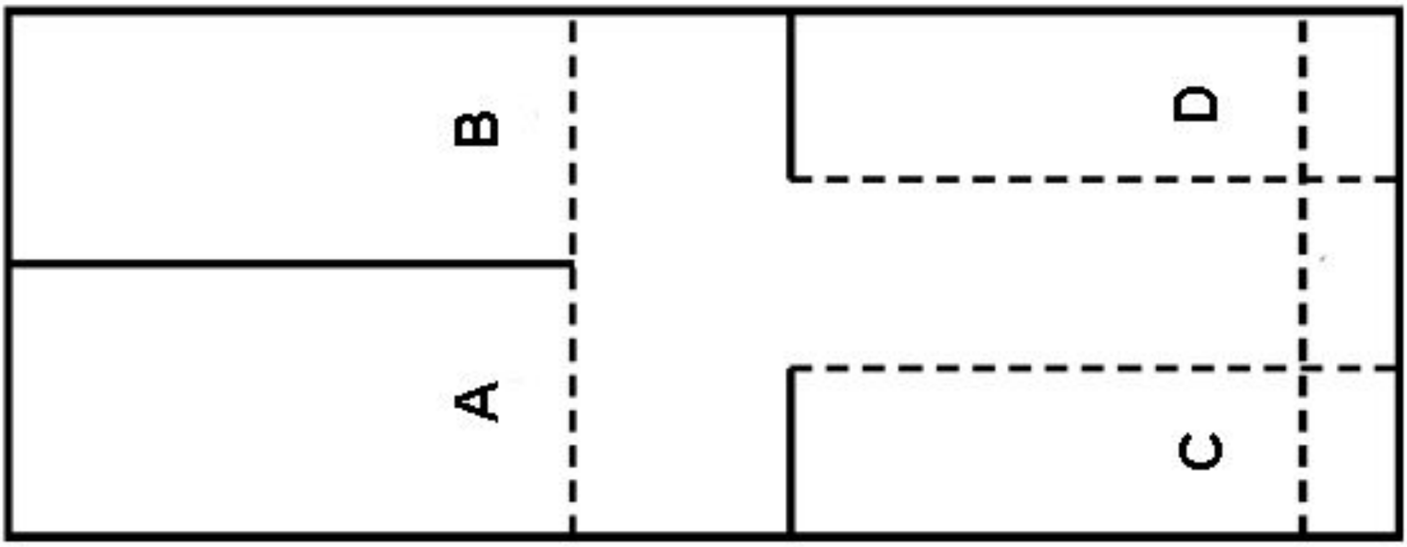
More than this, to operate the experiment I needed to use a ruler, although I could have done the whole thing in informal units, doubling and halving by turn. Understanding of fractions played a part in the folding and cutting, and deciding on the dimensions. Understanding of area is implicit in the final wing experiment, and also in the experiment with proportional weights.

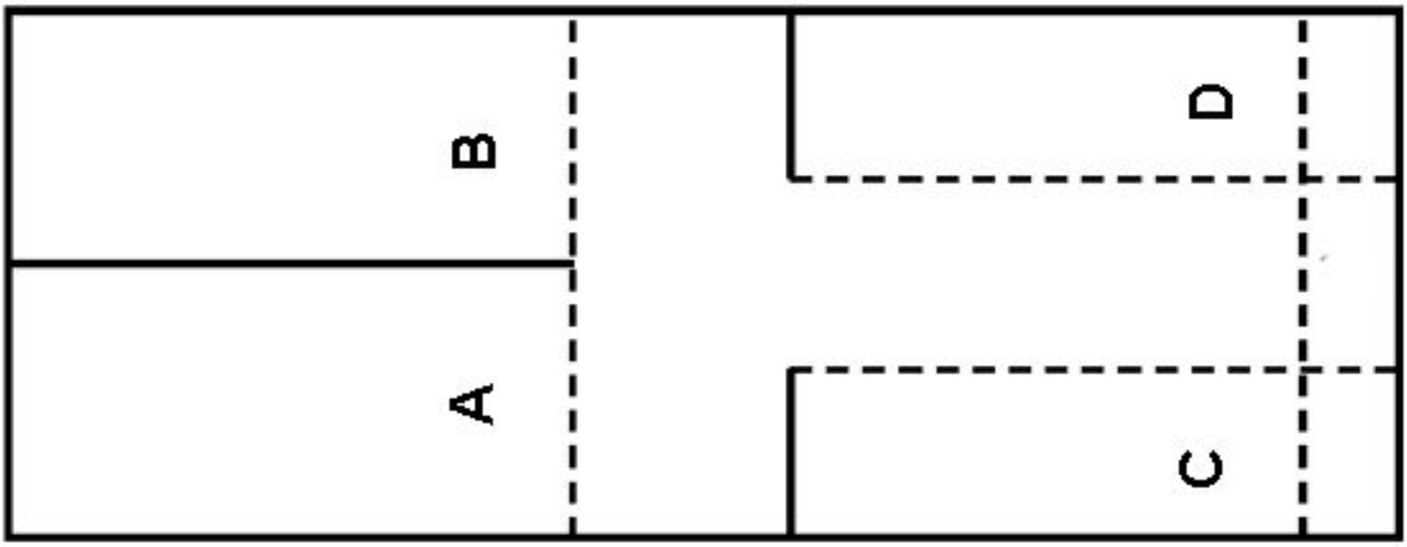
Measurement of time is important in generating data for tables. I think it highly unlikely that primary school children could generate graphs that are as clear as mine. I spent a lot of time running up and down stairs and checking results that seemed anomalous. Even so, if the whirlybirds are dropped from sufficient height, children can generate sensible times.

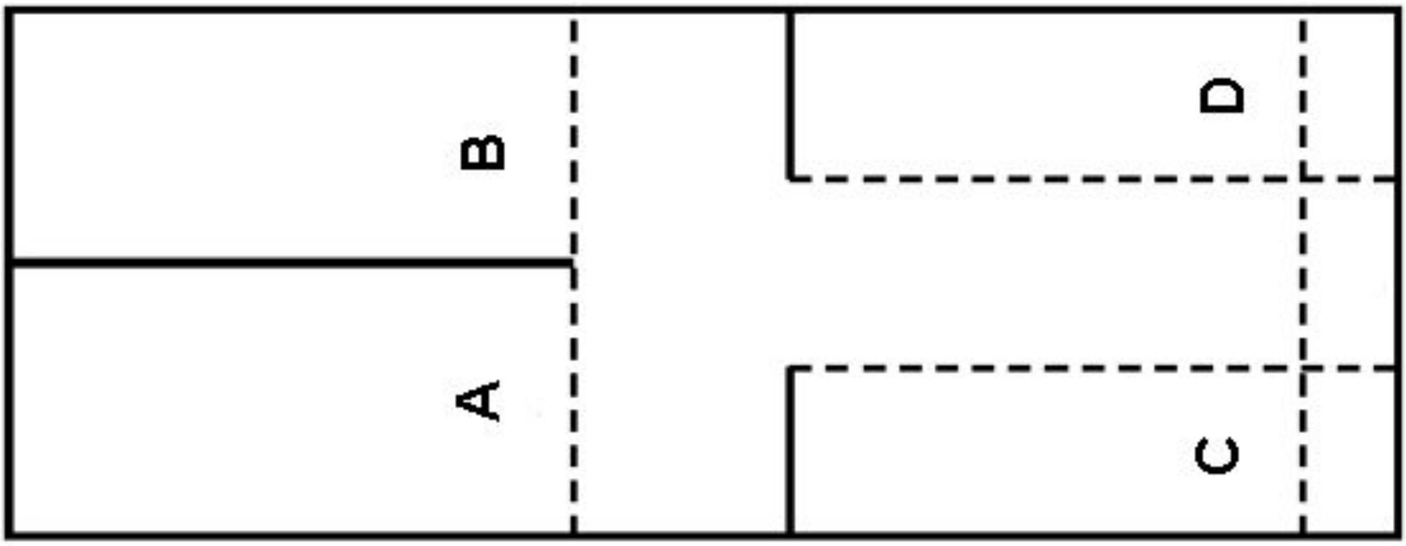
You may not feel like tracking your class through the entire sequence I've described, but perhaps focusing on one variable as a challenge to children would be appropriate. You can do quite a lot without a stopwatch. At least you'll know now the sort of results to expect. You'll need to be careful, when children are comparing whirlybirds, that they retain each of them for further comparisons. They tend to destroy trials if they don't work out well. Sticking them on a chart in order of flight time would be a good way of informally recording. Then they might work with the mathematics of area, or ratio. You could perhaps photocopy my graphical results for interpretation, after some informal trials to establish relevant factors.

And if you think I've covered all there is to discover about whirlybirds, try varying the wing shape, or investigate what affects spinning rate. You might like to try this yourself. Have a good weekend!

APPENDIX 3: Paper Helicopter Template







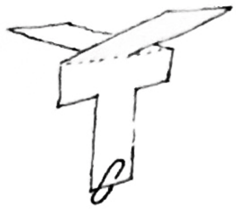
APPENDIX 4:

Pre/Post Sequence Assessment Task

Example of student post sequence response

Paper helicopters

Ben and Tamara were testing their paper helicopters. Tamara's helicopter had **longer wings** than Ben's. Both helicopters had one paper clip.



They each dropped their helicopter from the same height of 1.5 metres and measured the time to fall. They did this 5 times each.

Ben's times were:

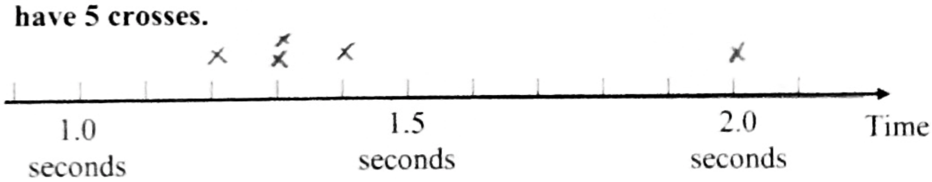
1.1 seconds, 2.0 seconds, 1.3 seconds, 1.4 seconds, 1.3 seconds

1. Draw a circle around the time for the fastest drop.

2. Order the times for the trials from fastest to slowest

	Ben's Times
Fastest drop	1.1
	1.3
	1.3
	1.4
Slowest drop	2.0

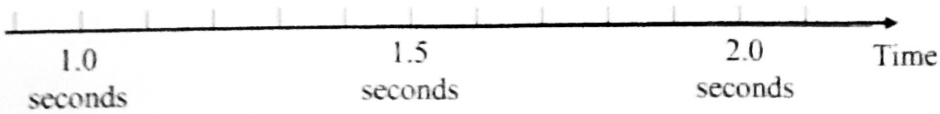
3. Represent Ben's times on the number line with crosses. You should have 5 crosses.



The time for Tamara's trials were:

1.2 sec, 1.5 sec, 1.9 sec, 1.8 sec, 1.8 sec

4. Represent Tamara's times on the number line with crosses. You should have 5 crosses.



5. Why did Ben and Tamara measure the drop 5 times instead of just one time? ben and tamara tested the drops 5 times because if they did it 1 time they wood not have eny thing to comper it to

6. Why did the times vary from trial to trial?

7. What is your best guess for Tamara's helicopter drop time? 1.9

8. What is your best guess for Ben's helicopter drop time? 2.0

9. Which helicopter was slower – Ben's or Tamara's? tamara

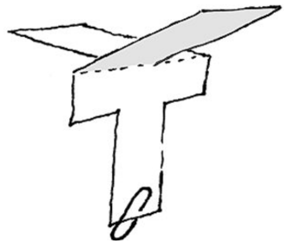
10. Why do you think it was slower? because tamaras halerkokter had longer wings

11. Draw a picture to show how the paper helicopter works.

Pre/Post Sequence Assessment Task

NAME:

Ben and Tamara were testing their paper helicopters.
Tamara's helicopter had **longer wings** than Ben's.
Both helicopters had one paper clip.



They each dropped their helicopter from the same height of 1.5 metres and measured the time to fall. They did this 5 times each.

Ben's times were:

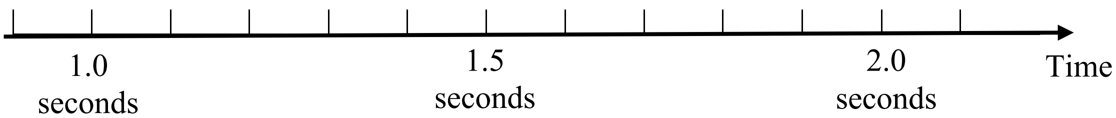
1.1 seconds, 2.0 seconds, 1.3 seconds, 1.4 seconds, 1.3 seconds

1. Draw a circle around the time for the fastest drop.

2. Order the times for the trials from fastest to slowest

	Ben's Times
Fastest drop	
Slowest drop	

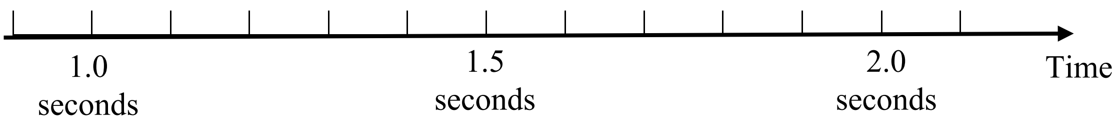
3. Represent Ben's times on the number line with crosses. You should have 5 crosses.



The time for Tamara's trials were:

1.2 sec, 1.5 sec, 1.9 sec, 1.8 sec, 1.8 sec

4. Represent Tamara's times on the number line with crosses. You should have 5 crosses.



5. Why did Ben and Tamara measure the drop 5 times instead of just one time?

6. Why did the times vary from trial to trial?

7. What is the typical time for Tamara's helicopter drop? _______

8. What is the typical time for Ben's helicopter drop? __________

9. Which helicopter was slower – Ben's or Tamara's? _____________

10. What may have caused it to go slower?

11. Draw a picture to show how the paper helicopter works.