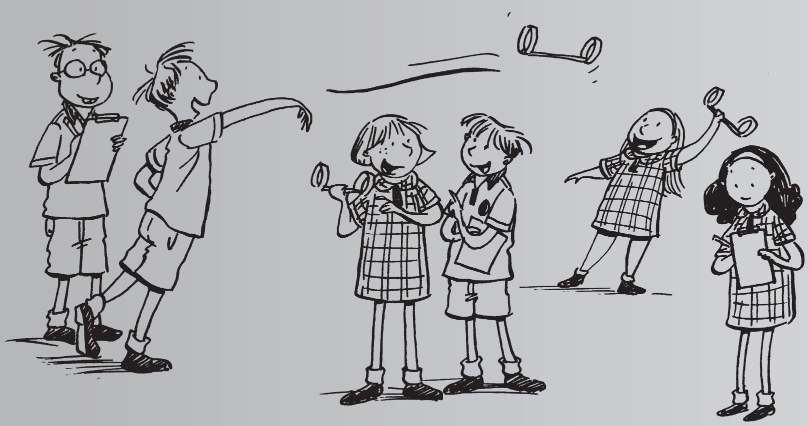
UNIT 2

Fight for Flight

What is the best design for a loopy aeroplane?



WHAT HAPPENS?

In this unit, students combine knowledge of the principles of flight with the technology process to determine the most effective design for a loopy aeroplane.

Students will:

- Create a set of 'identical' paper aeroplanes, test them and reflect on the process. (Discover)
- Become familiar with the technology cycle. (Devise)
- Plan a scientific investigation to determine the best design for a loopy aeroplane. (Devise)
- Use the technology process to develop ideas, design, construct and evaluate loopy aeroplanes. (Develop)
- Determine the best design for a loopy aeroplane, communicate their findings and justify their responses with data. (Defend)

TEACHER NOTES:

Students love making and testing paper aeroplanes. The challenge is for the whole class to work as a team and to use data to justify the best design.

Fight for Flight is a great cross-curricular unit that integrates technology design, science and mathematics. The teacher doesn't necessarily need to know about flight in order to do this unit – but this could be an ideal time to introduce the principles of flight. Some recommended websites have been listed on the book's support website.

Materials

- Straws (pack of 100)
- Tape, paper and scissors
- Other materials as determined by students
- Tape measures

Curriculum Links

- Technology – Design cycles
- Science – Forces of flight, fair testing

Mathematical Focus

- Number sense
- Measurement – cm, m and accurate measuring
- Statistics – measures of central tendency: mean, median (optional)

Resource Sheets

- Resource sheet 1: Building Loopy Aeroplanes
- Resource sheet 2: Fair Testing – Possible Intervening Variables
- Resource sheet 3: The Technology Cycle
- Resource sheet 4: The Principles of Flight
- Resource sheet 5: The Principles of Flight – Assessment

Support website

www.curriculumpress.edu.au/maths

All of the resource sheets are available on the support website to download as PDF files. Those that you might customise are also available as editable Word documents.

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DISCOVER

INTRODUCE AND CONSTRUCT THE FIRST LOOPY AEROPLANE

Provide students with a copy of Resource sheet 1. Instruct them to follow the directions exactly. If a student asks a question which is not covered by the instructions, make a decision for the class or seek a class consensus.

FLIGHT TESTING AND DISCUSSION

Encourage students to test their loopy aeroplanes to determine which one is 'the best'.

After the testing has taken place and the students are back at their desks, engage them in a class discussion. The following questions might be useful:

- Which was the 'best' aeroplane?
- How did you know?
- Would anyone dispute that [name]'s plane is the best?
- Why/why not?
- Will that plane always be the best?
- What did you decide the 'best' meant then?
- What if we decided the 'best' meant the one which flew straightest, or stayed in the air for the longest, or was the neatest one built? Would that change which was the 'best'?

At this point, allow students to test the planes as they wish. They will usually immediately compete on flight distance. Let them do it but do not get engaged in discussions about fairness. Rather, ask students to monitor and note those things that intervene (interfere) with obtaining an accurate and equitable result. For example:

- force of throw
- height of throw
- construction of plane
- environmental conditions.

Key Vocabulary

To be developed during the discussion:

- Variable
- Constant
- Intervening
- Bias

DEVELOP THE UNDERSTANDING OF FAIR TESTING

Continue the discussion and encourage students to consider whether they think:

- the test was completely fair
- there were factors that prevented us from testing the aeroplanes accurately.

Create a list for permanent display, showing what the students considered. They may need guidance to consider multiple sources of variability. Some possibilities are listed in Resource sheet 2.

Assessment Idea

Focused observation:

Consider whether or not students are able to explain fair testing and to identify some of the variables that may have affected test results.

DEVISE

Provide students with a copy of Resource sheet 3 or display in the class on a projector or interactive whiteboard.

INTRODUCE THE TECHNOLOGY CYCLE

Introduce the technology cycle and discuss each step. Have students identify what they have already done and which step each action would fit into. For example, the design was already provided (ideation), however the students made loopy aeroplanes (production) and tested them (evaluation). Keep the Technology Cycle chart on display throughout the unit.

Students often become obsessed about making sure that all testing methods and conditions are fair. They may need to be shown that there needs to be a balance between reasonableness and fairness.

Discuss the aspect of the technology cycle that they have not yet touched (investigation). What might investigation necessitate? What might they need to find out? (Possible answers include: how planes fly or alternative designs for paper planes.)

DISCUSS THE ATTRIBUTES OF FLIGHT

Elicit what students know about aircraft and how they fly. Discuss the principles of flight, if desired. It is not essential for students to understand the principles of flight in order to complete this mathematics investigation, but it is a perfect learning opportunity to do so, with the added benefit that this allows students to apply theoretical understandings to their designs.

PLAN THE INVESTIGATION

Ask students to consider the loopy aeroplane. What are some of the design alterations that could be made?

Students may consider the length of the straw, length and width of the rectangle that makes up the loops, the placement of the loops on the straw, what materials the loops are made from and so forth. At this point, do not restrict them from coming up with too many variables: it will become apparent to them later that they need to rethink their plans.

Once students decide which variables they wish to consider, have them work out how many aeroplanes they need to produce in order to test every combination. Leave them to work this out, as it is a purposeful way of having them consider the outcomes and how to code each combination of attributes for their loopy aeroplanes (see Fight for Flight In Action, p 29).

Once they have listed the number of aeroplanes required, find out whether or not they have noticed a pattern. For example, if they wish to consider two wing placements, two wing lengths and four wing widths, they will need 16 loopy aeroplanes (2 x 2 x 4).

TIP

Setting this up as a table may be necessary to help students to see the patterns developing:

Have students decide who will construct the aeroplanes and how they will maintain 'fairness'. Refer back to the lists constructed earlier on fair testing in the Discover phase (or see Resource sheet 2, p 33).

Variations/numbers of:			
placement of wing loops	length of loops	width of loops	number of aeroplanes required
2	2	4	16
3	3	3	27
1	4	4	16

This would link exceptionally well to a Science unit on forces or flight. If the students have not done any work on flight, an introduction could be very useful.

Resource sheet 4 provides a quick overview of the principles of flight. Be aware that this is a very simplistic model because an understanding of more complex issues of physics is necessary to fully understand flight (and this is not appropriate for the majority of children at this level). For example, terminal velocity is an important factor when considering weight. If further information is required for students, Bernoulli's Principle and Newton's Laws of Motion would be good beginning points. See the support website for recommended websites on the topic.

Assessment Idea

Task analysis:
Resource sheet 5
If assessing students' understanding of flight, have them label and complete a blank diagram with the forces of flight and explain these forces.

Mathematical Focus

- Multiplicative thinking
- Combinations (probability)

There are a multitude of variables for students to explore and it can be quite difficult to predict which combination they will choose to work with. One possible direction is illustrated in Fight for Flight In Action so you can see what the progression might look like.

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Mathematical Focus

- Understanding and calculation of mean
- Interpreting data
- Variability
- Measurement

Students will often think that collecting the data is the conclusion of an investigation, not realising that they need to analyse the data to determine patterns, make interpretations and respond to the question.

In the discussion, students may have suggested that all the results for each aeroplane could be added together. While this is not a statistically recognised calculation for an average, it still provides an overall measure for each aircraft and leads into a teaching moment for the concept of a mean.

Assessment Idea

Focused observation:

- Were students able to compute a mean?
- Did they understand that the mean represented the 'typical' flight distance?
- Did they identify that the largest mean indicates the aeroplane that flew the furthest overall distance, not necessarily the furthest on a single flight?

DEVELOP

DESIGN AND CONSTRUCT THE MODIFIED AEROPLANES

Have students build their designs, maintaining the quality control they discussed in fair testing.

TEST THE LOOPY AEROPLANES

Discuss testing methods, again referring to the principles of fair testing.

Students should consider testing in areas where the impact of the wind is limited and where there is little chance of the aeroplanes hitting something. An assembly hall would be a good choice. Also discuss the number of times each one should be tested, having students justify their responses, until a consensus is reached. Students should consider that once or twice is insufficient but that 20 times is impractical and would take too long. Ensure that students have considered a suitable method of recording the test results.

Have students test their aeroplanes and record their results.

USE AND DISCUSS THE RESULTS

Provide copies of the whole class results for the students and ask them to study them.

- What do they notice?
- Are the results helpful?
- Are there any results that appear incorrect?
- Were there any problems in the testing?
- How were those problems dealt with?
- Are there any observable patterns?
- Which is the best aeroplane? Is it the one that flew the furthest on a single trial, the most consistent – or something else?
- Is there something else we need to do with the data to make it easier to read, understand or work with?
- Is there a way that we could get one measurement for each aeroplane, to make comparison easier? (Sum or mean.)

ANALYSE THE RESULTS – MEAN

If students are familiar with calculating average, they may have raised this already. Take this opportunity to review the mean and the method of calculating it. Otherwise, teach the mean now and have students compute the mean for each aeroplane.

TIP

Students may have recorded their flight distances in centimetres or metres. If metres, they will be working with decimals and may benefit from using calculators. Microsoft Excel is a useful tool as students can be shown how to use the 'average' function and save considerable time – but only after they are able to calculate a mean for themselves!

Have students consider the individual mean for each aeroplane and identify any interesting results. For example, students may see that one aeroplane flew further than another, but that it was less consistent. This observation can be drawn out by looking at the variability of individual flight distances.

Raise the question of whether there is a way to compare all aeroplanes with the same attribute. For example, would it be possible to compare all narrow-winged aeroplanes to medium- and wide-winged aeroplanes? This can be done by calculating a 'mean of the means' for each attribute.

WIDTH

wing width	narrow	medium	wide
mean distance (metres)	2.05	1.64	1.62

For example, although in this case the narrow wings typically had a higher mean flight distance than the middle and wide widths, the distances are much less consistent (higher variability), which should be discussed.

PREDICTING RESULTS – DISCUSSION

Which aeroplane is the 'best' – based on the means the students have calculated?

Should this have been the best aeroplane? (See teacher notes, right.)

Was this the best one overall? If not, why do they think this result occurred? Were there other factors that could have affected the result?

If the unit also addressed the forces of flight, tie this learning back to what is known about flight:

- Knowing what you do about flight, why do you believe this was the best aeroplane? For example, wider wings increasing lift, or a longer wing strip increasing drag, etc.

By looking at the means calculated for each aeroplane, and then further calculating means for all the aeroplanes with a particular wing width, a particular wing length and so on, students are able to determine what the best wing width, wing length and wing placements were.

FIGHT FOR FLIGHT *IN ACTION!*

In the instance illustrated below, students chose to test modifications that would create the longest flight. The variables they chose to modify were the length and width of the rectangle making the looped wings and the placement of the loops on the straw.

Students decided to test three different variations of width (Narrow, Medium, Wide), length (Short, Average, Long) and placement (both Ends, Inset, One middle and one end). So, one aircraft type was Narrow wing, Short wing, loops at both Ends (coded as NSE). This gave a total of 27 (3 x 3 x 3) aeroplanes that needed to be built in order to have one of every possible type for comparison (see below), and this also happened to be a perfect number for a class of 27 students.

NSE	NSI	NSO	NAE	NAI	NAO	NLE	NLI	NLO
MSE	MSI	MSO	MAE	MAI	MAO	MLE	MLI	MLO
WSE	WSI	WSO	WAE	WAI	WAO	WLE	WLI	WLO

Each student constructed one aeroplane, helping each other to maintain 'quality control'. Each loopy aeroplane was checked by several other students to ensure it conformed to the design specifications.

Once an aeroplane was built, the students elected to test each one by throwing it five times, to eliminate as much bias as possible. The table below shows a small part of the resulting data.

Aeroplane	Throw 1	Throw 2	Throw 3	Throw 4	Throw 5
NSE	3.81	2.94	3.01	287	2.20
NSI	1.73	0.74	2.13	2.62	1.54
NSO	2.43	2.97	2.54	2.61	1.97

When students were asked what they thought they should do next with the data, one student decided that there were too many numbers (135 in total) and that if the numbers were added together there would be just one number to represent each aeroplane. Another student thought it was a good idea but suggested dividing that number by 5 to give a 'sort of overall score' for a single throw. This was the perfect opportunity to introduce mean and have the students calculate mean distances for each aeroplane.

Aeroplane	Throw 1	Throw 2	Throw 3	Throw 4	Throw 5	Average
NSE	3.81	2.94	3.01	287	2.20	2.966
NSI	1.73	0.74	2.13	2.62	1.54	53.628
NSO	2.43	2.97	2.54	2.61	1.97	2.504

Students calculated the mean score for their own aeroplane and then checked others' results to ensure there were no errors. They quickly realised that one of the measures in NSI was incorrect and a conversation on how to deal with errors ensued. Students also decided that rounding the flight distance to hundredths was enough as that represented centimetres. A new table was reproduced as follows:

Aeroplane	Throw 1	Throw 2	Throw 3	Throw 4	Throw 5	Average
NSE	3.81	2.94	3.01	2.87	2.20	2.97
NSI	1.73	0.74	2.13	2.62	1.54	1.75
NSO	2.43	2.97	2.54	2.61	1.97	2.50

The students then used these means to determine the best of each 'type'. They went off to calculate a mean score for all narrow-winged aeroplanes as well as for all medium- and wide-winged aeroplanes. The largest mean score was obtained by narrow-winged aeroplanes, so they concluded that narrow wings were best. Through this method they were able to argue the best length and placement of the loops as well, finally predicting precisely which design should have performed best overall (it had actually come second). When asked to justify the 'incorrect' finding, one of the students argued that looking at the best of each variable didn't consider how all the variables would interact together.

Have students reflect on what they discovered from the results (for example, narrow wings were better than wide wings).

DESIGNING BETTER THAN THE BEST

Set the students an individual task of using the information they obtained in the experiment to design an aircraft which is even better! It needs to be based on the results of the experiment and to use the same variables. Students write a paragraph or present a short justification about why their design would be better.

For example:

> 5 cm long wings were less effective than 6 cm wings, and this is possibly because drag increases with the smaller wings. I have designed my loopy aeroplane with 7 cm wings because they will be even more effective.

TO EXTEND

- Have students conduct the experiment a second time and compare the new data with the existing data, explaining any differences that may arise.
- Individually or in groups, students design and, if desired, conduct a second experiment which extends the knowledge they gained in the first trials (by trying different wing lengths, etc).

TO SIMPLIFY

- Limit the comparison to two designs, such as two wing widths, leaving the rest constant.

ALTERNATIVE INQUIRIES

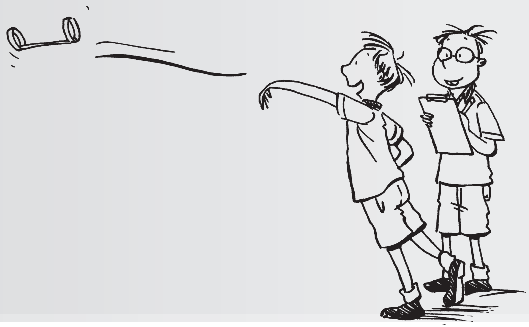
- Consider different variables, for example by adding weight to different parts of the aeroplane, having different numbers of loops or using different materials (plastic, cardboard, etc).

Assessment Idea

Task analysis:

Assess the students' predicted models to see if they logically follow on from their findings.

Building Loopy Aeroplanes



How to build a loopy aeroplane

1. Cut out two paper rectangles, each 5 cm x 20 cm.
2. Form each rectangle into a loop and tape it together.
3. Tape 1 loop to each end of a straw.

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Fair Testing – Possible Intervening Variables

Production

- Lack of accuracy in cutting or constructing the loops
- Variation in sticky tape usage (can be considerable)
- Loops taped at an angle
- Loops taped in an offset position
- Variation in overlap of loop ends so loops are actually different sizes

....

....

....

Throwing style

- Students leaning forward to throw
- Strength of throws
- Not starting from the same throwing point
- Throwing loops down versus loops up
- Height of thrower/height plane released from

....

....

....

Measurement

- Inaccurate measurement
- Inaccurate recording
- Incorrect units of measure

....

....

....

Environmental conditions

- Breeze/wind gusts
- Hitting/flying into obstacles

....

....

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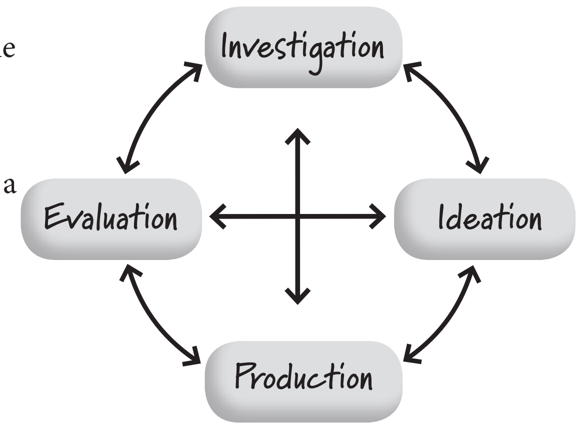
RESOURCE SHEET 3

FIGHT FOR FLIGHT

The Technology Cycle

The technology process is often considered a cycle – but the process is not always followed exactly as shown here. For example, designers often move from the Evaluation to the Production stage if all they need are minor adjustments to a design.



Investigation

Ideation

Production

Evaluation

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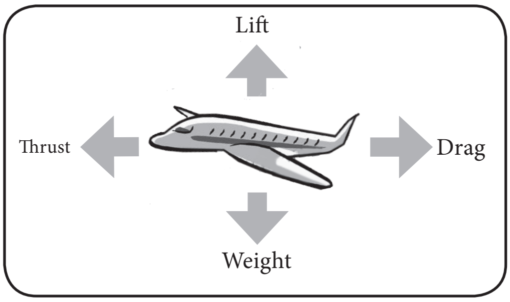
The Principles of Flight

There are four main forces which act upon flight:

drag thrust lift weight

It is necessary to understand how these forces work in order to understand flight.



Force 1: Lift

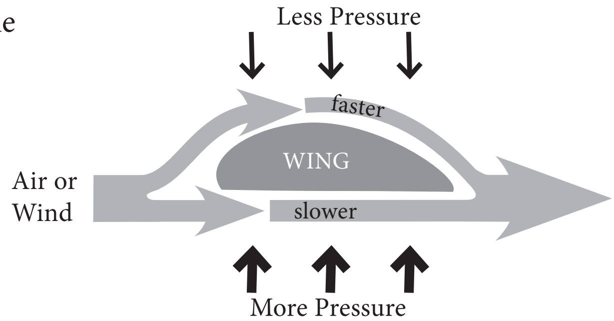
Lift is a force that opposes weight: if lift is greater than weight, the aircraft will ascend. If weight is greater than lift, the aircraft will descend.

Lift is created in two ways:

1 By air movement over and under the wing.

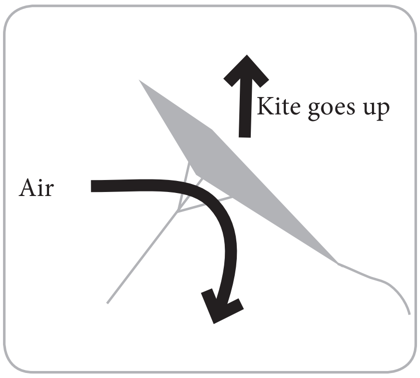
The air travelling under the wing moves more slowly and creates a high pressure area. The air travelling over the top of the wing moves more rapidly and creates a low pressure area. The wing is pushed upwards into the low pressure area and this causes the aeroplane to rise. This effect is known as Bernoulli's Principle.

Bernoulli's Principle



2 Deflection

When wind pushes against a wing that has been angled, the downward deflection of the wind creates the movement upward.



The Principles of Flight (continued)

Force 2: Drag

Drag is caused in several ways:

1 Resistance

The resistance of the aeroplane moving through the air.
You can feel this effect if you hold an exercise book at the end of your arm. If you hold it flat to the air as you move it fast, it seems as if the air is pushing against the book. If you hold it edge on to the air, it's easier to move it quickly, because it has less drag.

2 Friction

The movement of the air over the surface of the aeroplane creates friction. This friction increases drag.

Force 3: Weight

Weight is the result of gravity acting on the mass of an object.

Force 4: Thrust

Thrust is the force which pushes the aircraft forward. It can be provided in powered aircraft by jet engines, rockets or propellers. When you throw a paper aeroplane, you are providing the thrust.

Drag and thrust are opposing forces. If the thrust is powerful enough it will overcome weight and drag, and the aeroplane will fly. Once it is moving through the air, the air travelling over the wings creates lift.

Questions:

1 How do you think the effect of gravity could be decreased?

2 How can drag be reduced?

3 How can thrust be increased?

4 How can lift be increased?

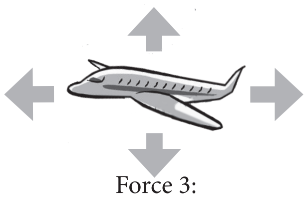
Now think about these questions as you consider the design of your loopy aeroplane. What would you change?

The Principles of Flight (continued)

1 Label the diagram below: what are the forces that act on aircraft in flight?

Force 1: ....

Force 4: ....



Force 2: ....

Force 3: ....

Force 1: ....

There are two ways in which this force occurs. Explain both of them, drawing diagrams to help you.

....

....

Force 2: ....

You have been told about two ways that this force occurs. What are they? Explain them.

1 ....

2 ....

Force 3: ....

Fill in the gaps.

This occurs when the force of .... acts upon the .... of an object.

Force 4: ....

This force occurs in different ways depending on the type of aircraft. Name three ways in which this can be provided: ...., ..., ...