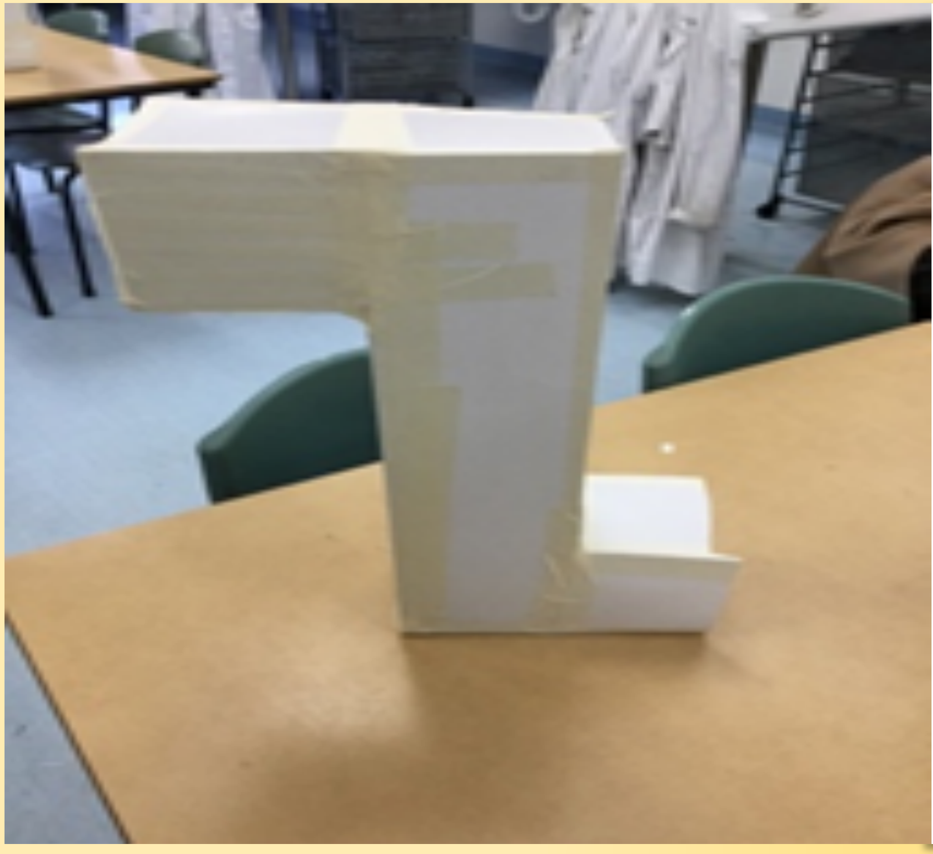
Light and Its Properties
Year 5



Students explore the path of light as it travels through different objects and from a source to our eyes. They construct and use a range of representations to describe observations, to show and model patterns or relationships between variables, to understand natural systems and mathematical concepts related to angle and reflection.

INTERDISCIPLINARY MATHEMATICS AND SCIENCE (IMS) LEARNING

DEAKIN UNIVERSITY
VANDERBILT UNIVERSITY
MACQUARIE University
Australian Government
Australian Research Council

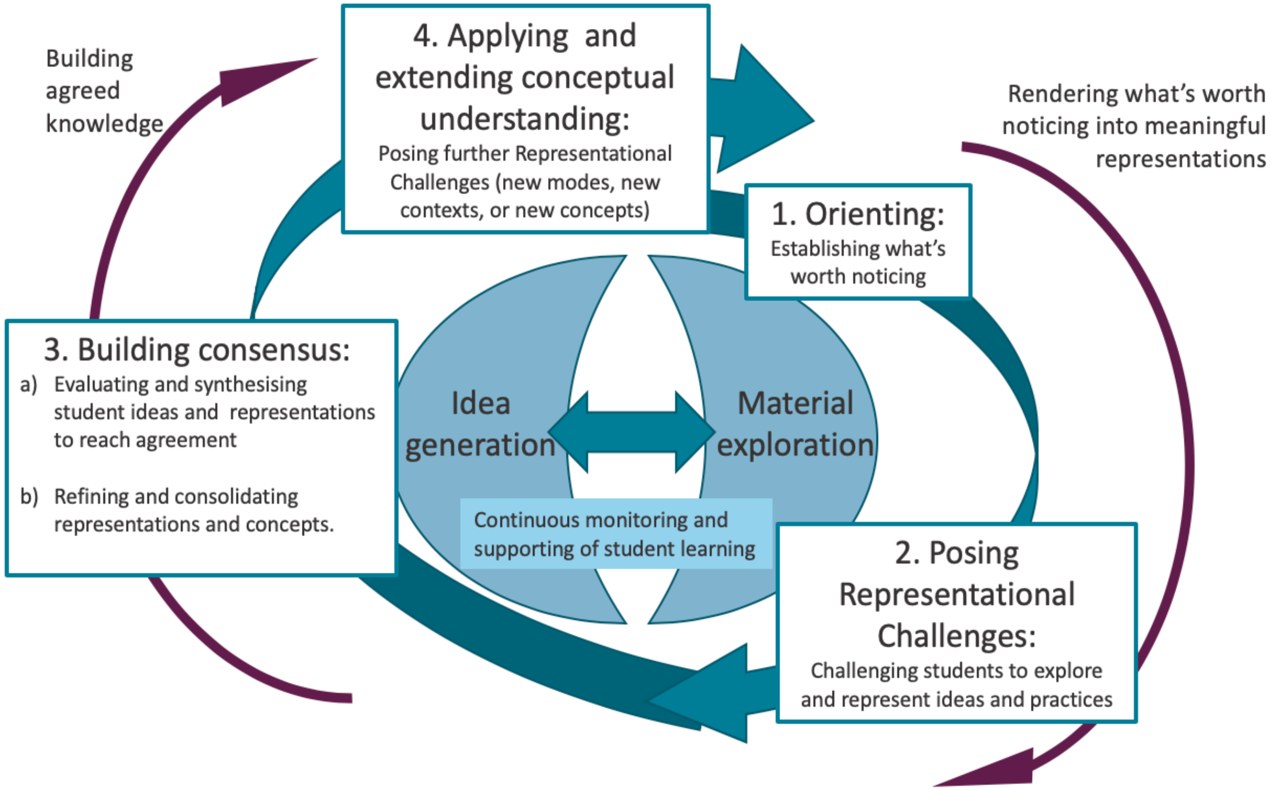
This teaching and learning sequence is one of a number that are designed to productively integrate mathematics with science, using a guided inquiry approach in which students construct, share, evaluate and revise multimodal representations to establish conceptual understanding. See website https://imslearning.org/

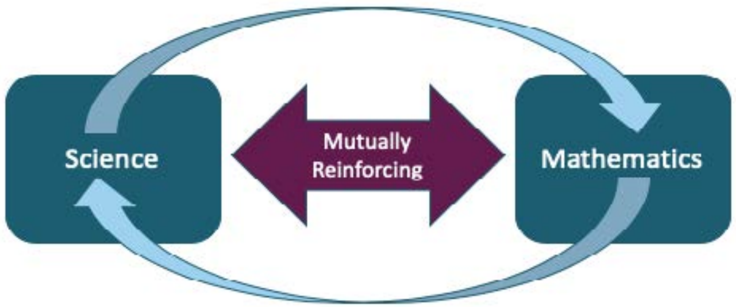
Interdisciplinary Mathematics and Science (IMS) Learning

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."*

Investigating light and its properties (Year 5): Sequence Overview

In this **teaching and learning sequence** students explore the path of light as it travels through different objects and from a source to our eyes. Students construct and use a range of representations to describe observations, to show and model patterns or relationships between variables, to understand natural systems and mathematical concepts related to angle and reflection.

Lesson Sequence - Outline

Lesson 1 Pre sequence assessment task and Light spectrum: Students begin by being able to describe light as being made up of seven colours (a spectrum that remains constant) and represent how light travels to our eyes. Recognising that the colour of an object depends on the properties of the object and the colour of the light.

Lesson 2 Transparent, translucent, opaque: Students start to think about different types of materials and how they can be classified as transparent, translucent or opaque.

Lesson 3 Shadows: Students investigate how a shadow is formed. The role that light and materials play in creating shadows form part of this lesson.

Lesson 4 Reflections 1: Light travels in straight lines and this can be demonstrated through the use of mirrors. Students can represent this, and how light reflects, through the use of ray diagrams. Student observe and use informal measures to estimate the differences between angles that form rays.

Lesson 5 Reflections 2: This lesson builds on Lesson 4 and continues students' exploration of how light travels. Further use of mirrors, and having students consider how they can represent how light travels and reflects through the use of ray diagrams.

Lesson 6 Periscope challenge 1: Periscopes are an effective and engaging fun way to practically test how light travels. This lesson begins with a laser maze challenge to demonstrate how light can be purposefully directed. Students then commence designing a periscope. Students observe and describe the angle of reflection.

Lesson 7 Periscope challenge 2: This lesson is devoted to students building their periscope. The notion of a 'net' is included here. Students sketch a net to represent the template of their periscope. Students understand the relationship between the 3D construction of the periscope and the plan in the form of a 2D net.

Lesson 8 Refraction: Students continue building on the concept of light traveling in straight lines and discuss and describe observations about light refraction.

Lesson 9 Refraction and magnification: Light can be magnified through different materials and by using transparent materials, so that we can affect the direction of light rays. This lesson introduces students to curved lenses (converging and diverging lenses) and seeks to show how light behaves when travelling through these lenses.

Lesson 10 Fun with light: This lesson is designed to allow students to build on their knowledge through an exploration of transparent materials effect the direction of light rays. The magnification of light through different materials and the properties of curved lenses (converging and diverging lenses) is included in the learning.

Post sequence assessment task: Students complete written post-test assessing interpretation of diagrammatic and pictorial representations which include the impact of light and dark and understanding of how light travels.

Investigating light and its properties Science and Mathematics Learning and Curriculum Outcomes

Learning Focus	Key Curriculum Outcomes (Victorian Curriculum)
Science ideas and practices • Classifying materials as transparent, opaque or translucent based on the extent to which light passes through them or is absorbed • Exploring the use of mirrors to demonstrate the reflection of light • Recognising the refraction of light at the surfaces of different transparent materials, for example, when light travels from air to water or air to glass • Recognising that the colour of an object depends on the properties of the object and the colour of the light source • Classifying materials as transparent, opaque or translucent based on the extent to which light passes through them or is absorbed	**Science** **Science as a human endeavor:** Science knowledge helps people to understand the effects of their actions (VCSSU041) **Physical sciences** Light from a source forms shadows and can be absorbed, reflected and refracted (VCSSU080) **Science Inquiry Skills** **Recording and processing** Use formal measurements in the collection and recording of observations (VCSIS068) Construct and use a range of representations, including tables and graphs, to record, represent and describe observations, patterns or relationships in data (VCSIS085) **Analysing and evaluating** Compare data with predictions and use as evidence in developing explanations (VCSIS070)
Mathematics Learning Focus: ideas and practices • Estimating, measuring and representing variability (length) • Select and use appropriate formal measures of length and convert between mm, cm and m including use of decimal notation • Collecting data and constructing, representing and interpreting data display • Developing skills in constructing graphical representations • Making informal inferences by reasoning about distribution and variation • Observe and describe features of angles and rotation (to construct ray diagrams) • Observe and describe mathematical patterns and relationships • Observe and represent features of 3D shapes and objects • Develop and apply transformation skills i.e., reflection	**Mathematics** **Using units of measurement** Choose appropriate units of measurement for length (VCMMG195) **Fractions and decimals** Compare, order and represent decimals (VCMNA190) **Data representation and interpretation** Pose questions and collect categorical or numerical data by observation or survey (VCMSP205) Construct displays, including column graphs, dot plots and tables, appropriate for data type, with and without the use of digital technologies (VCMSP206) Describe and interpret different data sets in context (VCMSP207) Construct and use a range of representations, including tables and graphs, to record, represent and describe observations, patterns or relationships in data (VCSIS085) **Measurement and Geometry** **Shape** Make models of three- dimensional objects and describe key features (VCMMG142) **Location and transformation** Identify symmetry in the environment (VCMMG144) Identify and describe slides and turns found in the natural and built environment (VCMMG145) **Geometric reasoning** Identify angles as measures of turn and compare angle sizes in everyday situations (VCMMG146)

Investigating light and Its properties (Year 5): Equipment/Resources

Lesson		Equipment/Resources
All Lessons		**Students:** student workbooks (unlined), pencils, colours and rulers **Teachers:** Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer (NB: Teacher
1	Pre-sequence assessment task and light spectrum	**Pre sequence assessment task:** See Appendix for document **Light Spectrum:** 3D shapes: different shaped prisms, thick plastic block, glass ball, etc.; torch; investigation planner **What's in the box:** Photocopy box; torch; cellophane; coloured object. **One set of each item for working groups of two or three students.**
2	Transparent, translucent, opaque	Variety of different materials for classifying e.g., papers, foil, Perspex tape, types of plastic, natural materials such as wood, leaves, liquids such as tea, water etc. **One set of each item for working groups of two or three students.**
3	Shadows	Glue sticks; torches; investigation planner; lego mini-figures or small plastic toys. **One set of each item for working groups of two or three students.**
4	Reflections 1	Foil sheets; small handheld torch; hula hoops; tennis balls. **One set of each item for groups of working two or three students.**
5	Reflections 2	Small handheld torch; Small handheld mirror; 2D or 3D objects; 2D shapes or letters; protractors. **One set of each item for groups of working two or three students.**
6	Periscope Challenge 1	**Laser maze challenge equipment**: Laser pointers, mirrors, A3 paper for maze template **Periscope Challenge:** scissors x 1 per student; thin correx or black card X 1 per student; rolls of sellotape; glue sticks x 5; periscope templates x 1 per student; sheets of plastic mirrors x 10; protractors.
7	Periscope Challenge 2	As per Lesson 6: Periscope Challenge 1
8	Refraction	1 or 2 Drinking straws; 1 regular drinking glass; water; pencil; 1 or 2 different coins. **One set of each item for groups of working two or three students.**
9	Refraction and magnification	Three carboard or plastic alphabetic letters; 1 pipette; water; cooking oil; cardboard; cling wrap. **One set of each item for groups of working two or three students.**
10	Fun with light	Convex and concave lenses; plane mirror; concave and convex mirrors; cardboard; milk carton; coloured counters. **Post sequence assessment task:** See Appendix for document

LESSON 1 – Light Spectrum

(Approximate duration: 120 minutes)

Curriculum focus:

Science ideas and practices
- Understand the path light travels in
- Recognise the different component of the light spectrum
- Understand how light reflects off different surfaces
- Understand how light refracts in different media

Mathematics ideas and practices
- Use Diagrams to visualise patterns and trajectories of light
- Incorporate Angles into diagrams that represent how light travels
- Incorporate evidence of the distance between objects
- Represent the properties of prisms with focus on the path that light takes when it travels
- Demonstrate Proportional reasoning (colours in spectrum) of how light occurs
- Calculate using mathematical instruments and represent diagrammatically angles of refraction
- Represent the concepts of reflection and symmetry and how they are applicable in understanding how light travels
- Represent the concepts of enlargement and how it is applicable in understanding the properties of light.

Equipment/Resources

Light Spectrum: Torch, 3D shapes: different shaped prisms, thick plastic block, glass ball, etc.; torch; Investigation planner.

What's in the box: Photocopy box; torch; cellophane; coloured object.

Equipment required for all lessons
Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens.

Pre sequence assessment task: See Appendix for document

Learning intention:

Students will experience and demonstrate understanding:
- Light from a source forms shadows and can be absorbed, reflected and refracted
- Light being made up of seven colours and represent how light travels to our eyes
- The colour of an object depends on the properties of the object and the colour of the light

Lesson at a glance:

Students begin by being able to describe light as being made up of seven colours (a spectrum that remains constant) and represent how light travels to our eyes. Recognising that the colour of an object depends on the properties of the object and the colour of the light.

LESSON 1 – Pre-test and light spectrum

(Approximate duration: 120 minutes)

Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
	Orienting Identify student prior knowledge of properties of light.	**Pre Sequence Assessment Task** (see appendix 4). **Establishing prior knowledge, understanding and skills** *(15 minutes)* Teacher read task with students answering independently. Answers can be shown through text or drawings with labels. **Engage** (10 minutes) Show various objects with different colours. Ask students what they see. Post a question: *If I wake up in the middle of the night and look around my room, do I see these objects? Do I see the colours of these objects?*	**Pre–sequence assessment** What underlying misconceptions do students have? What productive suggestions can students provide on: • distinguishing between colours, objects. • describing differences between seeing objects in the day and at night. • explaining why there are differences between seeing objects in the day and at night.
	Orienting Establish what is worth noticing and exploring further.	**SHARING AND DISCUSSION** *(15 minutes)* Reviewing questions: • *what is necessary for us to see things?* • *What is necessary for us to see colour?* • *Is there more than one colour in light?* • *How many colours do you think are in light? How do you and how can we find out?* Discuss the idea of colours bouncing off objects and to our eyes. In what ways do they bounce? Observe and describe the angle/s they form?	What productive suggestions can students provide about: • describing the different colours in light • observing the pattern of colours and orientation/formation • explaining why we see different colours
Mathematics: Diagrams Angles Lengths Properties Shapes of prisms	***Representational Challenges*** Explore and represent phenomena of reflection and refraction of light.	**INVESTIGATION – Light Spectrum** *(40 minutes)* Using the **investigation planner**, Students to predict which of the 3D shapes create the best spectrum and why, when a torch is shone on them NB: The lights will need to be turned off, and a dark space is required Ask students to observe closely the sides, vertices and angles created by the shape.	Can students note the different paths of light as it travels from air to perspex and back? Can students make ordered observations of: • the effect of angle on the degree of bending? • which colours are most bent?

Proportional reasoning (colour spectrum) Angles of refraction		NB: Can students predict what differences would occur if the 3D shapes were circular/round? Discuss how do we define as "best" spectrum (e.g. length, scope, pattern) and how can we record this for the experiment? Allow time for students to experiment with different shapes. Students to record their observations in the investigation planner.	Can students use the language of 'angle' consistently to describe what they observe?
Science: Path of light Light spectrum Reflection Refraction	***Building Consensus*** about light spectrum and ways to show how light travels.	**SHARING AND DISCUSSION** *(20 minutes)* Students to describe their observations and interpret these in terms of how the light is broken into different colours. [This sets up a puzzle which can be unpacked later in the week on refraction] Share examples of what students have done. Discuss these questions: • *How do we see light?* • *How do we see colours when the incoming light had no colour?* • *Are there patterns that you notice in the way the spectrum appears?* • *What other phenomena involving colours might you link to these ideas?* Show Bill Nye Video on colours (stop at 2:48) https://www.youtube.com/watch?v=XMVY33cZ9To Discuss these ideas: • *What did you find interesting about light in this video?* • *What questions can we ask about light?* Inform the class of what question will be investigated in the next lesson.	Do students make reasonable assumptions about how the colours of light relate to white light? Can they explain why the different angles create a spectrum, in terms of splitting of light into its component colours? What informal notions about light do students discuss?

LESSON 2 – Transparent, Translucent, Opaque

(Approximate duration: 120 minutes)

Curriculum focus:

Science ideas and practices

Describe the properties of materials that are transparent, translucent and opaque

Mathematics ideas and practices

- Organise and present understanding and examples of light graphically
- Applying formal and informal measurement techniques to show the properties of light.

Learning intention:

Students will experience and demonstrate understanding of ways to classify materials as transparent, translucent or opaque.

Equipment/ Resources

Variety of different materials for classifying e.g. papers, foil, Perspex tape, types of plastic, natural materials such as wood, leaves, liquids such as tea, water, oil.
Torches.

Equipment required for all lessons

Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Lesson at a glance:

Students start to think about different types of materials and how they can be classified as transparent, translucent or opaque.

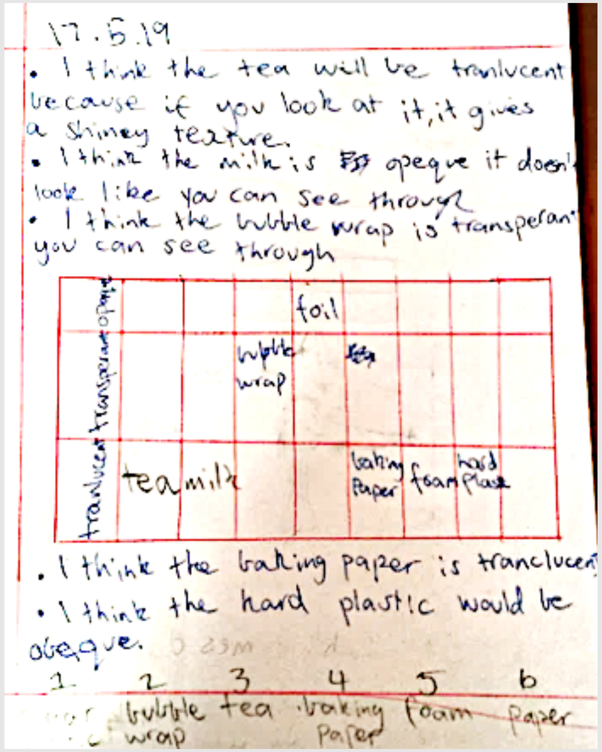
LESSON 2 – Transparent, Translucent, Opaque

(Approximate duration: 120 minutes)

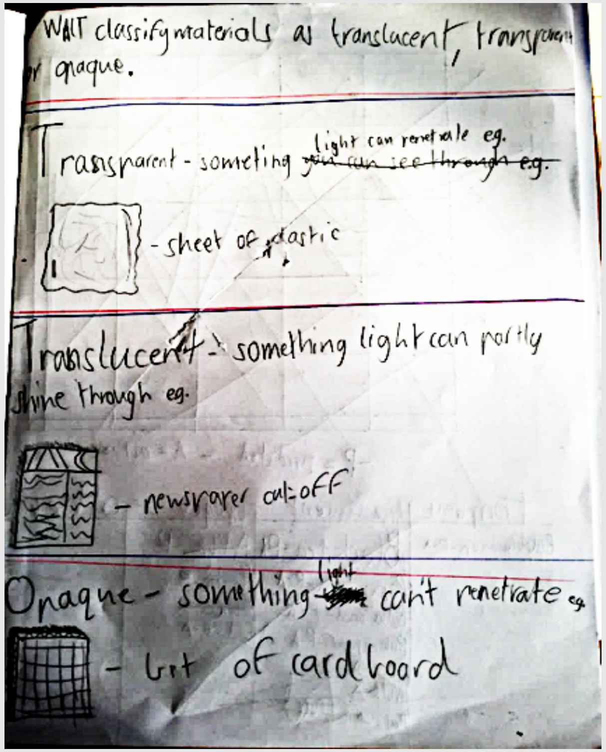
Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Transparent Translucent Opaque **Mathematics:** Constructing a scale Formal and informal measurement	***Orienting*** Establish what is worth noticing in relation to the optical properties of materials	**ENGAGE** *(20 minutes)* Review the lessons from last week. Probing questions: • *What would happen if you put something in the way of the light?* • *Can you think of some materials that can let a lot of light through?* • *Can you think of some materials that let some light through?* • *Can you think of some materials that don't let light through?* Introduce the terms transparent, translucent and opaque. Ask students to consider the difference and share some examples that they might know of. Encourage students to use their own words to describe these differences.	**What productive suggestions can students provide on:** • Which materials allowed a lot of light to pass through? • Which materials allowed some light to pass through? • Which materials didn't let light through? • Which materials made the best shadows? • How can we show how light travels through each of these materials?
	Posing representational challenges Explore and identify ways to represent the amount of light passing through each material	**INSTRUCTION** *(10 minutes)* Ask students to examine the items in their tub. Ask students to make predictions and explain their ideas to each other as to whether they will be transparent, translucent or opaque. Explain that students will be working in small groups to investigate the amount of light that different materials allow to pass through. Ask students how to design a test to check their predictions. What data to collect? How can we design a scale for ordering the degree of transparency/opaqueness? Encourage students to plan for their investigation using the **investigation planner**.	Can student relate this task to other forms of scales for measuring? How can students design a quantitative scale e g 1-10 that goes beyond descriptors such as not see-through, more see through etc.? Can students articulate the advantage of constructing a numerical scale?

Mathematics: Organise and present understanding and examples of light graphically	**Posing representational challenges** Explore and identify ways to represent the amount of light passing through each material	**INVESTIGATION – How light travels (small groups)** *(70 minutes)* Working in groups of three, students explore the different materials and investigate how much light each material can let through. Encourage students to represent their findings in various forms, such as diagrams, pictures, or digital images. Ask students to explain: • *how light behaves when it hits different materials?* • *How can we show these differences using diagrams?* [Note: some students might start to use arrows, so this could be an opportunity for students to discuss how the arrows can be used to show light rays, e.g. amount of light and direction of the light]	Can students represent light in different forms? How do students show the travel of light when hitting different materials? Can they use representations such as rays and arrows to indicate direction, absorption and reflection?
Science: Transparent Translucent Opaque	***Building Consensus*** Compare and contrast ways to represent optical property of materials.	**SHARING AND DISCUSSION (whole class)** *(20 minutes)* Ask groups to share their investigations, representations, and findings. Pick a few student work to show and share. Ask students to discuss whether the materials can be represented as a continuum of degrees of transparency. Probing questions: • *Which materials allowed a lot of light to pass through?* • *Which materials allowed some light to pass through?* • *Which materials didn't let light through?* • *Which materials made the best shadows?* • *How can we show how light travels through each of these materials to different extents?* Discuss what happens to the light that passed through the materials? How far does it travel? When does light stop traveling?	What observable properties of materials can students identify that allow them to predict the extent to which light will be transmitted? What observations do students make with light casting shadows? Can students document the type of material and its properties in a two way table? Can students annotate the diagrams to show the path of light and the extent of absorption?

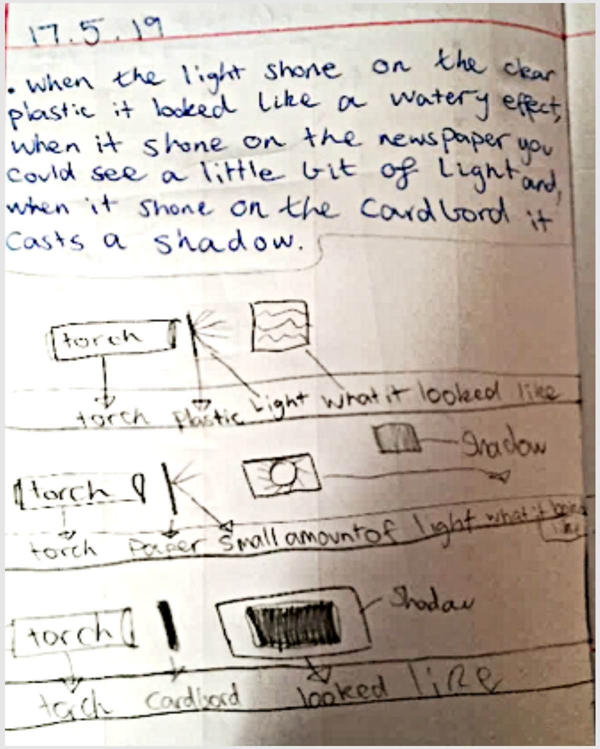
Samples of student work



Example 1: Representation of how transparent, translucent and opaque surfaces interacts with light.



Example 2: Representation of how transparent, translucent and opaque surfaces interacts with light.



Example 3: Representation of how transparent, translucent and opaque surfaces interacts with light.

LESSON 3 – Shadows

(Approximate duration: 120 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate the properties of shadows and how light travels that can result in shadow formation

Mathematics ideas and practices

- Construct displays, including column graphs, dot plots and tables, appropriate for data type, with and without the use of digital technologies
- Represent how enlargement of shapes occurs as a light source moves
- Represent angle and length of shadow

Learning Intention:

Students will experience and understand, the nearer the light source to the object the larger the shadow. This is because the nearer the object the more light it is blotting out. (Shadow is an absence of light).

Equipment/Resources

Glue sticks; Torches; Investigation planner; Lego mini-figures or small plastic toys

Equipment required for all lessons
Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Lesson at a glance:

Students investigate how a shadow is formed. The role that light and properties of materials play in creating shadows form part of this lesson.

LESSON 3 – Shadows

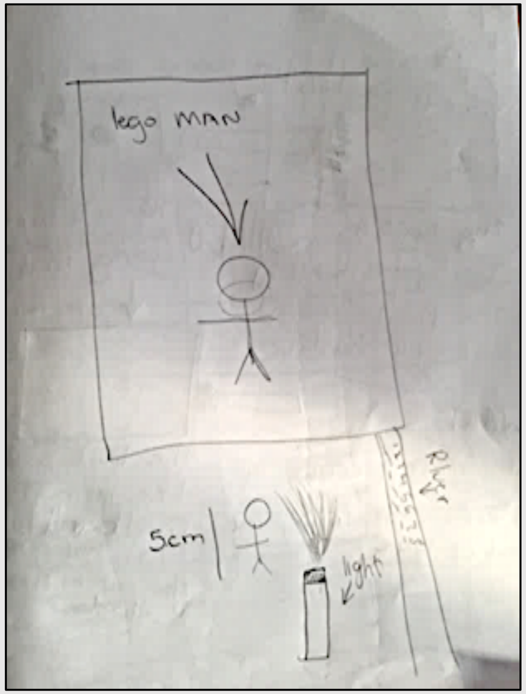
(Approximate duration: 120 minutes)

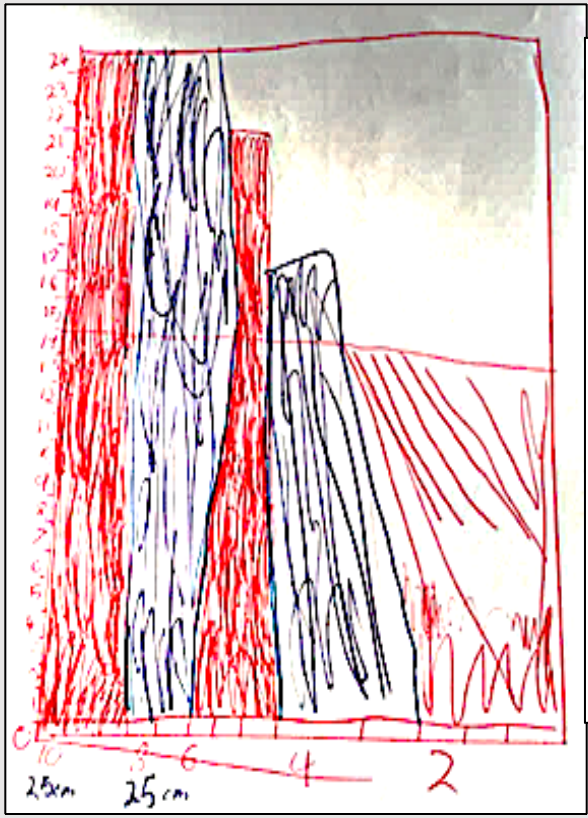
Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Formation of shadow	***Orienting*** Establish the focus on shadows as absence of light	**ENGAGE** *(10 minutes)* Revisit last week's lessons. What happens to light when it travels through different materials? What happens if light is blocked by an object? Probing questions: • *What is a shadow?* • *How can we make a shadow?* • *Can the same object caste different size shadows? How?* Discuss with students what they have noticed about their own shadows from the sun, over a day, or from an overhead light at night as they walk past it. Pose a question for investigation: are shadows larger when the object is further away or nearer to the light source?	Can students link the formation of shadow with the absence of light? Can students predict what happens to the length of shadows, linking this with angles?
Science: Formation of shadows Fair test	***Posing Representational Challenges*** Explore ways to represent relationships between the height of shadow and the distance of the light source to object.	**INSTRUCTION** *(10 minutes)* Introduce the torch and glue stick. Demonstrate the shadow of the glue stick made by torch light on the wall. • *What might affect the height of the shadow on the wall?* Discuss which of the variables will be changed, measured and kept the same in the investigation. Students to plan for their investigation using the investigation planner.	Can students make structured observations of light casting shadows? Can students predict and justify how and why shadows change in size? What suggestions do students make when it comes to introducing and changing variables? Can students sensibly suggest how these changes be mapped and recorded?

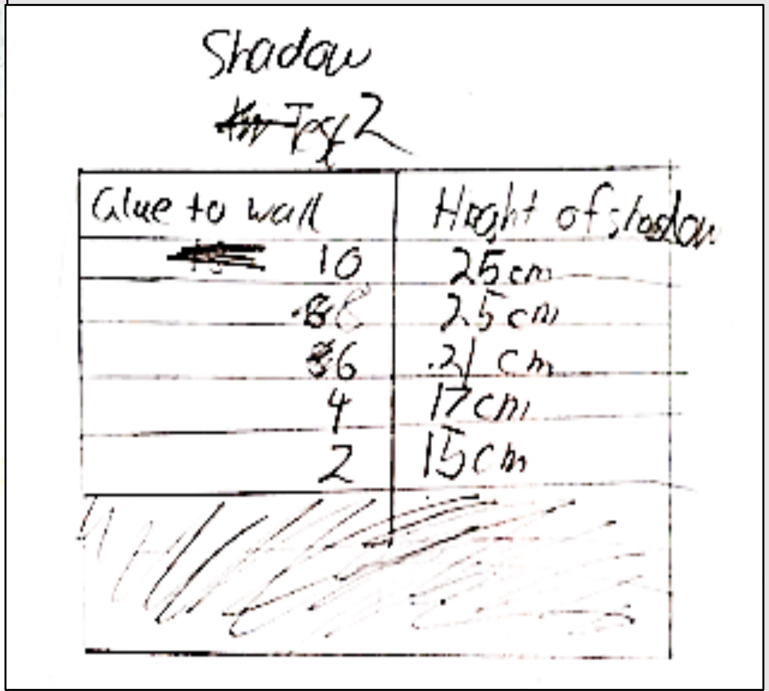
Mathematics: Construct displays, including column graphs, dot plots and tables, appropriate for data type, with and without the use of digital technologies Angle, size, and length of shadow	***Posing Representational Challenges*** Explore ways to represent relationships between the height of shadow and the distance of the light source to object.	**Shadow Play Investigation (Small Groups)** *(30 minutes)* Explain the students will be working in small groups to investigate what happens to the height of the shadow when we change the distance between the torch and the glue stick. Using the **investigation planner**, students working in groups of three to investigate the changes in height when the distance between the glue stick and the torch changes. Ask students to record the data in their investigation planners. Students to represent and discuss the data collected in small groups.	Can students identify ways to represent the relationships of the two variables? Can student identify patterns in the data?
Mathematics: Data interpretation Angle, size, and length of shadow	***Building Consensus*** Compare observations with data representations and consolidate understanding of the patterns demonstrated in data	**Whole Class Sharing** *(20 minutes)* Share examples of what students have done. Ask these questions: • *What did you notice about the size of the glue stick shadow compared to the actual glue stick?* • *How did the height of the shadow change? When was the shadow tallest and shortest?* • *What did you notice about the position of the torch and the height of the shadow? Do the data collected by your group reveal any patterns?* • *What do you predict will happen to the height of the shadow if the torch was 60 cm away from the glue stick?* • *Can we do a similar investigation using glue sticks of different widths?* • *What do you expect the results would be?*	What suggestions do students make in regard to the changes they are observing? What different ways do students represent their observations? Look for levels of development and sophistication in measurement and diagrammatical representations. Estimates of centimetres here. Can students identify the patterns of the two variables in the data? Can they generate a hypothesis based on the patterns?

Mathematics: Enlargement of shapes Size and area of shadow	***Applying and extending conceptual understanding:*** Generalise patterns identified to a new context of transposing 2D shapes.	**INVESTIGATION – Can a shadow expand? (small group)** *(40 minutes)* Ask the students to think about how can shadows be used to expand the size of shapes based on the shadow play activity. Challenge students to transpose more complex 2D shapes in size (e.g. lego mini figure). Can students work out a mathematical process for creating a given shape of double, or triple the size? [Teacher notes: Students to explain their thinking before they can do the investigation. This forces them to consider their data from the previous shadow activity and identify a pattern rather than just relying on trial and error for this task. Extending on this, they could work out the area of images that are doubled and tripled in size without light]	Can students use the patterns from the previous activity to predict how they might transpose a more complex 2D shape?
Science: Formation of shadow **Mathematics:** Enlargement of shapes Size and area of shadow	***Building Consensus*** Compare and contrast data representations to generate explanations for enlargement of shape size using shadows.	**Whole Class Sharing and Discussion** *(10 minutes)* Share examples of what students have done. ❖ Discuss these questions: ❖ *How can shadows be used to expand the size of shapes?* ❖ *What do we mean by enlargement?* ❖ *What patterns did we identify in the variables? (height, width, size or area)?* ❖ *How can we show and explain these patterns to other people?* Inform the class of what questions will be investigated in the next lesson.	Can students document the data and find relationships between the size of the shapes and what happens when enlarged (in two dimensions)? Can students come to a communal agreement on how shadows represent a mathematical transformation process?

Samples of student work







Students have used tables, graphs and drawings to show how the shadow changes length as the torch is held at different distances from a glue stick or small Lego figurine.

LESSON 4 – Reflections 1

(Approximate duration: 120 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate how light reflection occurs on different surfaces

Mathematics ideas and practices

- Describe translations, reflections and rotations of two-dimensional shapes.
- Identify line and rotational symmetries
- Estimate, measure and compare angles using degrees.
- Construct angles using a protractor

Learning Intention:

Students will experience and understand;

- Identify that light travels in straight lines
- Use mirrors to reflect light in different directions
- Use ray diagrams to show the reflection of light by a mirror

Equipment/Resources

Torch, foil sheets; Torch; Hula hoops; Tennis balls

Equipment required for all lessons

Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Lesson at a glance:

Light travels in straight lines and this can be demonstrated through the use of mirrors. Students can represent this, and how light reflects, through the use of ray diagrams. Student observe differences between angles that form rays.

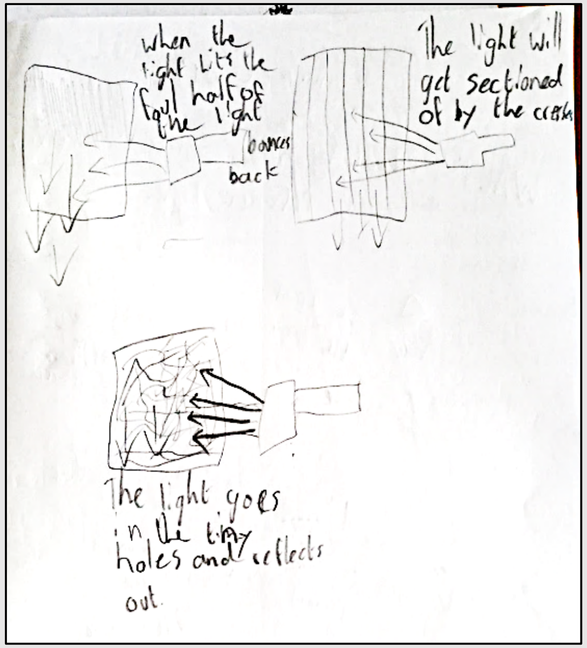
LESSON 4 – Reflections 1

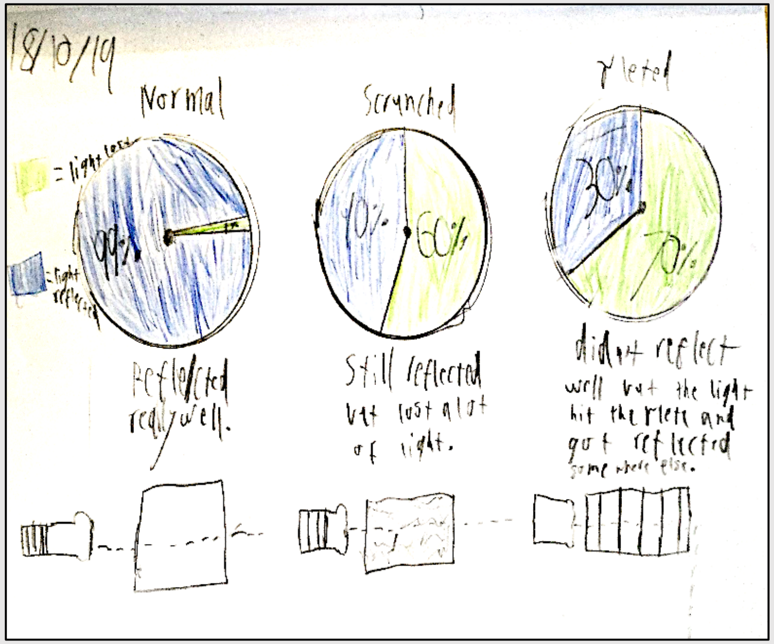
(Approximate duration: 120 minutes)

Learning focus	**Pedagogical stage**	**Lesson Outline** *(NB: time allocations a guide only)*	**Monitoring and supporting learning**
Science: Reflection **Mathematics:** Describe translations, reflections and rotations of two-dimensional shapes. Identify line and rotational symmetries	***Orienting*** Establish the focus of the lesson on reflection	**Introduction** *(10 minutes)* Review the lessons from last week. Discuss: ❖ *What do we know now about how light travels?* ❖ *What happens to light when it hits an opaque object?* Show students a piece of aluminium foil, a metal spoon and a mirror. Ask what happens when light hits these objects? Discuss initial student ideas [students might come up with words such as bounce back, shine, which can be used to introduce the word "reflection"] **Probing questions:** ❖ *What do we mean by an angle of reflection?* ❖ *How can we estimate the angle?*	Can students make reasonable suggestions about the paths of light when hitting these objects? Can students relate words such as reflection, bounce back, shine etc. with the paths of light?
Mathematics: Estimate, measure and compare angles using degrees. Construct angles using a protractor	***Posing representational challenge:*** Explore ways to show light reflection off different surfaces	**INSTRUCTION** *(10 minutes)* Explain that students will investigate and represent light reflections using different materials. Give students three pieces of foil, one to stay flat, one to scrunch up and one to pleat. **Foil investigation (small groups)** *(30 minutes)* Working in groups of three, students to design a test and investigate the reflection of light (from a torch) using 3 different types of foil. Students to record results and discuss why they got the results they did. ❖ *What did we notice?* ❖ *How can we show that light bounces off?*	What suggestions do students make in regard to the difference in light reflection using three different types of foil? What different ways do students represent their observations? Look for levels of development and sophistication in diagrammatical representations.

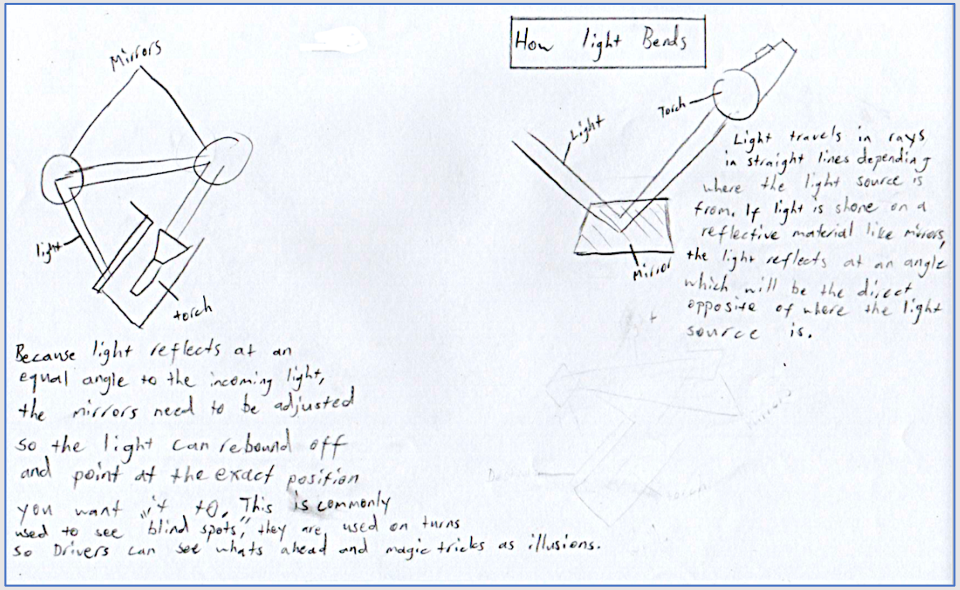
		Post a question: how can we test our ideas to show light bounces off objects?	
Mathematics: Describe translations, reflections and rotations of two-dimensional shapes. Identify line and rotational symmetries **Science:** reflection	***Applying and extending conceptual understanding:*** Explore analogical models that demonstrate light reflection off different surfaces	**Modelling light reflection (outside)** *(30 minutes)* Take the students outside Students are to think about how we can show how light bounces off objects using a small ball. Students are to observe that happens to the ball when hit a smooth surface as opposed to a rough surface. Discuss how this can be related to our foil experiments? What happens when the ball hits a wall at certain angle? What is the chance that the ball will bounce back at the same angle? [get a student to stand where she/he might be able to catch the ball] Discuss with the students: what does this tell us about how light travels and what happens to the light ray when it hits a surface. Can students observe and estimate the angle of bounce? How can we best represent the bouncing pattern of the ball?	What suggestions do students make in regard to the changes they are observing? Are students connecting the trajectories of the balls on different surfaces to the behaviours of light when hitting different types of foil? Can students observe and estimate the angle of bounce? What different ways do students represent their observations? Look for levels of development and sophistication in diagrammatical representations.
	Building Consensus Establish links between observations and representations Generate explanations based on representations of observed phenomena	**Representations and Sharing (whole class)** *(30 minutes)* Back in the classroom Students are to show how light travels when it hits the different foil pieces. Allow time for them to develop an explanation using representations. Share examples of what students have done. Discuss some of the representations showing the reflection of lights off different surfaces. Discuss as a class: • *What happens to the light when it hits each type of foil?* • *What other materials can reflect light?* • *What is the characteristic of a good light reflector?*	Student generated representations: Consider the different ways students are representing what they are observing. Can students link the features of a surface with how light behaves when hitting that surface, drawing on the modelling activity? Can students link these observations with the appearance of different surfaces when light falls on them?

Samples of student work





Students providing evidence of how light behaves through a window, from light reflecting off different surfaces. Note the right hand image where the student has developed a way to measure the amount of light reflected.



LESSON 5 –Reflections 2

(Approximate duration: 90 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate how light reflection occurs on different surfaces

Mathematics ideas and practices

- Describe translations, reflections and rotations of two-dimensional shapes.
- Identify line and rotational symmetries
- Estimate, measure and compare angles using degrees.
- Construct angles using a protractor
- Identify patterns in data

Learning Intention:

Students will experience and understand;

- Identify that light travels in straight lines
- Use mirrors to reflect light in different directions
- Use ray diagrams to show the reflection of light by a mirror

Equipment/Resources

Torch; mirror; 2D or 3D objects; 2D shapes or letters; Protractors

Equipment required for all lessons

Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Lesson at a glance:

This lesson builds on Lesson 4 and continues student's exploration of how light travels. Further use of mirrors, and having students consider how they can represent how light travels and reflects through the use of ray diagrams.

LESSON 5 –Reflections 2

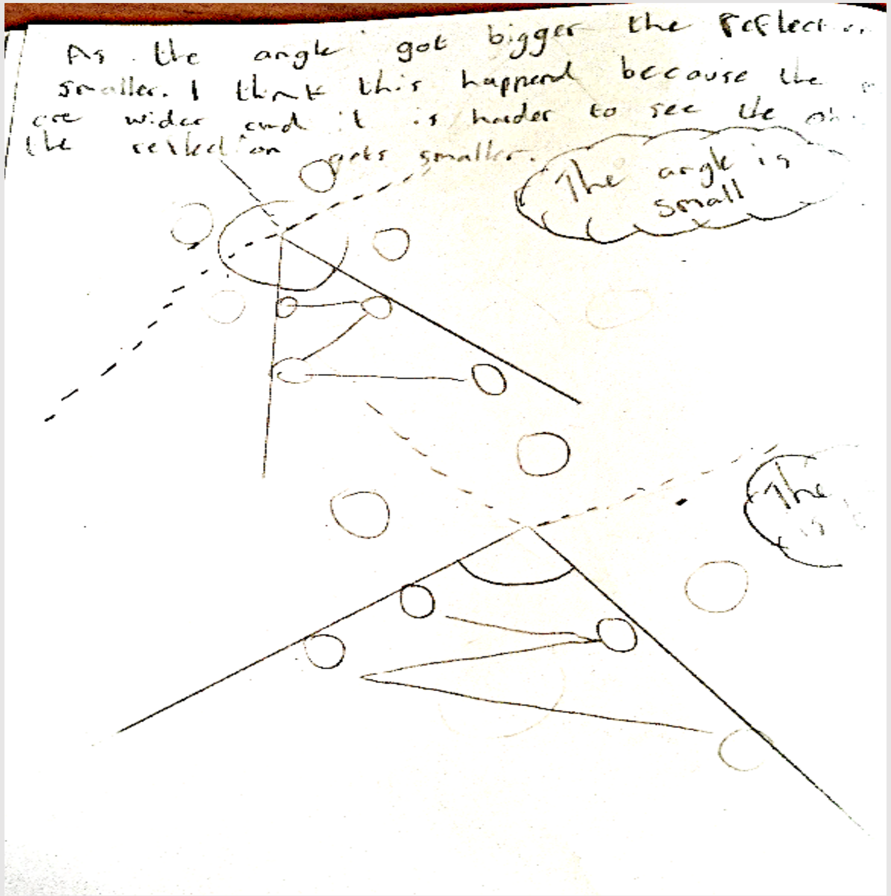
(Approximate duration: 90 minutes)

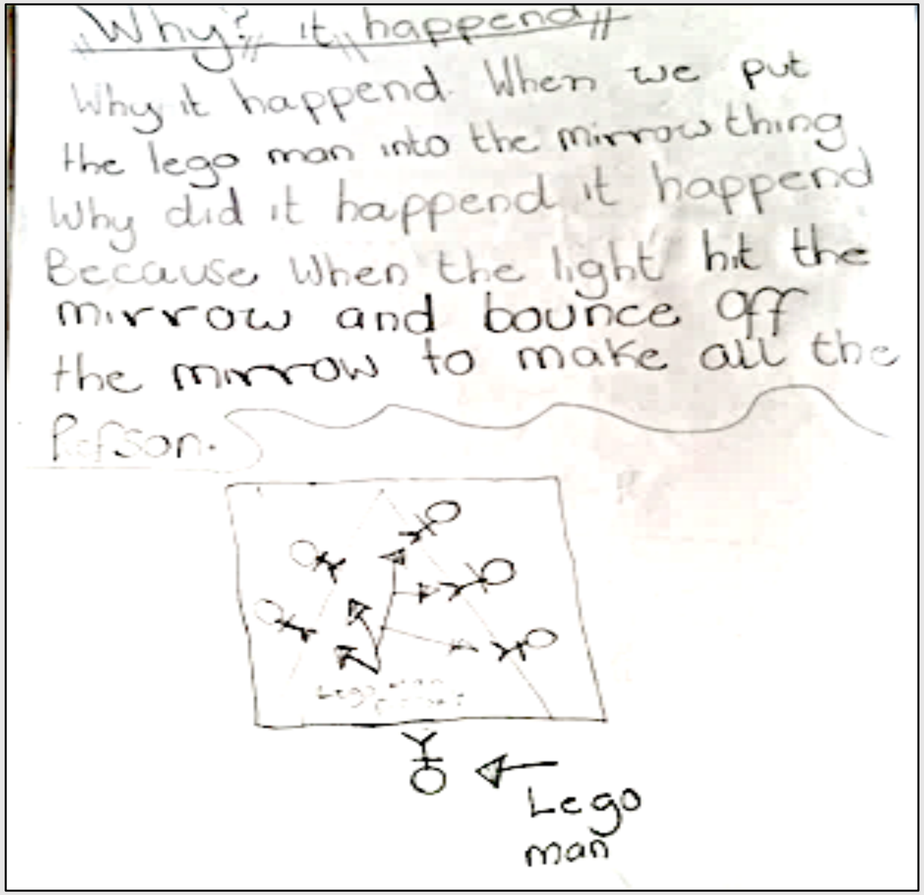
Learning focus	**Pedagogical stage**	**Lesson Outline** *NB: time allocations a guide only)*	**Monitoring and supporting learning**
Science: Reflection	***Orienting*** Review learning from previous lessons	**ENGAGE** *(10 minutes)* Review the lessons from last week. Discuss • How does the light travel when it hits a surface such as a flat foil or a mirror?	
Mathematics: Describe translations, reflections and rotations of two-dimensional shapes. Identify line and rotational symmetries Estimate, measure and compare angles using degrees. Construct angles using a protractor	***Posing representational challenges*** Explore and represent the formation of mirror images	**INVESTIGATION– Light reflection (small groups)** *(30 minutes)* Explain that students will be working in groups to investigate light reflection using mirrors. Give students a few plane mirrors and a range of 2D and 3D objects of different shapes (symmetric and non-symmetric shapes). Allow time for students to experiment with the mirrors and objects. Students can document predictions and actual effect of mirrors in a table of data. • What symmetries can students see in the 2D and 3D objects? Students to represent how light is behaving when hitting a mirror and how we see the different objects in the mirror? Ask these questions: • *How can we show how the light is traveling before hitting the mirror?* • *What happens to the light when it hits the plane mirror? What did you notice about the image of the symmetric and non-symmetric objects in the plane mirror?* • *How can we show how we see the objects in each mirror?* Discuss the use of ray diagram and what it allows us to show. Why do we need to observe and compare the angle of bounce in the ray?	What suggestions do students make in regard to what they are observing? What different ways do students represent their observations? Look for levels of development and sophistication in diagrammatical representations. Can students articulate or represent the symmetric relationship between the object and the image in the mirror? Can students relate the observation of mirror images to how light reflects off the mirror using representations including ray diagrams?

Science: Demonstrate how light reflection occurs on different surfaces **Mathematics:** Describe translations, reflections and rotations of two-dimensional shapes. Identify line and rotational symmetries Estimate, measure and compare angles using degrees. Construct angles using a protractor	***Applying and extending conceptual understanding:*** Explore multiple reflections using two mirrors and represent the relationship between angles of the two mirrors and number of images generated.	**Investigation – Multiple reflections (small groups)** *(20 minutes)* Ask student what happens if I have two mirrors placed in an angle? How many images would I be able to see? Does the number of the images change if I change the angle of the two mirrors? Give students two plane mirrors and a Lego mini figure. Students to experiment with different angles to see the number of images generated. This is an opportunity to start measuring angles using protractors. Some students may need assistance in understanding how to use these. Discuss ways to document the experiment and the findings. Students will need to use the protractor to measure the angle of the two mirrors and count the number of images generated. Students record the data and to show how they might represent the relationship between the degree of angles and the number of images.	Notice whether students start using ray diagrams. Observe the number of arrows students are incorporating and any indications of directionality. Can students represent the angle of the mirrors and the number of images generated in a meaningful way?
Science: Reflection **Mathematics:** Identify patterns in data	***Building Consensus*** Compare data patterns identified and relate the data patterns to observations	**REPRESENTATIONAL WORK AND SHARING** *(20 minutes)* Discuss what patterns did students notice in their data? Ask them to explain • the mathematics: the data using representations; observation of angles • the science: what happens to light when traveling between the two mirrors placed at different angles Share a few different examples of representing the data Students explain the science behind this.	How are students representing the angles they are measuring? What forms are the data being collated in? Can students identify patterns in the images, e.g. the relationship between the angle of the two mirrors and the number of images generated?

Mathematics: Describe translations, reflections and rotations of two-dimensional shapes. Identify line and rotational symmetries	***Applying and extending conceptual understanding:*** apply understanding of reflection in new context	**EXTENSION REFLECTION ACTIVITIES IF TIME** **Investigation – symmetry with mirrors** Challenge students to draw a reflection of 3D objects with and without a flat mirror. Using different alphabetic letters, such as A or B. • *Can you draw the reflection of the letter without a mirror?* • *What did you notice about the positions of the image and the object?* Discuss the idea of symmetry and ask student to think about why the image of the mirror is symmetrical to the object. How can we show this using a ray diagram? **Investigation – plane and curved mirrors** Encourage students to experiment with different mirrors (plane, concave and convex) and to observe *what happens to the image when the mirror is placed at different distances to the object?* Discuss these questions: • Why a mirror was needed to make the light go around the corner? • What did you notice about the images of objects in a concave mirror? (See demo https://www.youtube.com/watch?v=3e-LZPHBA2M) • What did you notice about the images of objects in a convex mirror? (See demo https://www.youtube.com/watch?v=qxlT19losBE)	Can students understand the notions of symmetry and axes? Can students observe a pattern between lines of symmetry and parts of the shape and number of sides? Can students relate the observation of mirror images to how light reflects off the mirror using representations including ray diagrams? Can they estimate and measure the angle size? Can they recognise angles as a rotation of 360 degrees rather than size of angle between rays? Do they show misconception that the length of the ray is the size of the angle?

Samples of student work





Example 1: Students providing evidence of how to measure angles using a protractor.

Example 2: Student representation of how a Lego man looks in the multiple reflections task.

LESSON 6 – Periscope challenge 1

(Approximate duration: 120 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate how light reflection occurs on different surfaces

Mathematics ideas and practices

- Construct angles using a protractor

Learning Intention:

Students will experience and understand;

- Identify that light travels in straight lines
- Use mirrors to reflect light in different directions
- Use ray diagrams to show the reflection of light by a mirror

Lesson at a glance:

Periscopes are a fun way to practically test how light travels. This lesson begins with a laser maze challenge to demonstrate how light can be purposefully directed. Students then commence designing a periscope. Students observe angle of reflection.

Equipment/Resources

Laser maze challenge equipment: Laser pointers, Mirrors, A3 paper for maze template

Periscope Challenge: scissors x 15; thin correx or black card; roll of sellotape; glue sticks x 5; periscope templates x 20;
plastic mirrors x 10; protractors

Equipment required for all lessons
Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

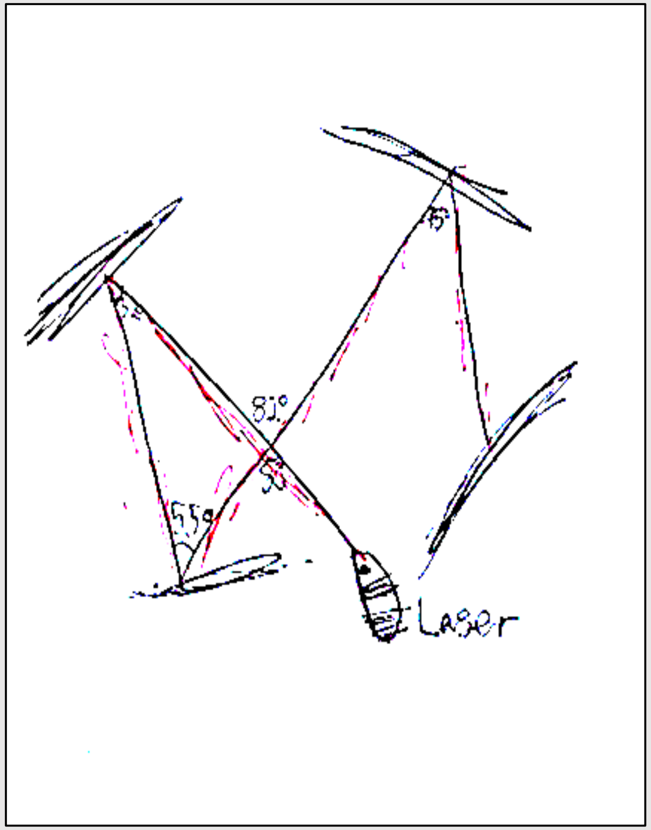
LESSON 6 – Periscope challenge 1

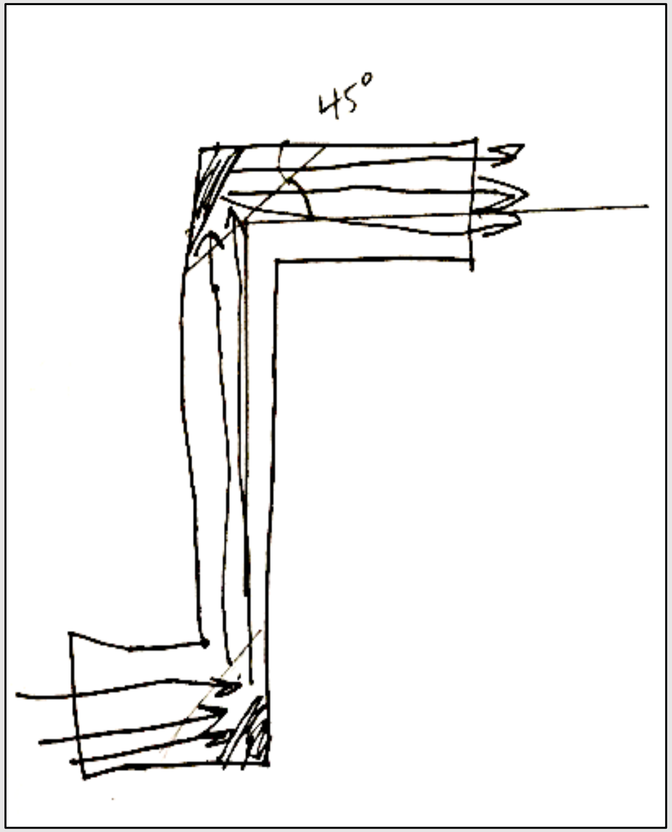
(Approximate duration: 120 minutes)

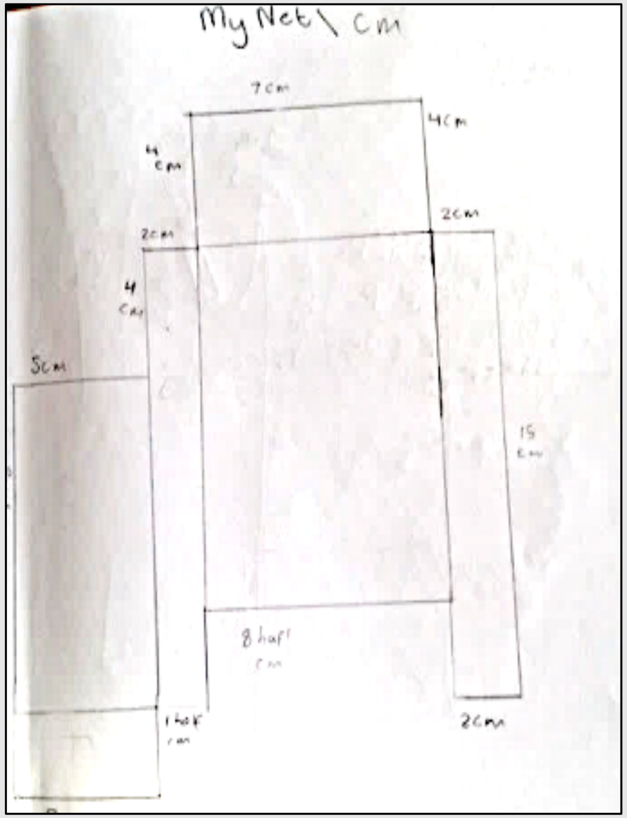
Learning focus	**Pedagogical stage**	**Lesson Outline** *(NB: time allocations a guide only)*	**Monitoring and support learning**
Science: Reflection	***Orienting*** Review ideas from the previous lesson Establish the focus of the lesson	**ENGAGE** *(20 minutes)* Review the lessons from last week. Discuss • *How does light travel?* • *What happens when light hits a plane mirror?* **Probing questions:** • *Can we see things over a tall wall or around the corners of a building?* • *What do we need in order for us to see things around corners and over walls?*	
Mathematics: Estimate, measure and compare angles using degrees. Construct angles using a protractor	***Posing representational challenges*** Explore ways to bounce off light using mirrors in a maze	**INVESTIGATION – Laser maze challenge** *(20 minutes)* Challenge students to identify how light can travel through a maze • *What do you need in order to direct light in certain directions in the maze?* • *Is there a predictable pattern how light changes its direction?* Students work with the maze challenge and represent how the laser beam travels in the maze.	Can students identify that the incident angle is the same as the reflected angle (the law of reflection)? Opportunities here to reinforce the use of protractors to set angles and recognise angles as a rotation of 360 degrees rather than just rays. Can students represent their observations by bringing together angle measurements and ray diagrams? Look for ways students develop these representations and understandings. Can students provide reasonable estimates without use of protractors?

Science: Reflection	***Orienting*** Establish the focus on periscope designs.	**Investigation Preparation** *(20 minutes)* Ask students how we see objects around the corner of the building? Explain that students will design and construct a periscope. Discuss examples of periscope with students, how it is used. Discuss evaluation criteria for the design with the students. ❖ *How can the learning from the laser maze challenge be used in designing our periscopes?*	Building on the laser maze challenge to begin to construct a diagram of how light travels through a periscope. What angles are needed? What size does the periscope need to be to perform effectively? Can students articulate the connection between the lazer maze and the periscope?
Science: Reflection **Mathematics:** Estimate, measure and compare angles using degrees. Construct angles using a protractor	***Posing representational challenges*** Explore design ideas that enable light travel through a periscope	**Investigation– Designing a periscope (small groups)** *(60 minutes)* Working in groups of 3, students to design a periscope. Ask students to make a design sketch and discuss how light travels in their periscope with their peers. Using the laser pointer, a piece of paper, and mirrors, students to test their design ideas. ❖ *How does the light travel in your periscopes?* ❖ *What do you notice about the angle of the mirrors?* ❖ *How does the angle of the mirror help the light to reflect?*	Building on the laser maze challenge to begin to construct a diagram of how light travels through a periscope. What angles are needed so the light can travel through the periscope? What size does the periscope need to be to perform effectively? Can students connect their observation of the laser beam in the maze with how light travels in a periscope? What would happen if the periscope is not built with right angles?
Science: Construct labelled diagrams **Mathematics:** Construct angles using a protractor	***Building Consensus*** Compare student designs of periscopes to identify criteria for a 'clear' design sketch.	**Whole Class Sharing and Discussion** *(20 minutes)* **GALLERY WALK** Encourage students to display their designs. ❖ What questions can you ask of other people's designs? Compare student work and discuss what we need to construct a 'clear' design sketch, so it is easy to follow when constructing a periscope.	Can students identify key design elements needed for sharing their ideas of periscopes?

Samples of student work







Example 1: Students documenting how light can be emitted from a laser pointer and made to go through a maze. This is then applied to the periscope sketch.

Example 2: Periscope sketch

Example 3: Picture of a net from periscope template.

LESSON 7 – Periscope challenge 2

(Approximate duration: 120 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate how light reflection occurs on different surfaces

Mathematics ideas and practices

- Construct angles using a protractor
- Estimate, measure and compare angles using degrees.

Learning Intention:

Students will experience and understand;

- Identify that light travels in straight lines
- Use mirrors to reflect light in different directions
- Use ray diagrams to show the reflection of light by a mirror

Lesson at a glance:

This lesson is devoted to students building their periscope. The notion of a 'net' is included here. Students sketch a net to represent the template of their periscope. Students understand relationship between 3D construction and the plan — a 2D net.

Equipment/Resources

Laser maze challenge equipment: Laser pointers, Mirrors, A3 paper for maze template

Periscope Challenge: scissors x 15; thin correx or black card; roll of sellotape; glue sticks x 5; periscope templates x 20;
plastic mirrors x 10; protractors

Equipment required for all lessons
Students: student workbooks, pencils, colours and rulers

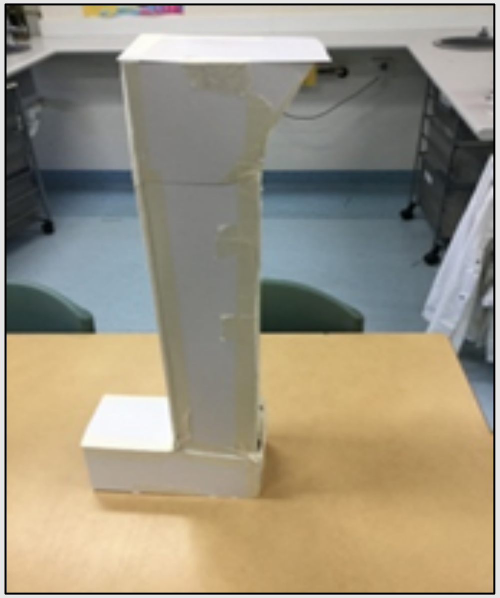
Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

LESSON 7 – Periscope challenge 2

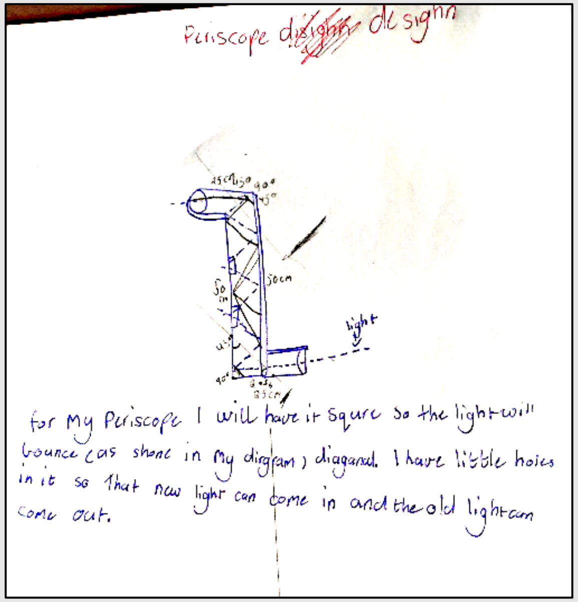
(Approximate duration: 120 minutes)

Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Reflection **Mathematics:** Estimate, measure and compare angles using degrees. Construct angles using a protractor	***Posing representation challenge:*** Showing the trajectory of light in periscopes	**Small Group Investigation: Constructing a periscope** *(60 minutes)* Continue working in groups of 3, students to construct a periscope. Once the periscope is constructed, ask the students to test it out. Ask students to add explanations to their design sketch: how we see objects around the corner of the building using the periscope.	Can students construct a 3D object based on their 2D design sketch? Can students explain how light travels in their designed periscope? Do they explain how the angles ae important? If the periscope does not function as expected, e.g. reversed image, can students find explanations for the problem encountered, drawing upon their understanding of light reflection?
	Building Consensus Consolidate ways to represent directions of light reflection using mirrors	**Whole Class Sharing and Discussion** *(30 minutes)* **GALLERY WALK** Ask students to display their designs and periscopes. One student staying with the display to explain the design ideas. The other two students walk around to check other groups' designs. Share some examples of designed periscopes. Discuss these questions: • *How does the light travel in your periscopes?* • *What do you notice about the angle of the mirrors?* • *How does the angle of the mirror help the light to reflect?*	This is an opportunity to listen for the vocabulary students are using in their conversations. Are they using words like 'reflection' and 'angles' to articulate what they are observing? Can students document differences in comparing angles? Explain how the angles are important for the periscope to work? Can students clearly articulate the directionality of light in the periscope using arrows? Can they use mathematics notations to label the angles?

Samples of student work



Example 1: Completed periscope



Example 2: Student drafting of periscope

Example 3: Completed periscope

LESSON 8 – Refraction

(Approximate duration: 150 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate how light refraction occurs in different media

Mathematics ideas and practices

- Describe translations, reflections and rotations of two-dimensional shapes.
- Identify line and rotational symmetries

Learning intention:

Students will experience and understand;

- Identify that light travels in straight lines
- Discuss and describe observations about light refraction

Equipment/Resources

Drinking straws; Glass; Water; Pencil; Coins;

Equipment required for all lessons

Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Lesson at a glance:

Students continue building on the concept of light travelling in straight lines and discuss and describe observations about light refraction.

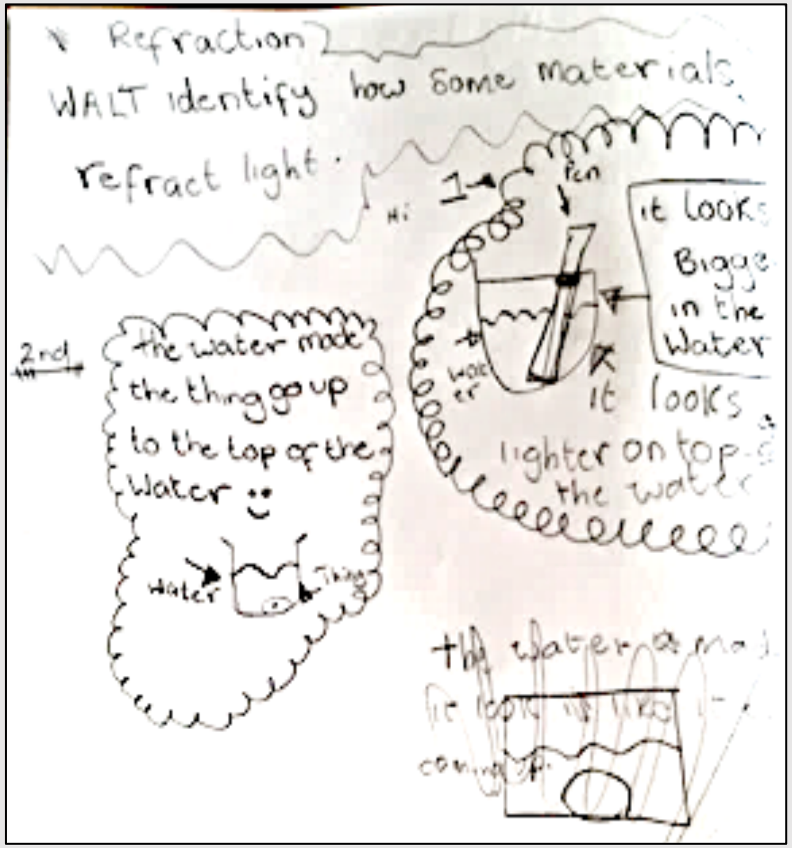
LESSON 8 – Refraction

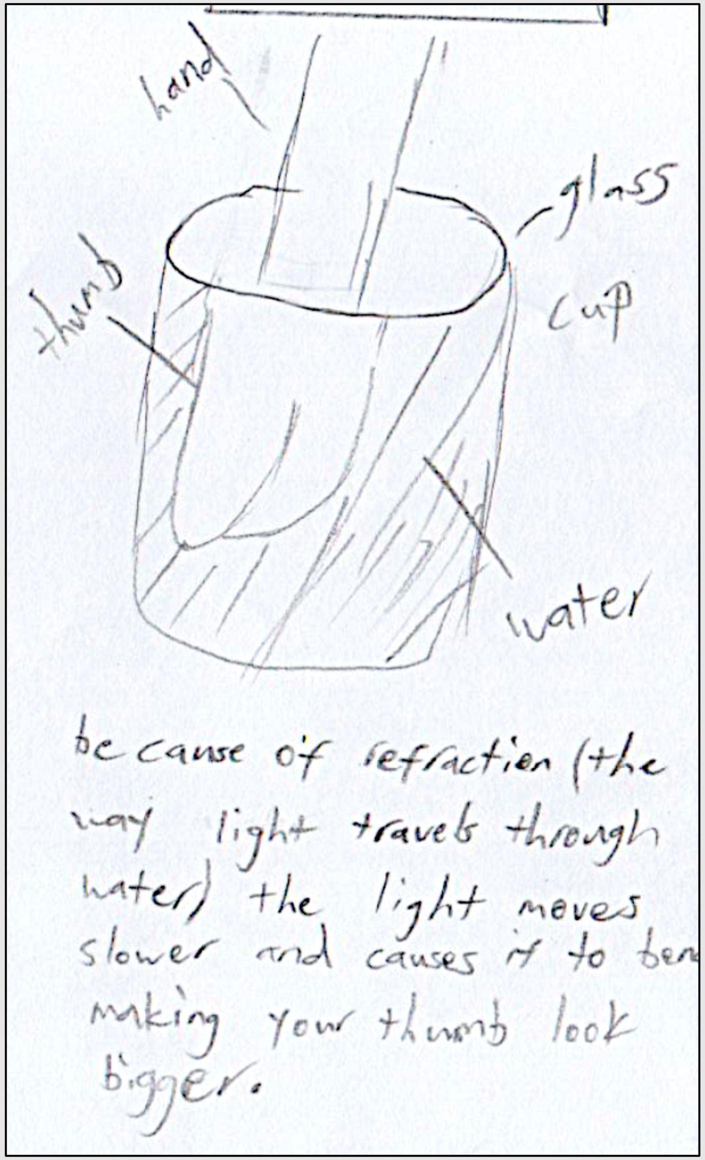
(Approximate duration: 150 minutes)

Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: refraction **Mathematics:** Describe translations, reflections and rotations of two-dimensional shapes. Identify line and rotational symmetries	***Orienting*** Review learning from previous lessons Establish the focus on refraction	**Class Discussion** *(20 minutes)* Review the lessons from previous weeks. Discuss ❖ *What do you know about transparent materials?* ❖ *Are you always able to see clearly through the materials?* Ask students what they noticed about their legs when standing in a swimming pool and why this happens. Allow students to provide explanations. Show a straw and a glass with water. Ask students to predict what happens to the straw when it is placed into the glass. Place the drinking straw into the glass and ask students about their observations as compared to their predictions.	Can students relate their everyday observation with the travel of light through different materials/medium?
Science: refraction	***Posing representational challenges*** Explore how refraction occurs when light travels from air to water	**Investigation – broken pencil in water (small groups)** *(60 minutes)* Explain that students will be investigating what happens to a pencil when it is placed in an empty glass and a glass with water. Working in groups of three, students observe what happens to a pencil when the glass is filled up with water. Students to draw what they see when the pencil is in an empty glass and when the glass is filled with water. Ask students to explain and show their observations and how the light ray travels when it hits water.	Can students generate explanations for why the pencil is 'bending' in water? Can they relate this to the reflection of light and bending in the light spectra activity, in earlier lessons?

Science: refraction	***Building Consensus*** Compare observations to generate explanations for why objects appear to be broken or bended	**Whole Class Discussion** *(20 minutes)* Ask students to share their work and explanations with the whole class. Discuss the idea of refraction of light and the changes in speed of light when it passes from one medium to another. ❖ *Why does the pencil look broken in water and look normal without water?* ❖ *What does that tell us about how light travels when it enters the water?* ❖ *What causes refraction?*	Can students articulate the difference between light traveling in air as opposed to water? Can students relate this observation to the 'bending' of the light entering from air to water – the idea of 'refraction'?
Science: refraction	***Applying and extending conceptual understanding:*** Apply the knowledge of refraction in a different context	**Guided Inquiry: Whole Class Demonstration** *(10 minutes)* Fishbowl demonstration. Demonstrate how a coin invisible at the bottom of a cup can slowly appear in sight when water is pouring in. Ask these questions ❖ What happens to the coin when water was poured in? ❖ What happens to the light when water was poured in? ❖ How can we explain this using the idea of refraction?	Can students see the connection between the bending of pencil to the slow appearing of the coin when water was poured in? Can students use the idea of refraction to explain the slow appearance of the coin?
Science: Refraction **Mathematics:** Estimate, measure and compare angles using degrees.	***Posing representational challenges*** Explore ways to represent refraction using ray diagrams	**Investigation (small groups)** *(30 minutes)* Encourage students to try the same investigation and develop an explanation using diagrams.	Can students use the ray diagrams to demonstrate the 'refraction' of light in this case?
Science: refraction	***Building Consensus*** Review observations across activities and consolidate understanding of refraction of light when entering a different medium	**Whole Class Discussion and Conclusion** *(20 minutes)* Share some examples of student work. Discuss some of these questions: ❖ *What happens to a beam of light when it passes through a glass of water? What about a glass of oil?* ❖ *What is refraction?* ❖ *What causes refraction?*	Can students articulate what happens to light when entering a different medium? Can students use representations of light travel to link the bending of light to the way images are distorted?

Samples of student work





Examples of student work: Student indicating how light refracts through water

LESSON 9 – Refraction and Magnification

(Approximate duration: 75 minutes)

Curriculum focus:

Science ideas and practices

• Demonstrate how light refraction occurs in different media

Mathematics ideas and practices

- Apply the enlargement transformation to familiar two-dimensional shapes and explore the properties of the resulting image compared with the original

Learning intention:

Students will experience and understand;

- Explore how transparent materials affect the direction of light rays
- Discuss how light can be magnified through different materials
- Explore the properties of curved lenses (converging and diverging lenses).

Equipment/Resources

Pipette; Water; Oil; Dishwashing liquid, Cardboard; Cling wrap

Thin, pliable wire, a large nail, scissors to cut the wire

Equipment required for all lessons

Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Lesson at a glance:

Light can be magnified through different materials and by using transparent materials, we can affect the direction of light rays.
This lesson introduces students to curved lenses (converging and diverging lenses) and seeks to show how light behaves when travelling through these lenses.

LESSON 9 – Refraction and Magnification

(Approximate duration: 75 minutes)

Learning focus	**Pedagogical stage**	**Lesson Outline** *(NB: time allocations a guide only)*	**Monitoring and supporting learning**
Science: Refraction reflection	***Orienting*** Review ideas of refraction and reflection	**Introduction** *(10 minutes)* Review the lessons from previous weeks. Discuss ❖ *How transparent materials affect the direction of light rays?* ❖ *Can a drop of water act as a magnifier?* ❖ *Can you think of other liquids that can be magnifiers?*	Can students make the connection between change of direction in light rays, and the distortion of images? Can students relate the curvature of the water class to that of a magnifying lens?
Mathematics: Apply the enlargement transformation to familiar two dimensional shapes and explore the properties of the resulting image compared with the original	***Posing representational challenges*** Explore the effects of refraction and ways to represent refraction	**Small Group Investigation** *(30 minutes)* Explain that students will be investigating whether liquids can magnify and why. Take a thin wire and twist it around a nail to form a small loop. If you dip the loop in water, a small round drop should form inside it. (If it doesn't, your loop is probably too large.)  "If you hold this loop close to the writing on this page, you should see it has a magnifying effect. Very early microscopes used drops of liquid, such as honey or water, for lenses. Some of these were capable of high magnification". Provide students with a range of liquids (e.g. water, oil, dish washing liquid) to experiment with how droplets might magnify differently. Students record their observations in the workbook and represent and explain what they observed using drawings and text. Students to estimate the size of the change (the magnification) using informal measures.	Can students link the magnifying effect of a drop of water, oil or other liquid with the idea of refraction introduced in the early lesson? Can student estimate the size of the magnification? E.g. twice as big? Proportion of magnification? Can students organise their recording to sensibly compare the degree of magnification in different liquids?

Science: Refraction reflection	***Building Consensus*** Compare observations to generate explanations for refraction	**Whole Class Discussion: Investigation Review and Explanation** *(15 minutes)* Students to share what they have done. **Probing questions** ❖ *What did you notice of the letter B with a drop of the liquid?* ❖ *Which liquid is the best magnifier?* ❖ *Why did the size of the letter change with a drop of the liquid? Which representations are most effective for showing that?*	Can students explain the magnifying effect of the letter using the idea of light refraction? Can students represent using ray diagrams how bending of light might occur through the lens to cause distortions and magnification?
Mathematics Identify patterns in data Generalise from data patterns	***Building Consensus*** Establish patterns in data to generate explanations of refraction by converging lenses	**Whole Class Discussion: Review** *(20 minutes)* Discuss the representations including data displays by different student groups. ❖ *What does your data show?* ❖ *What do the different data displays show? What don't they show?* ❖ *What results can be draw from this data?* ❖ *How certain are we of the results?* Discuss examples of magnification in everyday life. Next lesson inform the class.	Can students make sense of the data they collected? Can they relate the data with their observations?

LESSON 10 – Fun with light and post-sequence assessment task

(Approximate duration 120 minutes)

Curriculum focus:

Science ideas and practices

- Demonstrate how light refraction occurs in different media
- Demonstrate how light reflection occurs on different surfaces

Mathematics ideas and practices

Learning intention:

Students will experience and understand;

- Explore how transparent materials affect the direction of light rays
- Discuss how light can be magnified through different materials
- Explore the properties of curved lenses (converging and diverging lenses).

Resources/Equipment

Students: student workbooks, pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

Materials: Convex and concave lenses; Plane mirror; Concave and convex mirrors; Cardboard; Milk carton; Color chips

Lesson at a glance:

This lesson is designed to allow students to build on their knowledge through an exploration of transparent materials affect the direction of light rays. The magnification of light through different materials and the properties of curved lenses (converging and diverging lenses) is included in the learning.

LESSON 10 – Fun with light and post-sequence assessment task

(approximate duration 120 minutes)

Learning focus	**Pedagogical stage**	**Lesson Outline** *(NB: time allocations a guide only)*	**Monitoring and support learning**
		Summative Assessment *(30 minutes)* Provide students with a clean copy of the post-sequence assessment task for students to complete.	
Science: Reflection Refraction	***Building Consensus*** Consolidate ideas of reflection and refraction in the unit	**Whole Class Discussion: Learning Review** *(10 minutes)* Summary the key learning from the sequence. What did we learn about? ❖ *How does light travel?* ❖ *What is reflection and how does it relate to us being able to see things, and to what we see in a mirror?* ❖ *What is refraction and what sort of things around us can be explained using refraction?*	Can students sensibly relate light travel, reflection and refraction to visual phenomena? Can students describe details of shadows, images in mirrors, and refractive effects, using ideas of light rays?
Science: Reflection Refraction	***Posing representational challenges*** Explore the application of reflection and refraction in designing a device	**Small Group Investigation** *(60 minutes)* Explain that students will be challenged to construct a device that can help us to see things which we do not normally see with our eyes. Provide students with multiple mirrors (plane and curved) and a range of lenses (converging and diverging). Students to construct any of the devices using reflection and refraction: • Telescope • Kaleidoscope • Microscope [NB: When working with the microscopes, the students are dealing with magnification and proportion. Multiplication is applicable here and can be drawn out. Ask students to provide a diagram of their device and an explanation of how their device works using the concepts learned from the sequence.	How do students represent what they are observing? What connections are they now making to the earlier lessons? How did the students deal with magnification and proportion? Did they use multiplication informally and make explanations about their observations in terms of "times" the magnification?
Science: Reflection Refraction	***Building Consensus*** Identify criteria for evaluating the design ideas, including ways to represent how light travels in each designed device.	**Gallery Walk & Review** *(20 minutes)* Students to display their devices and diagrams. One student staying with the display to explain the design ideas. The other two students walk around to check other groups' designs. Class celebration of the learning in the unit.	Can students reasonably explain their design ideas and link these ideas to the learning in the sequence, e.g. reflection, refraction? What evaluation criteria can the students use/develop to judge the designs?

Key Understandings about Light, Vision, Reflection and Refraction

Historically, it was a considerable scientific achievement to understand vision in terms of the eye as a sense organ that receives light that is scattered from objects. Early ideas of vision held by thinkers such as Plato and Aristotle, and then the great Islamic scientists, were of vision as some sort of active engagement of the world by the eye; almost as if some sort of 'signal' was sent out by the eye to perceive objects. Students have difficulty in understanding the eye as a passive receiver of light. They also have difficulty with the idea of light as an independent entity that travels through space so that the role of a light source in helping us to see, and the relationship of colour of an object to the colour of the illuminating light, is problematic. Further still, ideas about how images are formed in mirrors and lenses are problematic without scientific notions of vision, and of light as a travelling entity. It is therefore important to be aware of the children's ideas when teaching them about light, vision and colour.

Key concepts of light, vision and colour

The activities in this topic are designed to explore the following key concepts:

- We see when light is reflected from objects into our eyes.
- Ordinary surfaces reflect or scatter light in all directions. Mirrors reflect light at an equal angle to the incoming light. Many surfaces, such as polished floors, both scatter and reflect light.

- Shadow shapes are areas of no reflected light or areas where the reflected light is less intense that the surrounding area.
- Most objects we see are due to scattered light from the objects.
- Some surfaces reflect more light than others. Black surfaces reflect the least light.
- Our brain puts together the stereo view we have of the world.
- Our eyes and brain can be misled.
- An image is produced when light that is reflected or emitted from an object changes direction before entering the eye to be seen.
- Our image in a mirror is equally far behind the mirror as we are in front of it.
- Light can change direction going into or out of water or glass, which results in an image of the object that may be a distorted shape when compared with the object.
- Glass and water can split light into their constituent colours as they bend.
- White light consists of all the rainbow colours.
- Colours of light and pigments can be mixed together in different ways to give different results. Colours of light mix differently from colours of paint, pencil or crayon.

Students' alternative conceptions of light, vision and colour

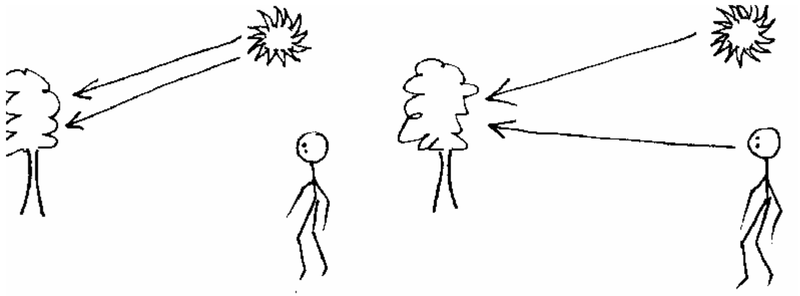
Research into students' ideas about this topic has identified the following non-scientific conceptions:

- Young children often make no connection between the eye and the object in the vision process. No explanation for the processes of vision is given: 'we see with our eyes' is sufficient explanation for the vision process.
- Older children often think of vision as something emanating from the eye to the object: a 'visual ray', or 'active eye' model of vision.
- Older children also think that light only needs to illuminate an object for vision of that object to occur; this is the 'general illumination' model.
- It is possible to see in situations where there is no light; it is totally dark.
- Light is only a source (for example, candle flame), an effect (for example, patch of light on a wall), or a state (for example, brightness); there is no recognition that light exists as an entity in space between the source and the effect it produces (young children thinking).
- Light from dim sources remains at the source; light from other sources of light travels away from the source a few metres or more, depending on the brightness of the source (young children thinking).
- Light from a source travels further at night than during the day.
- Shadows are entities independent of light; light allows shadows to be seen, rather than shadows being a result of absence of light (young children).
- Light stays on the mirror during reflection.
- Light does not reflect off non-mirrored surfaces.
- The image of an object in a plane mirror lies on the surface of the mirror.
- Lenses are not necessary to form images.
- The function of a colour filter is to dye white light the colour of the filter.
- White light is pure, not a mixture of coloured light.
- The rules for mixing colour paints and crayons are the same as the rules for mixing coloured lights.
- Colour is an innate property of an object.

The vision process

Students have difficulty with the idea of the eye as a passive receiver, and this is supported by the everyday language associated with 'seeing': 'cast your eye on that', 'her icy stare pierced his defence'. Even 'look over there' has an active ring to it that acknowledges the way we attend to objects, but misrepresents the physical nature of the visual process.

You may find that very few of the students have a scientific understanding that light needs to enter the eye for vision to occur. Common alternative conceptions are shown in the figure below.



Understanding the science of light and vision

The science underpinning the activities in this unit, and the student conceptions that will inevitably need to be engaged with concerning light, vision, mirror images, and refraction, are discussed in the Deakin publications on Ideas for Teaching Science P-8, in the document 'Light, Vision and Colour"

https://deakinsteme.org/resources/ideas-for-teaching-science-years-p-8-education/

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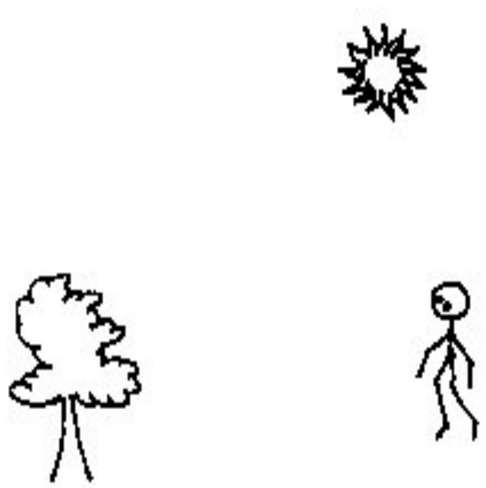
Pre/Post Sequence Assessment Task

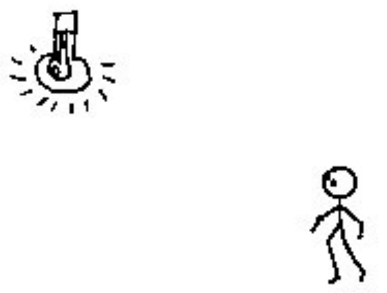
Name:

1a. Draw arrows to show how light from the sun helps the person to see the tree.



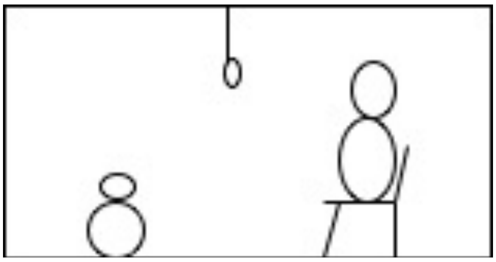
Explain what you think is happening with the light, the person and the tree

1b. Draw arrows to show how light from the bulb helps the person see the bulb.



Explain what you think is happening with the light bulb and the person.

2. A man is sitting in a room with a cat. The room has no window and the door is closed. The only source of light is an electric light globe.



When the light is switched on how does the light help the man see the cat? Explain.

When the light is switched off and there is no light in the room can the man see the cat? Explain.

Can the cat see the man? Explain.

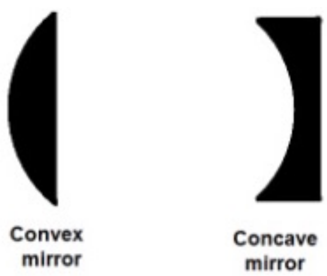
3. Draw a diagram to show how light travels in your periscope for you to see around corners. Please use labels to show us what you are drawing.

Write down here to explain what is happening with the light and the periscope.

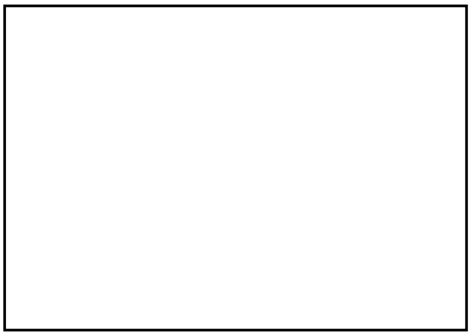
4. Johnny is looking into the mirror. Can you draw what he sees in the mirror?

Can you explain how he sees himself in the mirror?

5. The rear view mirror in your car has been broken and you need to make a temporary repair. You only have access to a spherical (round) concave mirror and a spherical convex mirror. Would either of these be suitable? Explain what you think.



6. When sunlight shines through the corner of a full aquarium the light rays are bent.
a. Complete the diagram to show the path of the light ray.



b. Explain why light rays bend when they pass from one medium to another (e.g. from air to glass), striking the boundary between the two media at an angle.

c. When white light passes through the corner of an aquarium or through a glass prism a spectrum of colours may be formed. Why does white light break up into colours under these circumstances?

Supporting Resources and References

Learning Resources (e.g. Primary Connections)
Deakin Ideas for teaching science P-8
https://blogs.deakin.edu.au/sci-enviro-ed/early-years/light-vision-and-colour/
Primary connections:
http://www.scootle.edu.au/ec/viewing/S7084/Light-shows-2012/index.html

Resource Links & Videos
On eyes and vision:
https://www.youtube.com/watch?v=t3CjTU7TaNA
https://www.youtube.com/watch?v=W5k_S8N0pFo&feature=emb_title
Visual illusions:
https://faculty.washington.edu/chudler/flash/nill.html
http://www.bbc.com/future/bespoke/story/20150130-how-your-eyes-trick-your-mind/index.html
Shadows:
https://www.youtube.com/watch?v=J-3fHDUmnf0
Reflection and illusions
https://www.generationgenius.com/videolessons/light-reflection-and-vision-video-for-kids/
https://www.youtube.com/watch?v=TcqyoYfHIFM&feature=youtu.be
Fun with Physics: DYI Optical illusions
https://www.youtube.com/watch?v=YiW_JIqVIEs&list=PLN6Fz3VnYzeaaZa9pS_4NhTxC4uyIb3m7&index=19