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POEs, Post Boxes, and IAIs

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Introduction

The following teaching and learning strategies are designed to elicit students' ideas about scientific concepts you wish to teach them. These strategies are:

- Prediction Observation Explanation (POE) strategy,
- Post box strategy, and
- Interview About Instance (IAI) strategy.

These strategies are beneficial for a couple of reasons. First of all, they are student-centred with the result that they can engage the students. Students become consciously aware of not only their own ideas but those of other students. Meaningful discussions of different ideas can occur when the ideas are the students' own. The second reason that these strategies are beneficial is that research has shown that unless the teaching exposes and addresses students' alternative conceptions the chance of changing the students' views to be more scientific may be difficult to achieve.

The elicitation of ideas from students may uncover any or all of the following:

1. Students may already understand the concept you had intended to teach; or
2. Students may hold non-scientific views; or
3. Students may have no knowledge of the concepts you intend to teach.

Each of these scenarios gives the teacher information about planning for teaching and learning strategies. If a teacher finds that the students already know the concepts he/she wishes to teach then there is little point teaching it, unless one would want to needlessly bore the students. A teacher may wish to extend the topic into higher conceptual levels or to broaden the topic into related areas.

Where non-scientific views, or alternative conceptions, are found then the teacher needs to plan teaching and learning activities whereby students come to realise that the scientific concepts are superior to their own concepts. Posner, Strike, Hewson and Gertzog (1982) consider that, if students are to change their ideas, then they must first feel that their present ideas are unsatisfactory in some way. However, dissatisfaction with a view may not provide sufficient reason to change it. If students are to accept a new idea, such as a scientific one, it needs to be intelligible, plausible and fruitful to them; although the students would not express it in these terms.

In circumstances where the students have no knowledge of the concepts you intend to teach, it is important to plan teaching and learning activities that link with what the students already know. This may involve the use of models whereby the students come to understand a scientific phenomenon or process through making connections with everyday occurrences that they are familiar with.

The following sections outline each strategy and provide examples in specific topic areas. While only a few examples are provided for each strategy you should appreciate that such strategies apply to all science topics. It is hoped that you will be able to construct your own resources to apply these strategies. To assist you in this undertaking I have included a list of key concepts and alternative conceptions (see Appendix 1) for the following topics:

- Astronomy;
- Electricity;
- Magnetism;
- Sound;
- Forces, Motion and Machines; and

- Light and Vision.

Prediction Observation Explanation (POE) Strategy

The 'predict-observe-explain' (POE) strategy requires students to carry out three tasks.

Task 1: A physical situation is demonstrated to the students who are then required to predict the result of a specific change to the physical situation. Students are also asked to explain their prediction.

Task 2: When the change is made, students are to describe what they see.

Task 3: Students are required to reconcile any conflict between prediction and observation

(White & Gunstone, 1992).

An example of a POE is shown in Appendix 3. This POE explores students' views as to how real images are formed by a convex lens. A translucent screen is used in the physical situation as it allows students to see the image from both sides of the screen in a darkened room. A key aspect of this strategy is that every student needs to commit to a prediction. For this reason, the teacher should develop POE sheets for each student to fill out (as shown in Appendix 3). Give a few silent minutes for each student to write down an explanation, with reasons. A general discussion of the different predictions and reasons may follow before the teacher enacts the change.

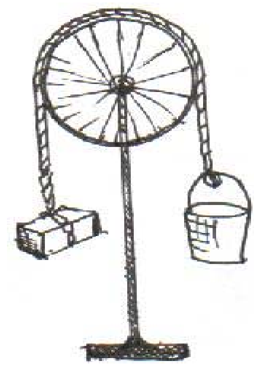
I have conducted this POE on a number of occasions with Year 10 science and Year 11 physics students. Most students will predict that only half the image will be seen; an alternative conception. When the change in the arrangement is made the resultant full image is quite surprising to the students. Students are to write down and agree on the observation made. One should observe a full but less bright image.

As many students find this a surprising result a lot of discussion may need to follow to explain it. One could revert to a ray diagram, showing the students that some rays from each point on the object can still pass through the half lens to construct the image. Alternatively, the teacher may use a laser to show how light emanating from a point on the object will always hit the corresponding image point no matter which place the laser light passes through the lens. Referring back to the Appendix 3 POE sheet another three POEs may be undertaken with the students. Again, each time the students are expected to commit to a prediction, with reason(s), before enacting the change.

Other examples of POEs that may have a 'surprising' event (in other words the event exposes an alternative conception) for students are:

- **Optics:** Images in plane mirrors: predict what you will see in a mirror when you move further away from the mirror. Have a student are to stand in front of a plane mirror attached a wall. Ask the student to determine how much of their image they are able to see in the mirror. For example, the student may only be able to see their image from their face down to their chest. Students are then to predict whether the student looking into the mirror will be able to see more/less/about the same amount of their image if they were to step back a few paces.
- **Gravity**: Predict which object will hit the ground first. Try objects of different masses and sizes. Include objects of the same weight but different sizes. For example, drop 2 A4 sheets of paper, one of which is scrunched into a ball.
- **Electricity**: Predict the level of brightness on a globe if another globe is placed in series in a circuit. Try to predict the outcome to a globe placed in parallel. Try to predict the outcome to the different placement of a switch in an electric circuit that contains a battery, globe, switch and connecting wires.

- **Forces**: A famous POE was developed and used by Dick Gunstone on Tertiary Physics students. It involves a bicycle wheel, a brick, a bucket of sand and some rope. The physical situation (shown in the diagram opposite) presented to the students had the bucket of sand and brick on the same level and at rest. Students were to predict the outcome if the brick were to be raised a short distance so that the brick and bucket of sand were no longer level.



- **Motion:** Students are to predict the shape of a position versus time graph for a particular motion. The best results occur where the graph is produced at the same time as the motion is occurring. I have found the use of a motion detector attached to a graphic calculator and a view screen (this projects the calculator image onto a screen) produces a position versus time graph of a particular motion in real time.

White and Gunstone (1992) point to a number of issues in using POEs within the classroom. These include:

- It is important that students are presented with situations for which they feel are relevant and real, and are able to make a prediction based on some personal reasoning. The POE strategy is unlikely to be of much value if students engage in pure guessing.
- It is necessary to have a classroom where students feel free to give their opinions at appropriate times. The manner in which predictions with reasons are made can vary but it is important to get some commitment from every student before the observation stage.
- It is important that the class views are summarised and fed back to the students during the prediction stage. In this way students, on the one hand, do not feel they are alone in their thinking and, on the other hand, they come to appreciate that different views can exist among their peers.
- Following the observation stage importance needs to be placed in gaining agreement by all students as to what is actually seen. Observations by students may not be uniform as their observations are influenced by their predictions. To ensure that students make the correct observation it is important that the POE is designed so that observations are made direct as possible.
- POEs are easier to set up and can be used frequently. However, it is most important that the POEs do not always provide discrepant events for the students. This can lead students to develop a negative approach to this strategy which may result in them predicting an outcome contrary to their personal reasoning. They will not be engaged in critical thinking which is what you want them to do. Therefore, include POEs where many of the students are likely to find their predictions in line with their observations. Such POEs still have value as students need to provide an argument about why something should occur before it happens.
- POEs provide valuable information to guide sequencing and presentation of content.

Post box Strategy

The Post box strategy determines anonymously students' concepts about a topic or phenomenon (Bell, 1993). The strategy has three steps.

Step 1: Students are provided with a sheet of questions they are to anonymously respond to. Students write their answers on the sheet; they are not to discuss their answers with any other student, nor are they to write their name on the sheet.

Step 2: Students are to separate each question, with its response, and then post each question to a separate box placed at the front of the classroom. Therefore, if there are five questions then the teacher provides five boxes. The teacher divides the class into research teams; the number of teams should equal the number of questions asked. Each team is given a box of questions and responses. They are to analyse the responses, determining the popularity of each idea.

Step3: Each research team is to report to the rest of the class their findings. They are to indicate the popularity of each of idea that was found.

This strategy is useful, particularly in classroom where students are reluctant to express their ideas in open discussions. Throughout this strategy the students' concepts are elicited in an anonymous and thus non-threatening manner. The analysis and reporting of different views allow for student generated discussions and an appreciation by all the students that there can be a range of different concepts to explain or describe the same phenomenon. The Post box strategy as an introductory exercise to a topic develops a sense of purpose and motivation for learning the topic as the students are dealing entirely with their own ideas and so have ownership of the activity. In this strategy, the teacher may find that some of the students express the scientific concept and so there will be no need to put this view across to the students. The role of the teacher will be working with the students so that discussions and activities lead all the students to accept the scientific idea.

An example of a Post box question sheet is given in Appendix 2; the topic is Light. I have found success in using this sheet in science classes at Year levels from 7 to 10, and a Year 11 physics class. The questions focus on concepts related to vision, luminous objects and the extent of light travel from luminous objects.

In making up questions for the Post box sheet bear in mind the key concepts you wish to teach. You may wish to determine if the students hold any specific alternative conceptions and so specific questions, such as "Can you see objects in a room that has no light?" may be asked. Refer to Appendix 1 for lists of concepts and alternative conceptions for a variety of topics.

Interview About Instances (IAI) Strategy

The Interview About Instances (IAI) strategy has been used by researchers exploring students' understandings of concepts in science in interview situations (Gilbert, Watts & Osborne, 1985). An IAI strategy is a conversation that an expert has with one student that is focussed on questions asked in relation to a series of line diagrams. The questions probe the student's ability to understand a concept within a physical setting. For example, the set of line diagrams below focus on exploring a student's understanding of the relationship between forces and motion.

Whilst the strategy was originally used in interview situations between a single student and a researcher there is plenty of scope to use the interview cards within a classroom setting. For example, the cards may be shown to single or multiple students as a way to initiate a discussion. It is important to note that there is a lot more than just asking a single question for each diagram. The teacher must be prepared to follow up a student's response by asking further, more probing, questions. As with each of these strategies that probe students' understandings of a concept the teacher should not be too judgemental when students are giving their initial responses.

Another way in which the interview cards may be used in a classroom setting is described in Appendix 4. A series of interview cards a displayed around the classroom. Each student is given a question sheet to fill out as he or she moves from one card to the next. Once the students complete the sheet a general classroom discussion can follow.

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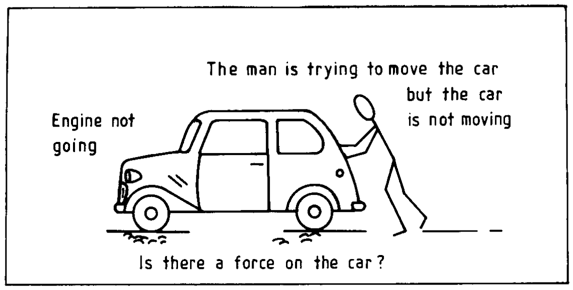

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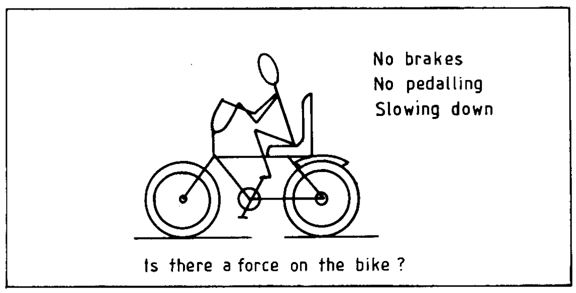

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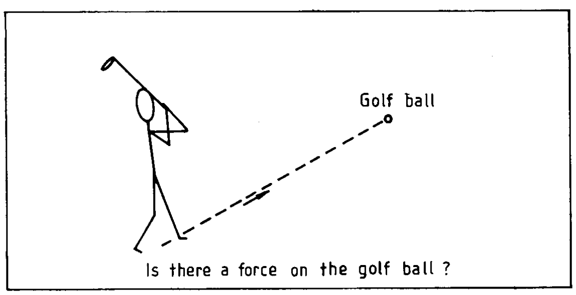

Taken from Osborne and Freyberg (1985, p. 42)

Conclusion

The material in some of the strategies may be used for other types. For example, the prediction part of a POE may form a question as part of a Post box question sheet or may be drawn and shown in diagrammatic form on an IAI card. The concept and alternative conception lists in Appendix 1 provides a valuable resource to construct your own POEs, Post Box question sheets, or IAI cards.

Bear in mind that whilst these strategies are an excellent means to elicit the views of the students they provide valuable information the teacher can use to plan for the effective teaching of science concepts. It is most important that the teacher follows up on the students' ideas. If activities are undertaken that employ the students ideas then the students will see themselves as part of the teaching and learning process.

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Appendix 1

Astronomy

Concepts of Astronomy

The Earth

- The Earth is spherical.
- 'Down' refers to the centre of the Earth (in relation to gravity).

Day and night

- Light comes from the sun.
- Day and night are caused by the Earth turning on its axis. (It should be noted that 'day' can refer to a 24-hour time period or the period of daylight; the reference being used should be made explicit to students).
- At any one time half of the Earth's shape is in sunlight (day) and half in darkness (night).

The changing year

- The Earth revolves around the sun every year.
- The Earth's axis is tilted 23.5 degrees from the perpendicular to the plane of the orbit of the Earth around the sun. The earth's tilt is always in the same direction.
- As the Earth revolves around the sun its orientation in relation to the sun changes because of its tilt.
- The seasons are caused by the changing angle of the sun's rays on the Earth's surface at different times during the year (due to the Earth revolving around the sun).

The Earth, moon and sun

- The Earth, moon and sun are part of the solar system, with the sun at the centre.
- The Earth orbits the sun once every year.
- The moon orbits the Earth in one lunar month (about 28 days). The moon is the Earth's only natural satellite.
- The moon turn on its axis at a rate that means we always see the same face.
- The moon orbits the Earth at an angle to the plane in which the Earth and sun are located.

The phases of the moon and eclipses

- The moon is visible because it reflects light from the sun.
- The sun always illuminates half of the moon's sphere.
- The moon appears to change shape (its phases) each month because we see different amounts of the illuminated surfaces of the moon at different times each month due to the relationship between the positions of the Earth, sun and moon at a particular time.
- The phases of the moon occur in a regular pattern.
- Eclipses occur in two ways: when the earth lies between the sun and the moon causing a shadow – full or partial – over the moon (that is a full or partial eclipse), or when the moon lies between the Earth and the sun and casts a shadow – full or partial – over part of the Earth (that is, a full or partial solar eclipse). These occur regularly.

The solar system and stars

- Stars emit light. The sun is a star. The sun emits light.
- The sun is the centre of the solar system and is the only body in the solar system that emits light.
- The sun is the solar system's main source of energy.
- The planets orbit the sun. Some planets, other than the Earth, have their own moons (natural satellites).
- The planets are great distances from the Earth, but relatively much closer than the stars, apart from the sun.

The universe

- The solar system is only a small component of one particular galaxy, the Milky Way, which is made up of millions of stars.
- Even the nearest stars (apart from the sun) are gigantic distances away compared to the planets.
- The universe (which is everything that exists) is comprised of countless galaxies. Our galaxy, the Milky Way, is not the centre of the universe.

Alternative Conceptions of Astronomy

The Seasons

- The seasons are caused by the elliptical orbit of the Earth. When the Earth is closest to the Sun it is summer.
- Summer occurs when the Earth is tilted towards the Sun and is therefore closer to it.

The Moon

- The Moon is not in free fall.
- The Moon gives off its own light.
- The Earth blocks the sun's light, casting a shadow on the moon.
- The different shadow effects are due to the Earth's tilt, its rotation or its revolution around the sun.
- The amount of light reflected off the Earth onto the moon causes the changed shapes.
- The side of the moon reflecting the sun's light affects the shapes.

Gravity

- The force that acts on an apple is not the same one that acts on the Moon.
- The gravitational force is the same on all falling objects.
- There are no gravitational forces in space.
- The gravitational force on the Space Shuttle is nearly zero.
- The gravitational force acts on one mass at a time.
- Moon stays in orbit because the gravitational force on it is balances by the centrifugal force.
- There is no gravity in a vacuum.
- The Earth's spinning motion causes gravity.
- Gravity only acts on things that are falling.
- Free falling objects can only move downwards.

Comets

- Comet's tails are created as comets burn up passing through the Earth's atmosphere
- Comets only appear to have long, fiery tails; this is due to their speed and/or that they are really ball-shaped.
- Comets are made up of gases and/or dust (these gases are stated or implied to be burning).

Space travel

- Spacecraft travel in straight lines from one planet to another.
- Spacecraft can be launched anytime to travel from one planet to another.
- Spacecraft are not affected by the Sun.
- Jets can fly in space.
- Weightlessness means there is no gravity.
- Rockets need something (like air) to push against.

Stars and outer space

- Stars reflect light from the sun
- Stars are planets.
- Stars seem to have points because they are a long distance from us.
- The composition of stars explains the points, for example, burning balls of hydrogen whose flames appear as points.
- Space is not something
- Black holes are big.

- Light always travel in straight lines.
- Things in space make sounds.
- If the Sun were to become a black hole, the Earth would get sucked into it.

Tides

- Tides are caused by the moon orbiting the Earth every 24 hours
- There is only one high and one low high tide each day
- The elliptical orbit of the moon around the Earth causes the tides; when the moon is closer to the Earth it is high tide.
- High tides occur when the moon is visible (maybe only at night)
- High tide occurs on the opposite side of the Earth to the low tide.
- The Sun has no effect on the tides.

The planets

- The morning and evening star is not equated with the planet Venus, but is believed to be a star.
- Planets give out their own light
- The planets contain dust and rocks and a gaseous atmosphere and water
- The planets are all similar in structure to the Earth.
- Planets orbits are circular.
- All the planets revolve about the sun with the same period.
- Revolution is the same as rotation.

Electricity

Concepts of Electricity

Static Electricity

- Charged objects will attract uncharged objects.
- Objects can be charged by rubbing.
- Some materials are charged more easily than others.
- An object becomes charged when it loses or gains electrons.
- Objects can carry either a positive or negative charge, depending on what they are made of and what they are rubbed with.
- A negatively charged object has gained electrons; a positively charged object has lost electrons.
- Like charges repel, unlike charges attract.
- Charged objects will discharge over time as charge leaks to the atmosphere.
- Charge can move about on conductors, but not very much on insulators.
- Sparks are the movement of electrons through the air from one object to another. Lightning is sparking effect.
- Earthing is where charge is shared between a charged object and a large conductor (usually the ground).
- We measure the quantity of charge with a unit called a Coulomb.

Current Electricity

- Electric current (measured in Amperes) is the flow of electric charge (measured in Coulombs) around a circuit.
- A complete circuit is needed for an electric current.
- Conventional current comes out of the positive terminal of a battery and back into the negative terminal, whereas electrons actually flow the other way.
- Switches stop the flow of current.
- The current out of the battery from the positive terminal is the same as that entering the battery through the negative terminal. Current is not diminished around a circuit.
- Metals conduct electric current, most other substances are insulators.
- The voltage (measured in Volts) of a battery is the energy (measured in Joules) supplied to each unit of charge (measured in Coulombs).

- Electric circuits involve the transformations of electrical energy into other forms such as heat, light, movement etc.
- The amount of energy given to each unit of charge diminishes around the circuit.

Household Electricity

- Household electricity runs on 240 Volts Alternative Voltage and Current.
- A complete circuit includes the generator, wires and the appliance in the home.
- A fuse/circuit breaker breaks a circuit when too much current passes through it.
- Households have a number of parallel circuits each with their own fuse/circuit breaker.
- The wires from the generator are called the active and neutral. A third wire, the earth, is connected to the neutral wire and the ground.
- The earth wire is not normally part of the circuit. It comes part of the circuit if it comes in contact with the active wire.
- Physically touching an active wire completes a circuit where current is passed from active wire, person, ground and then back to the neutral wire

Alternative Conceptions of Electricity

- The Electric Power Companies supply electrons for your household current.
- We pay Electric Power Companies for power.
- ‘Static’ and ‘Current’ Electricity are two types of electrical energy.
- “Electricity” is used up in electric circuits.
- Charge is used up in electric circuits.
- Energy is used up in electric circuits.
- More devices in a series circuit means more current because devices “draw” current.
- Electric power is the same as electric energy.
- Electricity means the same thing as current, or voltage, or energy.
- Batteries store, and supply, electrons or “electricity” to the electric circuit.
- A wire from a battery to a bulb is all that is needed for the bulb to light up.
- The electric energy in a circuit flows in a circle.
- Electric current is a flow of energy.
- The stuff that flows through wires is called “electric current”.
- Electrons travel at, or near, the speed of light in the wires of an electric circuit.
- Voltage flows through a circuit.
- Voltage is energy.
- High voltage by itself is dangerous.
- Electrons move by themselves.
- Current is the same as voltage.
- A conductor has no resistance.
- The bigger the battery, the more voltage.
- Batteries create energy out of nothing.
- AC charges move all the way around a circuit and all the way back.
- AC voltage and current remains constant as in DC circuits.

Magnetism

Concepts of Magnetism

- Magnets exert a force that can be described as a push or a pull.
- Magnets exert a force field that is called a magnetic field. A magnetic field is a region in space around a magnet that will exert on another magnet or magnetic material.
- Magnets attract materials composed of iron and nickel; these materials are described as being magnetic.
- Magnets vary in strength, size and shape.

- Magnets have a North and South Poles. The attracting power (magnetic field) of the magnet is greatest at its poles
- Like poles of a magnet attract; unlike poles repel.
- Atoms are tiny constituents of matter and act like tiny magnets. In magnets and magnetic materials atoms form groups called domains where their magnetic poles are aligned.
- In magnets domains align themselves (North Poles are in the same directions). In non-magnetic materials domains do not align themselves magnetically.
- Magnetic materials are made into temporary magnets by bringing them nearby a permanent magnet.
- The Earth can be considered to be one large magnet.
- Temporary magnets can be made from a nail, wire and battery as an electric current produces magnetism.

Alternative Conceptions of Magnetism

- Poles are only at the ends of magnets.
- Big magnets are stronger than little ones.
- Larger magnets are stronger than smaller magnets.
- The magnetic and geographic poles of the Earth are located at the same place.
- The Geographic and Magnetic poles are identical.

Sound

Concepts of Sound

- The production of sound requires an object to vibrate.
- The speed of vibration of the sound source gives the frequency of the sound.
- The size or amplitude of the vibration gives the loudness of the sound.
- Sounds that reflect off objects are echoes.
- Sound travels much faster in solid objects than in air.
- Sound requires a medium to travel in. Sound can't travel in space.
- The particles in the material in which the sound moves vibrate at the same frequency as the source.
- Sound is the transmission of kinetic energy from particles in the source to particles in the medium for which the sound travels.
- Sound travels as a travelling disturbance (wave) due to collisions in the material in which it moves.
- Sound waves are disturbances called longitudinal waves where the particles in the material vibrate forwards and backwards to the forward moving wave direction.
- Sound is pressure waves of compressions (high pressure) and rarefactions (low pressure) travelling away from a vibrating source.
- Most sounds that are heard are due to resonance.
- Objects have their own natural vibration pattern (resonant frequencies) and can give a characteristic note (frequency) when hit (or blown).
- Resonance is the natural amplification of sound frequencies (resonant frequencies) in an area (resonating chamber) different to the sound source.
- Speaking and hearing are resonance effects. The mouth and nose cavity acts as a resonating chamber for speech; the ear canal acts as a resonating chamber for hearing.
- The speed of sound in air is around 340 metres/second.
- We use two ears to judge where the direction to a sound source.

Alternative Conceptions of Sound

- The loudness and pitch (or frequency) of sounds are confused with each other.
- You can hear and see a distant event at the same moment.
- Hitting an object harder changes its pitch.

- In a telephone, actual sounds are carried through the wire rather than electrical impulses.
- Human voice sounds are produced by a large number of vocal cords.
- Sound moves faster in air than in solids (air is "thinner" and forms less of a barrier).
- Sound moves between particles of matter (in empty space) rather than matter.
- Sound can travel through space.
- In wind instruments, the instrument itself vibrates itself not the internal air column.
- As sound waves move, matter moves along with them.
- The pitch of whistles or sirens on moving vehicles is changed by the driver as the vehicle passes.
- The pitch of a tuning fork will change as the tines of the fork slow down (run out of energy).

Forces, Motion and Machines

Concepts of Forces, Motion and Machines

- A force is just a push or a pull.
- Forces always come in pairs and involve two objects. One object applies a force (action force) on another object and, in return, the other object applies an equal and opposite force (reaction force) on the first object.
- Forces can be contact forces involving object that are in contact or forces.
- Forces can be field forces where one object sets up a force field in the area around it.
- There are different types of forces. For example, tension, compression, friction, normal.
- Multiple forces on an object add to produce a net force.
- An object with a zero net force on it is either at rest or moving with constant speed.
- Inertia is the property of all objects with mass and represents a resistance to change its motion.
- An object with a non-zero net force will change its motion. This may involve the object, speeding up, slowing down and/or changing direction.
- In an interaction between two or more objects the total energy remains the same. Energy may be transferred from one object to another or it may transform from one type of energy into another.
- There are different types of energy. For example, kinetic, gravitational potential, elastic potential, heat, and sound.
- A machine is a device that transmits and modifies force. There are different types of machines. For example, incline plane, lever, wheel and axle, pulley and gears.
- A machine gives mechanical advantage which is equal to the output force (load) divided by the input force (effort).

Alternative Conceptions of Forces, Motion and Machines

<u>Mass, weight and gravity</u>

- A kilogram of feathers iron weighs more than a kilogram of feathers.
- Weight and mass are the same thing; weight is not considered as a gravitational force.
- There must be air for gravity to take effect; therefore, there is no gravity on the moon, nor is there gravity out in space.
- Earth’s magnetism and spin are connected with gravity.
- Things fall naturally without the need for a force.
- Heavier things fall faster than light things.
- Gravity only acts on an object when it begins to fall and when falling; gravity ceases to act when the object lands on the ground and becomes stationary.
- All objects can be moved with equal ease in the absence of gravity.

<u>Describing motion - kinematics</u>

- Two objects side by side must have the same speed.

- Acceleration and velocity are always in the same direction.
- Velocity is a force.
- If velocity is zero, then acceleration must be zero too.
- Heavier objects fall faster than light ones.
- Acceleration is the same as velocity.
- The acceleration of a falling object depends upon its mass.
- If the speed of an object is increasing then so is its acceleration.
- Velocity is another word for speed. An object's speed and velocity are always the same.
- Acceleration always means that an object is speeding up. Acceleration is always in a straight line. Acceleration always occurs in the same direction as an object is moving.
- If an object has a speed of zero (even instantaneously), it has no acceleration.

Forces and Motion (explaining motion – dynamics)

- Forces are only associated with movement.
- Forces get things going rather than also making things stop.
- Forces are associated with living things; physical activity and muscular strength.
- Inanimate object do not apply forces.
- Forces keep objects in motion.
- When an object is moving, there is a force in the direction of its motion.
- A moving object has a force within it which keeps it going.
- Force as a property of a single object rather than as a feature of the interaction between two objects.
- If the pushing force ceases there is a force on the moving object which keeps it moving but which gradually gets used up and then the object stops.
- Friction is associated with heat.
- Friction only occurs between solids.
- If an object is at rest, no forces are acting on the object. Only animate objects can exert a force. Thus, if an object is at rest on a table, no forces are acting upon it.
- A force is needed to keep an object moving with a constant speed.
- Action-reaction forces act on the same object.
- Inertia is the force that keeps object in motion.

Energy

- Energy gets used up or runs out.
- Something not moving does not have energy.
- Gravitational potential energy is the only type of potential energy.
- Energy is only caused by life, animal activity.
- Conservation of energy means that energy should be conserved.
- Energy and force are the same thing.
- Energy is a thing.
- An object at rest has no energy.
- Gravitational potential energy depends only on the height of an object.
- Doubling the speed of a moving object doubles the kinetic energy.
- Energy can be changed completely from one form to another (no energy losses).
- Energy is truly lost in many energy transformations. Things "use up" energy.

Pressure

- Only wind, and not still air, has a pressure.
- Air pressure is a downwards influence.
- A vacuum sucks.
- Pressure is the same as force.

Momentum

- Momentum is the same as a force.
- Momentum and kinetic energy are the same thing.

Machines

- Machines must have a motor.
- Machines are only inanimate objects.

Light and Vision

Concepts of Light and Vision

- Light (radiant energy) is an entity that travels through space.
- Light travels very fast – 300 000 km per second in space.
- Light travels in straight lines.
- We see when reflected light is reflected from objects into our eyes.
- Some objects are sources of light (a globe, the sun, a flame); most things we see reflect light.
- Having two eyes is necessary for judgement of depth.
- Our brain puts together the stereo view we have of the world.
- Our eyes and brains can be misled.
- Light emitted from luminous object keeps travelling until absorbed by something.
- Each point on a luminous object emits light in all directions (isotropic emission).
- Ordinary surfaces reflect/scatter light in all directions (diffuse reflection). Mirrors reflect light at an equal angle to the incoming light (specular reflection). Many surfaces, like polished floors, both scatter and reflect light.
- Some surfaces reflect more light than others. Black surfaces reflect the least amount of light.
- Light can be bent going into or out of water or glass, and this causes images of different shapes and sizes.
- Light incident perpendicularly to a transparent surface of a material does not change direction in passing through the material.
- Refraction of light is the change in speed as light passes from one transparent material into another.
- White light consists of all the rainbow colours (spectrum) (ROYGBV).
- The colour of an object is not a property of the object. It just reflects light of a particular colour and absorbs other colours.
- The primary colours of light are red, blue and green. The secondary colours of light are yellow, magenta & cyan.
- The image in a plane mirror is inverted, and symmetrical with the object.
- Our image in a plane mirror is equally far behind the mirror as we are in front of the mirror.
- Curved mirrors cause images of different sizes and shapes.
- Image formation in a lens or mirror requires:
    - (i) That all the light that passes through a lens, or reflects off a mirror, contributes to the formation of an image, and
    - (ii) The light from each point on the object that passes through the lens, or is reflected from a mirror, either converges to the corresponding point on the image (real image), or appears to diverge from the corresponding point on the image (virtual image).

Alternative Conceptions about Light and Vision

Research into students' understandings of light and vision has found a range of alternative conceptions in a variety of areas.

Light is an Entity

- The effects of light are instantaneous. Light does not travel with a finite speed.
- Light is only associated with either the source or area of illumination.

Rectilinear (straight-line) Motion of Light

- Light is associated only with either a source or its effects. Light is not considered to exist independently in space; and hence, light is not conceived of as "travelling".
- Light bends around objects, like clouds.
- Lines drawn outward from a light bulb represent the "glow" surrounding the bulb.
- A shadow is something that exists on its own. Light pushes the shadow away from the object to the wall or the ground and is thought of as a "dark" reflection of the object.
- Light actually consists of rays.

<u>Vision</u>

- The only condition to see an object is if light shines on the object. Light does not travel from the object to the eye.
- Something is emitted from the eye when looking at an object.
- The object and observer only need to be bathed in light for the observer to see the object.
- The eye receives upright images.
- The lens is the only part of the eye responsible for focussing light.
- The lens forms an image (picture) on the retina. The brain then "looks" at this image and that is how we see.
- The eye is the only organ for sight; the brain is only for thinking.

<u>Isotropic Emission of Light from Luminous Objects</u>

- Light is not necessarily conserved. It may disappear or be intensified.
- Light from a bulb only extends outward a certain distance, and then stops (or fades away). How far it extends depends on the brightness of the bulb.

<u>Reflection of Light</u>

- Light reflects from a shiny surface in an arbitrary way.
- Light is reflected from smooth mirror surfaces but not from non-shiny surfaces.
- Curved mirrors make everything distorted.

<u>Refraction of Light</u>

- Light always passes through a transparent material without changing direction.
- When an object is viewed through a transparent solid or liquid material the object is seen exactly where it is located.

<u>Colour of Light</u>

- A white light source, such as an incandescent or fluorescent bulb, produces light made up of one colour.
- Sunlight is different from other sources of light because it contains no colour.
- When white light passes through a prism, colour is added to the light.
- The rules for mixing colour paints and crayons are the same as the rules for mixing coloured lights.
- The primary colours for mixing coloured lights are red, blue and green.
- A coloured light striking an object produces a shadow behind it that is the same colour as the light. For example, when red light strikes an object, a red shadow is formed.
- The shades of grey in a black and white newspaper picture are produces by using inks with different shades of grey.
- When white light passes through a coloured filter, the filter adds colour to the light.
- The different colours appearing in coloured pictures in magazines and newspapers are produced by using different inks with all the corresponding colours.
- Colour is a property of an object, and is independent of both the illuminating light and the receiver (eye). For example, a red jumper contains red coloured molecules.
- When a coloured light illuminates a coloured object, the colour of the light mixes with the colour of the object.

<u>Image Formation in Mirrors and Lenses</u>

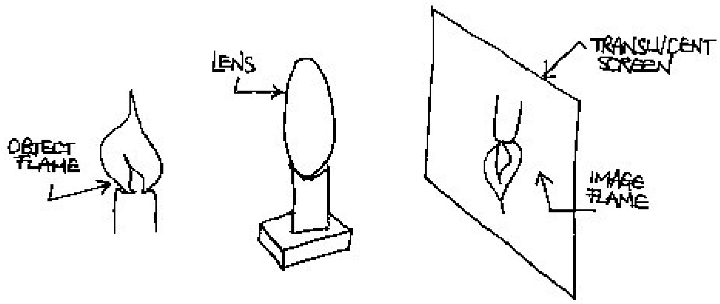
- A mirror reverses everything.

- For an observer to see the mirror image of an object, either the object must be directly in front of the mirror, or if not directly in front, then the object must be along the observer's line of sight to the mirror. The position of the observer is not important in determining whether the mirror image can be seen.
- An observer can see more of his/her image by moving further back from the mirror.
- The way a mirror works is as follows: the image first goes from the object to the mirror surface. Then the observer either sees the image on the mirror surface or the image reflects off the mirror and goes into the observer's eye.
- Students will often think about how a lens forms an image of a self-luminous object in the following way. They envision that a "potential image" which carries information about the object leaves the self-luminous object and travels through the space to the lens. When passing through the lens, the "potential image" is turned upside down and may be changed in shape.
- Blocking part of a lens surface would block the corresponding part of the image.
- The purpose of the screen is to capture the image so that it can be seen. The screen is necessary for the image to be formed. Without a screen there is no image.
- An image can be seen on the screen regardless of where the screen is placed relative to the lens. To see a larger image on the screen, the screen should be moved further back.
- An image is always formed at the focal point of the lens.
- The size of the image depends on the size (diameter) of the lens.

Appendix 2

Where is the image in a Convex Lens?

Can you see the image of the candle flame?



The image can be seen on both sides of the translucent screen. In comparing the image to the original flame the features are: ____

<u>Predictions about images formed by lenses:</u>

1.

Prediction:

With this arrangement predict what will happen to the image if I cover the top half of the lens? Give your reason(s).

____

Observation:

Describe the image now.

____

Explanation:

Does your prediction match the observation or do you need another explanation?

____

____

Other POEs may follow with students making predictions about the following arrangement changes.

2. If the screen is moved closer to the lens what will happen to the image?

____

3. If I remove the screen predict what will happen to the image?

____

4. If I remove the lens predict what will happen to the image?

____

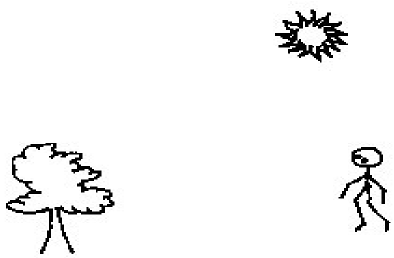
Appendix 3

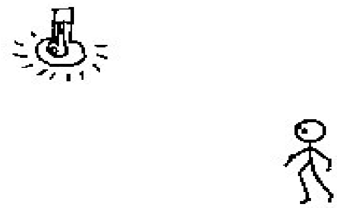
Ideas about Light

1. (a) For the two situations shown below:

(i) Draw arrows to show how light from the sun helps the person to see the tree.

(ii) Draw arrows to show how light from the bulb helps the person see the bulb.





(b) My idea of seeing can be written as: To be able to see an object ____

2. If you were placed in a room where there was no light would you be able to see?________ What about spending some time in this room, would you be able to see? ____________ Can a cat or owl be able to see in a room where there was no light? Why do you think this? ____

3. If you were directly behind someone can you attract their attention by just staring at them? __________ Why?________________ ____

4. (a) Which of the following objects <u>make</u> light (<u>circle</u> them).
Glowing coals of a fire at night; Glowing coals from a fire during the day; moon; mirror; A bar heater operating at night; A bar heater operating during the day; TV operating at night; TV operating during the day; Glow-in-the-dark sticker at night; Glow-in-the-dark sticker during the day.
(b) Does daylight affect the amount of light an object gives out? Please explain.____

5. A person is standing outside shining a torch parallel to the ground.
(a) If it is night-time how far will the light travel from the torch? _____________________
(b) If it is day-time how far will the light travel from the torch? _______________________
(c) Does the daylight affect how far light travels from an object? Please explain. ____

Appendix 4

What gives off light?

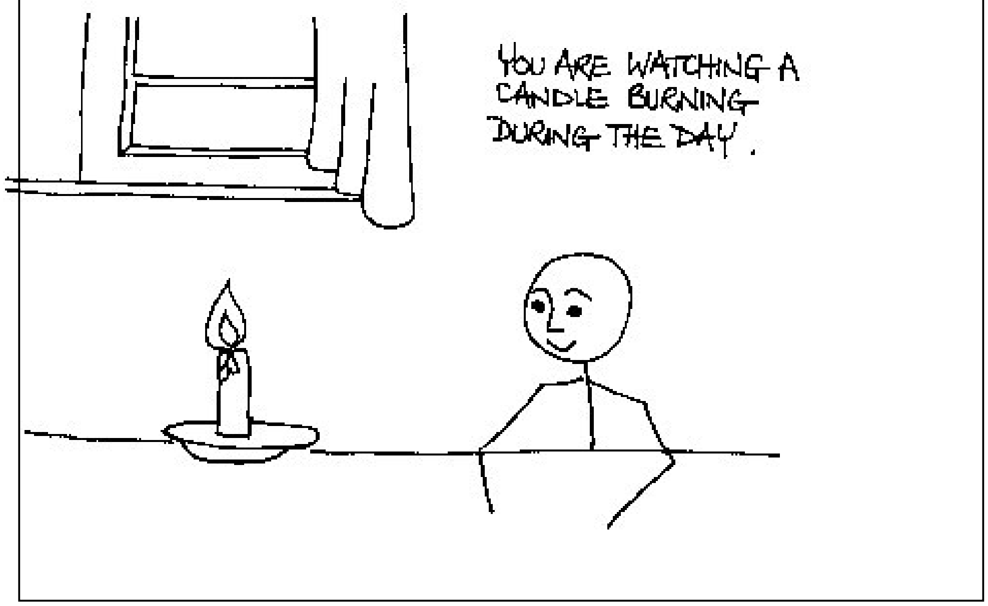
Move around the room looking at the cards (examples are shown on the next page). For each card fill in the spaces provided on this work sheet. For sections A, B, C & D place a tick in the appropriate section; the letters mean the following:
The light from the object

A: stays on the object
B: comes out about halfway towards you
C: comes out about as far as you but no further
D: comes out until it hits something

Card Number	Object	Does the object make light?	A	B	C	D
1	Candle (daylight)					
2	Candle (night-time)					
3	Bar Heater (daylight)					
4	Bar Heater (night-time)					
5	Movie Screen					
6	Light Bulb (daylight)					
7	Light Bulb (night-time)					
8	Television (daylight)					
9	Television (night-time)					
10	Mirror					
11	Glowbug (daylight)					
12	Glowbug (night-time)					
13	Moon					

1. A person is standing outside shining a torch parallel to the ground.
   a. If it is night time how far will the light from the torch travel? ____________________
   b. If it is day time how far will the light from the torch travel? ____________________
   c. If the torch is pointed directly up at night how far will the light from the torch travel? ____________________
2. Name three objects, not listed above, that give off light. ____________________
3. Does the brightness of the object determine how far the light from it will travel? Explain why____________________
4. Does the daytime affect the amount of light an object gives off? Explain why ____________________
5. Does the daytime affect the distance the light travels away from an object? Explain why.____________________

CARD 1



CARD 12