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Teacher Resource: 3D Zoetrope

This activity is a guide for running a 3D zoetrope activity with your students, based on Questacon Smart Skills Teacher Workshop 2. Potential curriculum links are provided at the end of this document, but this activity can be used in many ways across stages 3 to 5. There are many cross-subject links that can be explored through this activity which has a STEAM focus (Science Technology Engineering Arts and Maths).

In this workshop, participants use simple materials and some electronics to build an animated zoetrope that helps demonstrate the principles behind animation and movies. Animation and movies rely on still images being flashed quickly in front of our eyes to create an illusion of motion for the human brain. In the 3D zoetrope, this effect is achieved with physical objects, a flashing light and a spinning platform. The name zoetrope comes from the Greek words: “zoe” meaning "life" and “tropos” meaning "turning".

The activity encourages participants to observe, try and refine different prototype designs, modelling the innovation process, developing creative problem solving skills and promoting artistic creativity in designing an animation. The activity also incorporates a smart phone app to create the strobe light effect.

Resources and requirements

There are two main parts to the 3D zoetrope: the spinning platform and the animation materials. The materials needed for each area will be discussed independently.

The spinning platform

The spinning platform can be created in many ways but from our experimentation we’ve found that the platform should rotate at a consistent rate, anywhere from 30 to 80 rotations per minute (RPM). Many different materials can be used, but we created our platform using:

- A paper coffee cup
- An old CD or DVD
- A 3D printed widget- download the file for this from Thingiverse
- A small, low RPM motor (30-80 RPM)
    - We purchased ours from eBay seller “coolcool_go, selecting 3V 45RPM & 60RPM Torque Gear Box Motor from for about $7 per motor
- AA battery holder and AA batteries
- Crocodile clips

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Some alternative spinning platforms include:

- A plastic plate. This can be stuck on top of the CD, as per the instructed spinning platform. This larger surface gives more opportunity for animation.
- A lazy suasn. This is a great circular spinning platform, but getting it to spin at a constant speed can be a challenge. There are ways to achieve this, so it can be worth investigating.
- A record turntable. These rotate at a constant low speed and are easily switched on and off. Turntables can now be found in hifi stores again, but they can also be picked up at charity shops or tip shops. When they don't work, they often just need a new turntable belt as the rubber has degraded. These can be picked up online for less than $10 or you can just use an appropriate sized rubber band for this purpose! Students can use old records as the base to create their animation on, or you can cut cardboard or coreflute to the same size. Old records can also easily be picked up from charity shops for around $1 (if you pick the really bad ones!).

The animation materials

Any available materials can be used to create your animation. Many identical items are often useful to create the repeated units needed, while simple, flexible and malleable materials can be easy to work with. Some ideas include:

- Pipe cleaners
- Skewers, toothpicks
- Colourful craft pom-poms
- Plasticine, BluTac
- Bobby pins, florists wire, thin wire coat hangers, paperclips
- Small, cheap toy figurines
- Dice or coins
- Stickers or cardboard shapes

Smart phone, tablet apps and software

While a strobe light can be purchased from various electronic stores and scientific classroom suppliers, the LED flash on a smart phone can also be converted into a strobe light using an appropriate app. There are many apps out there that can perform the function, but we've found the following work well:

- For android phones: Strobily or LED Strobe
- For iPhones: Strobe Tachometer

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3D Zoetrope Activity

Introduction	Introduction to the activity including how movie makers and artists have created movies and animation through still pictures and objects. A playlist of zoetropes has been created at this YouTube link. This playlist shows a couple of examples of older 2D animation techniques and also has a few clips of 3D zoetropes to inspire workshop participants. Throughout this workshop students can work individually or in small groups.
Part 1: Build a spinning platform	Gather the materials to make your spinning platform. The instructions below correspond to the photos that follow: 1. Push the 3D printed widget into the CD, so that the smaller cylinder is wedged firmly through the hole of the CD 2. Push the shaft of the motor into the hole of the widget, noting the D shape. 3. Place your batteries in the battery holder. Connect the battery holder to the motor using the crocodile clips. Your disc should start spinning! Can you make it spin the other way? Disconnect one of the crocodile clips momentarily to stop the disc spinning. 4. Make a small slot in the top of your paper cup and gently push the motor into it. You may need to use some masking tape to hold the motor in place. Cut a small notch on the rim of the cup, to allow the crocodile clips to pass out from under the cup. You can now reconnect the crocodile clips to the battery and you have your spinning platform ready for part 2




Some points worth noting:

- If you can't 3D print the widget, you can use other objects. An eraser, cut into a circle, with a small drill hole works well to slide onto the motor shaft. You can then attach your spinning disc to the eraser. It's best not to glue anything on to the motor shaft as it could jam the motor and makes it harder to reuse.

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	• The crocodile clips are used to easily connect the batteries to the motor. If you are going to keep the zoetrope for a longer period, you may want to solder the battery to the motor. You could even include a switch so you can easily turn the zoetrope on and off! • Using a container to hold up your motor can help your disc spin more easily and can also be used to contain your electronics. You can investigate something sturdier than a paper cup if you want to make a spinning platform that lasts longer. • If you decide to use a record turntable or other spinning platform that is common to all groups, you can skip this step and focus more on the animation.
Part 2: Creating the animation	Create an animation using a range of different materials on your spinning disc. You will need to setup a number of "frames" around your disc that will animate. Just like in film animation, each object should move a small amount from the last to create the illusion of movement. For a smooth animation, the participants should also think about how their animation will loop around the disc. This challenge can be quite open ended, with a large range of materials possible to create the animation. There are no rules or guidelines that are necessary to follow to create the animation, however if you think this scope may be too broad, you could limit the challenge in the following ways: • Ask your students to start by animating a simple pattern with just one object such as a paper clip, pipe cleaner or rolling dice • Limit the scope by giving your students a theme to animate e.g. sports or animals • Limit the types of materials available to your students e.g. they can only use pipe cleaners and hot glue Once some students think they have a complete animation, you can introduce part 3. This allows students to then test and refine their animation. Students should cycle between testing and refining for a while to create a high quality animation
Part 3: Introducing the strobe light *Testing and refining the animation*	You will need to make sure that the animation testing takes place in a dark space, otherwise the animation effect is difficult to see. Rooms without windows work well, such as store rooms. Alternatively, you may be able to create mini dark spaces in cardboard boxes. Once students have an animation to test, you should introduce the strobe light. You may wish to use a commercial strobe light, but a good simple adjustable light (especially for early testing) is a mobile phone LED. *The following instructions are based on the Android Strobily app, but you can use many apps on both Android and Apple devices.*

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	Open the Strobily app and select the strobe function. Within this function, there are two main variables that can be changed: **Strobe rate:** The strobe rate is adjusted using the toggle on the right hand side of the screen. The rate is given in hertz, which simply indicates the number of flashes per second. You can fine tune this rate in small increments. Adjust the rate, so that the objects start to look animated. Can you make the objects appear to stay in one spot? **Strobe duration:** If you're using the "Strobily" app, you can also change how long the light stays on with each flash. This setting is under "Duty cycle" and you can change the length of the flash as a percentage. This setting is a fine balancing act- too long and the objects appear blurred; too short and the objects are too dark! Experiment with the strobe duration and determine what percentage allows you to see the object most clearly. Students should experiment and change the two variables to try and strengthen the illusion of their animation. From our experience running workshops, generally the best settings are: • Strobe rate: around 6Hz • Strobe duration: 0% (i.e. the shortest flash possible!)
Extension questions	Consider the following questions to help prompt extension and further engagement of your students: • Can you create a multi-level or tiered animation? • Can you create animation with more "frames"? • Can you create objects to be animated that can be easily and repeatedly changed?
Wrap-up	Each group demonstrates/tests their 3D zoetrope for the group and reflects on: • How they went about designing and testing the animation? • What worked well, what didn't work well? • How would you improve the animation given more time or resources?

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Possible extensions

The following extensions discuss how this activity could be applied to many different subject areas.

Mathematics

You could explore the mathematics behind the 3D zoetrope to try and create a stronger animation effect. You can also use it to explore the theoretical values for the strobe and spin rate to see whether this works in real life. Some questions to ask include:

- At what rate is the spinning disc rotating?
- How many "frames" or "objects" do you have on your disc?
- What rate do you need the strobe to flash in order to:
  - Make the objects appear to animate "on the spot"?
  - Make the objects move forwards?
  - Make the objects move backward?
- Can you describe why we see or don't see these "movement" effects?

Biology

Investigate how the human visual system (eyes and brain) interpret movement and animation from static, fast moving frames. The middle temporal gyrus located in the visual cortex, processes motion and creates the phi phenomenon (where the brain edits individual frames together to create the sensation of movement).

The Arts (Media and Visual Arts)

You could explore other animation techniques that use different ways to create moving images. These include:

- Simple flip books: http://www.raftbayarea.org/readpdf?isid=280
- A 2D zoetrope, similar to the original cylindrical zoetrope using simple everyday materials. Instructions can be found at Resource Area For Teaching (RAFT) website
- 3d printed phenakistoscope from Dan
- A version of the phenakistoscope using a bit more technology to create a very strong effect. Arduinos are used to time a spinning motor and flashing LEDs http://playmodes.com/web/phenakistoscope/

Technologies (Design and Technologies)

Another option is to 3D print objects to animate. For some inspiration, search for "zoetrope" on Thingiverse to see a few ideas.

You can also use computers or tablet apps to create objects that you can 3D print for animation. The design programs 123D Design and 123D Sculpt are both easy to use applications that allow you to create 3D objects on your computer (Windows and Mac) or iPad and then export them as objects to 3D

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print. 123D Design uses regular shapes to create designs, while 123D Sculpt allows you to work with objects more like clay. The latter program also allows you to "pose" figures, which can be quite useful to animate them for the 3D zoetrope.

Both of these programs come from Autodesk3D and can be downloaded from the 123D website or the App Store.

STEAM

You could use the 3D zoetrope to have students create animated models of cyclic processes in other areas of science. Through this process students will use artistic skill and creativity to communicate scientific concepts. Some ideas are:

- Seasonal activity
- Lunar eclipses or the lunar cycle
- The water cycle, carbon cycle, nitrogen cycle or phosphorus cycle
- Cell division, mitosis, DNA replication or asexual reproduction
- Nervous and endocrine systems signaling
- Reproductive stages of different animals e.g. tadpoles to frogs

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Curriculum Links

Australian Curriculum: Science

Science Enquiry Skills Strand

This workshop's activities relates to Science Inquiry Skills across all years by encouraging:

- Questioning and predicting
- Planning and conducting
- Processing and analysing data and information
- Evaluating
- Communicating

Science as a Human Endeavour Strand

If this workshop is extended to research and discuss the many different techniques used to create animations and explore how moving pictures were developed in an historical context through to modern animation, it links to the Science as a Human Endeavour Strand.

Science Understanding Strand

This activity links to Physical sciences units in the Science Understanding Strand. The activity can be used to investigate physical forces, properties of materials and energy conservation and transfer,the effects of objects in motion.

Year 7 Physical sciences

Change to an object's motion is caused by unbalanced forces acting on the object (ACSSU117)

Year 8 Physical sciences

Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems (ACSSU155)

Year 10 Physical sciences

Energy conservation in a system can be explained by describing energy transfers and transformations (ACSSU190)

The motion of objects can be described and predicted using the laws of physics (ACSSU229)

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Australian Curriculum: Design and Technology

Knowledge and Understanding Strand

Years 7 and 8

Analyse how motion, force and energy are used to manipulate and control electromechanical systems when designing simple, engineering solutions (ACTDEK031)
Analyse ways to produce designed solutions through selecting and combining characteristics and properties of materials, systems, components, tools and equipment (ACTDEK034)

Years 9 and Year 10

Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions (ACTDEK043)
Investigate and make judgments on how the characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions (ACTDEK046)
Investigate and make judgments, within a range of technologies specialisations, on how technologies can be combined to create designed solutions (ACTDEK047)

Processes and Production Skills Strand

Years 7 and 8

Critique needs or opportunities for designing and investigate, analyse and select from a range of materials, components, tools, equipment and processes to develop design ideas (ACTDEP035)
Generate, develop, test and communicate design ideas, plans and processes for various audiences using appropriate technical terms and technologies including graphical representation techniques (ACTDEP036)
Effectively and safely use a broad range of materials, components, tools, equipment and techniques to make designed solutions (ACTDEP037)

Years 9 and 10

Critique needs or opportunities to develop design briefs and investigate and select an increasingly sophisticated range of materials, systems, components, tools and equipment to develop design ideas (ACTDEP048)
Apply design thinking, creativity, innovation and enterprise skills to develop, modify and communicate design ideas of increasing sophistication (ACTDEP049)