Contents

Introduction

The following report details two scientific investigations suitable for a year 9 class. The investigations are centred on a contemporary issue, relevant to the local North Queensland context. Australian Curriculum links and descriptions of learning outcomes are included. The Temperature Control investigation was performed for proof of concept and as a tool for reflective learning; data is recorded and discussed in relation to learning goals, a conclusion on the efficacy of the overall investigation is also given.

The Issue

Global warming is a serious international issue with many social, economic and environmental repercussions if left unaddressed. While some contention exists surrounding the causes of global warming, evidence indicates that energy consumption and the release of carbon dioxide (CO^2) through the burning of fossil fuels, play a significant role (World Wide Fund for Nature, 2018; Houghton, 2009). The impact of global warming can include; significant polar ice melts, raising sea levels, ocean acidification, and more frequent and extreme weather events (Australian Government, 2020).

Among the most frequent and damaging extreme weather events and natural disasters affecting Australia are Bushfires and Heatwaves (Australian Government, 2020). Heatwaves in particular have claimed more lives than any other natural hazard in Australia (Coates, Haynes, O'Brien, McAneney, & De Oliveira, 2014). A study from Cowan, et al. (2014) used climate modelling techniques to predict heat wave patterns in Australia for the remainder of the 21st century. The mean projected outcome shows that northern tropical regions will experience the largest increase in heat wave frequency and duration (Cowan, et al., 2014). This information, coupled with increasingly longer, hotter seasons, can lead Australians towards consuming more energy in cooling their residents and businesses.

Approximately 40% of energy used in the home is directed towards heating and/or cooling (Commonwealth of Australia, 2020), for commercial buildings and office spaces, this figure is approximately 30% (Commonwealth of Australia, 2020). Over 90% of the Energy consumed in Australia is generated from the burning of fossil fuels (Commonwealth of Australia, 2019). Given that the burning of fossil fuels is heavily implicated in global warming, it is clear that a cyclic effect is being generated. As temperature rise, more energy is consumed in cooling, which in turn increases the demand for fossil fuel-based electricity in Australia and thus further contributes to raising temperatures.

The local context

The context for the following investigations is a city in North Queensland. This area is described as having a dry tropical climate; a prolonged dry season punctuated by an intermittent wet season (Bureau of Meteorology, 2020). While the city is considered an urban location, it services many neighbouring rural and remote communities, and thus has heavy agricultural and industrial influences (Townsville City Council, 2020). Recently, the region has experienced controversy regarding the approval for construction of the new Adani Carmichael coal mine. The controversy stems from the weighing of economic benefits, from the creation of jobs, against environmental costs, such as immediate damage to local flora and fauna and contribution to climate change and global warming.

Relevance to Cohort

The aforementioned controversy poses a dilemma for local students. Many of the students' families rely on the mining and related industries for their livelihood; however, students are also being regarded as the future custodians of the planet, and local environment. The present cohort are year 9 students, enrolled in science, mathematics and technology. As such, they are encouraged to engage with cross-curriculum priorities in order to expand their world views and help develop the tools and language to better engage with and understand the wider community (ACARA, 2014). Specifically, this topic is directly related to the sustainability priority, in which students are learning to appreciate and respect competing world views regarding ecosystems, social justice and community needs, as well as develop systems of thinking necessary for the design and creation of a more equitable and sustainable future (ACARA, 2014; Barr, et al., 2008).

Additionally, this topic will draw on year level appropriate concepts, as set out by the Australian Curriculum, Assessment and Reporting Authority (ACARA). Specifically, students will be asked to apply their science, mathematics and technology learning to investigate solutions for minimising energy consumption. This can be best observed in the below concept map (figure 1).

Assumed Prior Learning

The present cohort is assumed to have successfully completed year 8 science, mathematics and technology subjects, demonstrating a sound achievement standard in each curriculum. Specifically, students are able to describe matter in terms of the arrangement and motion of particles and explain the different forms energy can take, and how it is transformed within and transferred between systems. Students are also assumed to have been studying year 9 science for two semesters. As such, they are now familiar with thermal energy transfer and the wave and particle theories of electromagnetic energy.

Curriculum Content Description

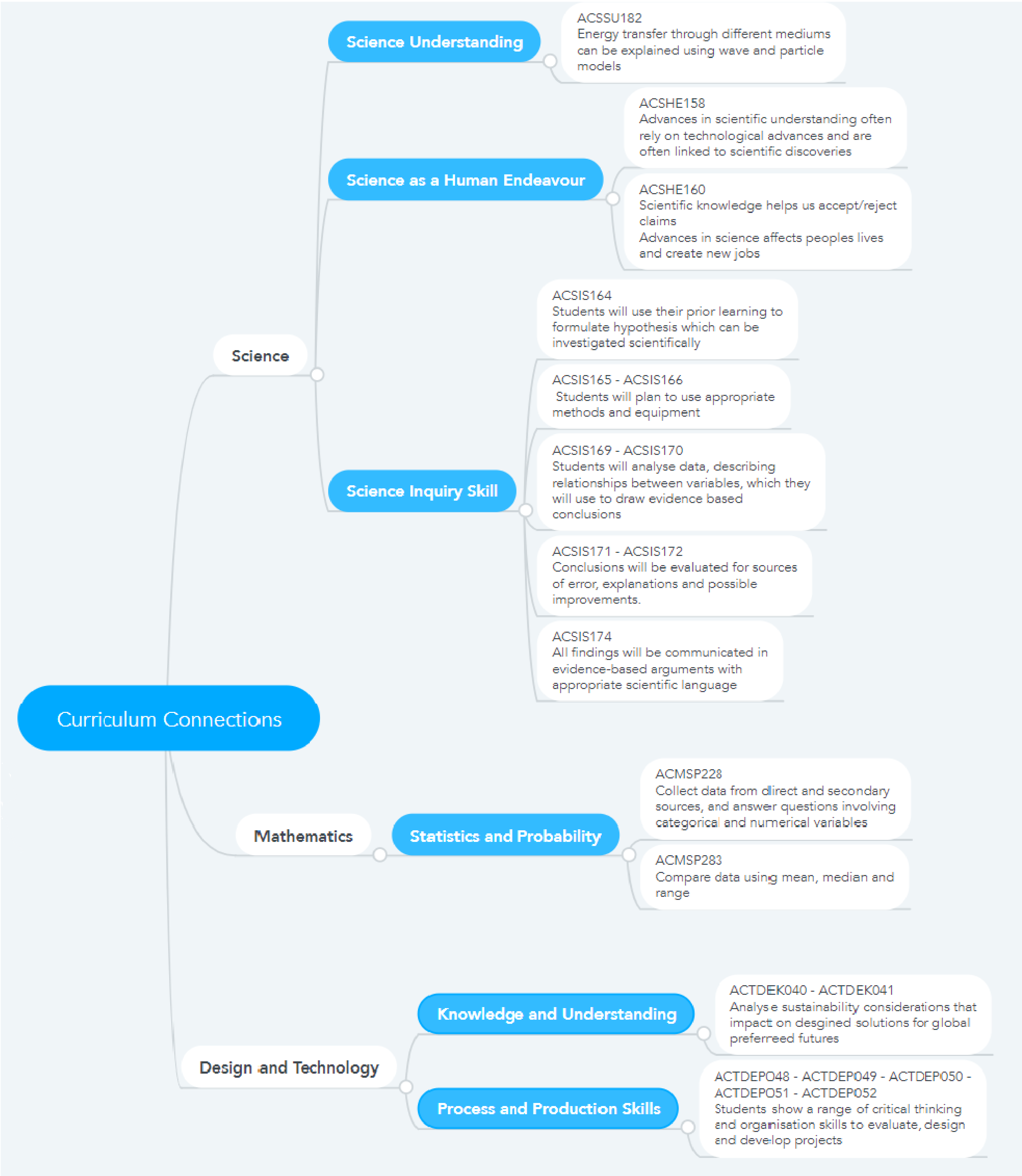


Figure 1: Curriculum Concept Map

Investigation 1: Solar Device

Relevance to Issue

This Investigation requires students to work in small groups and develop a solar powered device. The device must (a) utilise energy transfer theory, (b) have a justifiable application in the household, and (c) be accompanied with a schema detailing energy flow from the Sun. The aim of the device is to assist in reducing reliance on non-renewable energy sources, thereby reducing household contributions to global warming and climate change.

Engagement and Motivation

Inquiry-based learning is the key strategy used to facilitate student engagement with and motivation for science learning and participation with this investigation. In short, students are provided a problem/scenario in which they are challenged to apply fundamental science concepts in constructing a contextually relevant solution (Goodrum, 2019). This investigation is not only open-ended, it also requires students to work in small groups (2-3 students per group). Therefore, it utilises hands on learning for engagement and enhancing understanding, as well as conceptual refinement through group discussion (Goodrum, 2019).

Learning Goals and Success Criteria

Students are learning about natural thermal energy transfer via conduction, convection and radiation. Students are also learning how thermal solar energy is harnessed and utilised in the real-world context for day to day living.

Students will demonstrate their learning by selecting appropriate materials and developing designs based on scientific understanding, to build a solar powered device. The device will utilise one or more of the energy transfer methods in its operation. Students will also be able to describe this operation through the use of a detailed schema which includes a correctly labelled energy flow diagram. Finally, students will provide evidence of the efficacy of their device by collecting and analysing data.

Working Scientifically

Note; as this investigation is open-ended, students' specific approaches can vary. However, below is a general model of the science inquiry skills utilised in this investigation. This model is derived from the Australian Curriculum (2014) and supported by arguments from Dawson, Venville, and Donovan (2013).

Questioning and Predicting

Students pose questions about how different household appliances/tools work to utilise/produce heat. Students make predictions about the effectiveness of various materials and methods for harnessing solar energy in replicating the effects of these appliances/tools.

Planning and Conducting

Students work in groups to discuss and refine their designs and investigation strategies. Students also plan measurement strategies for testing the efficacy of their devices. They will make observations and record appropriate data.

Processing and Analysing Data and Information

Students tabulate the data from their recordings. Observations and calculations are made of the data in order to compare and contrast the patterns and results of different variables on their devices. Conclusions are made based on understanding of scientific concepts.

Evaluating

Students make judgements on the reliability and validity of their investigations. They identify possible sources for error as well as potential for improvements to their design.

Communicating

Students use a variety of methods to explain their designs and the results achieved. This can be achieved through the schematic of energy flow, as well as by presenting collected data as a table or graph.

Student Management and Safety Considerations

This investigation is designed to be conducted during a mixture of class and home time. Preliminary learning of related science contexts occurs in the classroom, and will require adequate classroom management. However, students are encouraged to work closely with their group members for the majority of the project. In this case, class time should be offered for the teacher to answer questions, assess designs and provide general guidance. In this way, the teacher facilitates student-centred, inquiry-based learning (Panasan & Nuangchalerm, 2010).

Investigation 2: Temperature Control

Relevance to Issue

This investigation addresses the reliance on fossil fuels for residential air conditioning. Students are required to investigate a range of methods and materials which can be implemented in maintaining consistent temperatures inside the home. Students work in groups to create two model houses, the first being a pilot design, the second being an improvement on the first. The goal of the investigation is to produce a final design which efficiently and effectively maintains a cooler internal temperature, compared to the outside weather. Students are also challenged to use recycled, low cost materials.

Engagement and Motivation

This investigation also utilises inquiry-based learning to capture student engagement and motivation (Goodrum, 2019; Panasan & Nuangchalerm, 2010). Similar to the Solar Device investigation, the present task is open-ended, requires group work and features a main hands-on component.

Learning Goals and Success Criteria

Similar to the previous investigation, students are learning about natural thermal energy transfer via conduction, convection and radiation. Students are also learning how different materials can facilitate/mitigate energy transfer rates, based on their properties of thermal resistance.

Students will display their learning by constructing a model house, justifying their design and material considerations using appropriate scientific terminology and theories of energy transfer. Students will also show their comprehension of science inquiry skills by collecting and analysing data, and presenting their findings in conjunction with possible sources of error and recommendations for improvement. Finally, students will improve on their design and create an 'up-graded' model.

Working Scientifically

Note that this investigation was carried out in the home context, by a single researcher. Outlined below is the procedure used, which aligns with the 'working scientifically' structure. This procedure closely mirrors that which would be used in the school context.

Questioning and Predicting

Key concepts considered for this task include the understanding of heat as thermal energy, and the transfer of this energy through conduction, convection and radiation. Thermal conduction relates to the physical contact between excited, fast moving particles of a higher energy state, with slower moving particles of a lower energy state. The collision between these particles transfers heat/kinetic energy at the molecular level. Convection refers to the movement of volumes of (liquid or gaseous) particles. For example, as air is heated by an energy source, its density lowers and it begins to rise. Cooler air is displaced and moves down towards the energy source to be heated. This process is cyclic and explains how thermal energy is transferred within large volumes of fluids. Finally, Radiation (Electro Magnetic Radiation) refers to propagating fields of electromagnetic radiant energy, originating from the acceleration of charged particles. This energy travels through space and can be explained as either waves of specified frequency and wavelength, or as photons. Radiation excites particles within an object and can explain heat transfer over long distances.

It is hypothesised that in order to create model houses which maintain cooler internal temperatures, it should be constructed of materials which resist thermal conduction and thermal radiation. Designs should also account for thermal convection occurring both in and outside the building. Specifically, houses created with insulating layers and painted in light colours should feature a lower thermal energy transfer rate and remain cooler throughout the day.

Planning, Conducting and Safety Considerations

Pilot Design. In order to reduce thermal conduction, cardboard was chosen as the base material. Cardboard features two flat layers of kraft paper surrounding a third corrugated layer. The corrugated layer helps separate the inner and outer layer with trapped air, reducing the energy transfer rate towards the inside of the home. Additionally, the house was painted white in order to reduce heating via radiation. Light, 'shiny' colours are more effective at reflecting thermal radiation, rather than absorbing it.

Upgraded Design. This model was developed after the construction and analysis of the pilot design. The upgraded design featured ventilation at the top and bottom of the walls. The house was placed so that the vents aligned with the average wind direction. It was theorised that ventilation at the top of the wall would allow hot air to escape the house, while the ventilation at the bottom of the wall would facilitate the flow of cool air into the house. The house was also raised off ground level to allow ventilation along the floor.

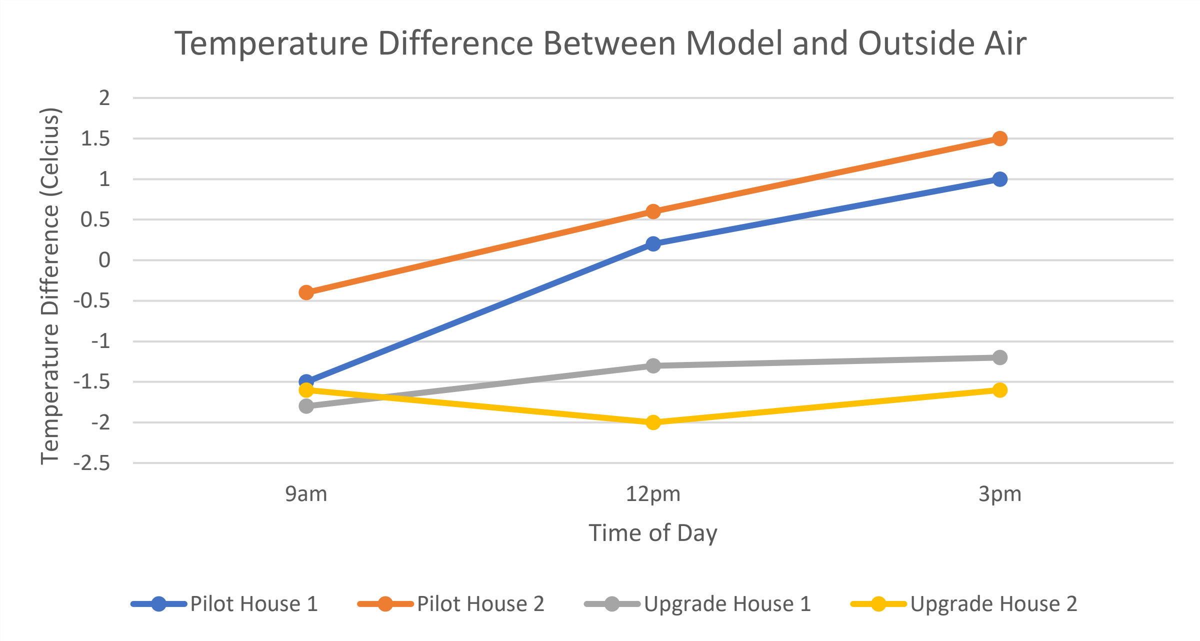
Measurements. Air temperature measurements will be taken with a digital thermometer. A small hole will be made in the side of the house to allow the thermometer to make a reading, whilst minimising extraneous heat transfer from opening the models. Recordings of both outside air temperature and house models' internal temperatures will be taken three times a day at 9am, 12pm and 3pm (these times coincide with school hours). Measurements will be taken over two days to create an average result. The results for the two designs are discussed below. Appendix A provides images of the two designs.

Safety Considerations. During the construction of the models, cutting tools pose a potential laceration concern, the paint used may be harmful if it makes contact with the eyes or is accidently consumed. Additionally, as much of the measurements take place outside, there is a heat/burn risk from the sun. Accordingly, participants conducting this investigation should wear personal protective equipment (gloves, safety glasses, face mask) when cutting or using spray paint. Safety precautions should also include the use of a hat and sunscreen to minimise risk of sunburns or heat illness.

Processing and Analysing

Pilot House Temperature Tests			
Day 1			
	Time of Measurement		
	9am	**12pm**	**3pm**
House Temperature	20.5	25.8	26.6
Outside Temperature	21.5	25.6	25.6
Temperature Difference	-1.5	0.2	1
Day 2			
	Time of Measurement		
	9am	**12pm**	**3pm**
House Temperature	22.5	26.4	27.4
Outside Temperature	22.9	25.8	25.9
Temperature Difference	-0.4	0.6	1.5

Upgraded House Temperature Tests			
Day 1			
	Time of Measurement		
	9am	**12pm**	**3pm**
House Temperature	20.1	23.9	23.1
Outside Temperature	21.9	25.2	24.3
Temperature Difference	-1.8	-1.3	-1.2
Day 2			
	Time of Measurement		
	9am	**12pm**	**3pm**
House Temperature	20.0	24.5	24.9
Outside Temperature	21.6	26.5	26.5
Temperature Difference	-1.6	-2	-1.6



Both trials for the pilot house shows a negative difference in temperature at 9am. The temperature changes to a positive difference at 12pm and 3pm. Both trials for the upgraded house show negative temperature differences throughout the day. All temperature measurements for the upgraded house were less than for the pilot.

Evaluating and Communicating

Over the two trials, the pilot model was slightly cooler than outside air temperature at the beginning of the day. However, as the day progressed, it maintained higher than average temperatures. This was likely due to trapped hot air inside the house. The insulating properties of the cardboard worked to slow the heat transfer to the inside of the house. However, once the inside air temperature eventually rose, the heat was insulated within the house. The house was unable to cool throughout the day. The 'upgraded' design addressed the ventilation issue, allowing for more air flow inside and around the model. The results showed the house was able to maintain slightly cooler temperatures compared to outside. The position of the vents likely allowed hot air to escape while facilitating the influx of cool air. Additionally, raising the house allowed increased air flow along more surface area. This assisted with cooling the walls. Finally, by angling the house, it was possible to reduce sun exposure whilst facilitating air flow. The implications for North Queensland housing design are that, through careful engineering and consideration of the natural weather patterns and environment, reliance on heating/cooling technologies can be reduced.

Improvements could be made by adjusting the material of the roof to one with greater reflective properties. Additionally, increasing the insulation quality/thickness may also help reduce inside temperatures. More accurate results could be obtained by taking more frequent, hourly measurements. Additional trials would assist in developing a more accurate average temperature difference. Testing both models on the same day would increase measurement accuracy by comparing the houses to the same weather conditions.

Critique

This investigation requires students to apply their scientific investigative skills, theoretical understanding and knowledge about materials and design to create a model house. Students considered their understanding of energy transfer in their pilot designs, then, using the investigative process, critically analyse their models and re-address their conceptual understandings in order to make improvements. Students collected data, tabulated and created graphical displays using digital technologies. This data was then subject to simple mathematical calculations and the results interpreted to provide contextually significant considerations.

Difficulties for students may be in the sourcing of materials, particular for those with financial difficulties. Students were encouraged to use affordable/recycled materials; however, this may affect the quality of their designs. Regardless, success criteria and assessment should be based on the student's demonstration of their understanding of thermal energy transfer, along with justified design decisions.

In short, this project was simple, easy to conduct at home or in the school environment, and likely serves as an excellent learning activity.

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Appendix A