SIEMENS

Scheme of Work

Overall learning objectives

- Interpret data presented in various ways to provide evidence to evaluate a system and support a cost benefit analysis.
- Apply concepts of energy transfer and sustainability to understand and evaluate a system.
- Apply concepts of efficiency and streamlining to develop ideas about how a system can be improved and made more sustainable.
- Produce and modify designs to meet a design brief and study solutions to learn how other designers have manipulated materials to meet a design brief.

Overall learning outcomes

- A clear explanation of the key features of a Greenpower Challenge car.
- Developed ideas about the design and production of a suitable body.
- Production of a well-structured and effectively argued case for involvement in the Greenpower Challenge. (Note: if it is decided not to encourage students to contemplate an entry for the Greenpower Challenge then an alternative outcome could be: "Production of a well-structured and effectively argued case for using a rechargeable vehicle for practical everyday use.")

Curriculum Learning Objectives

Students should be able to:

Mathematics:

- Identify the mathematical aspects of a situation or problem.
- Choose between representations.
- Simplify the situation or problem in order to represent it mathematically.
- Use appropriate variables, symbols, diagrams and models, select mathematical information, methods and tools to use.

Science:

- Explore how the creative application of scientific ideas can bring about technological developments and consequent changes in the way people think and behave.
- Share developments and common understanding across disciplines and boundaries.
- Explain that forces are interactions between objects and that they can affect their shape and motion.

Technology:

- Apply knowledge of materials and production processes to design products and produce practical solutions that are relevant and fit for purpose.
- Make links between principles of good design, existing solutions and technological knowledge to develop innovative products and processes.
- Explore the impact of ideas, design decisions and technological advances and how these provide opportunities for new design solutions.

NOTE: Siemens Solid Edge High School Edition software provides schools with industry leading CAD technology enabling your students to design, capture, evaluate, and develop their ideas. Students can focus on learning engineering principles; all types of projects from machines to stylised products can be created. This free download is available to any Secondary School and provides the school with a perpetual site license. Usage of the Solid Edge High School Edition is intended for academic course work, so files cannot be opened in commercial versions, and 2D drawings are watermarked. To obtain the free academic site license a teacher or school official simply needs to register at **www.siemens.com/plm/solid-edge-highschool**.

Your students can also obtain their own free copy of Solid Edge for use outside the classroom in support of their studies by registering at **www.siemens.com/plm/solid-edge-student**.

The Solid Edge software is easy to learn and use and has in-built introductory 'Getting started' tutorials. Addition tutorials and educational content can be obtained from the Solid Edge Academic Resource Center:
www.plm.automation.siemens.com/en_us/about_us/goplm/arc/se-academic/educator/index.shtml

Introduction

Students are introduced to the Greenpower Challenge and the feasibility study they will be developing.

The Greenpower Challenge, an initiative of The Greenpower Education Trust, is supported by Siemens and promotes sustainable engineering to young people. The Greenpower Challenge is currently running in the following countries;

- United Kingdom - www.greenpower.co.uk
- USA - www.greenpowerusa.net
- China - www.greenpowerchina.com
- Poland - www.greenpowerpolska.pl
- South Africa - www.greenpowerza.co.za

Narrative: this episode is intended to introduce the context to the students and to make them familiar with the aspects of the study they will be developing and presenting.

Learning objectives

- Understand the scenario being presented and the challenge for this topic.

Learning activities

1. Start off by showing students pictures of entrants in the Greenpower Challenge and ask for suggestions as to what the activity might be about.
2. Then explain that it is a competition that many schools enter, that it involves students working as a team to design and build a-single-seat electric car, and then competing in head-to-head races. Explain that the cars are powered by rechargeable batteries (rather larger and more powerful than the kind of battery that would be used in a camera or mobile phone), that the cars are similar in terms of technical design and that to win, a team's car has to travel the furthest distance in the allotted time has to keep going the longest (rather than to be the fastest).
3. Introduce the scenario by saying that the Head Teacher has heard about the Greenpower Challenge and thinks that this is something that some students would be interested in competing in. Explain that the Head Teacher knows it will involve constructing a battery powered car from a kit of parts, or design a car from scratch and entering it in a race. The Head Teacher knows success in the race will depend not so much on maximising speed as endurance and range, so energy efficiency and aerodynamic effectiveness will be important. Explain that the Head Teacher has asked for a feasibility study to make the case to the school's governors, explaining the project and justifying the money to be spent on the kit of parts to build the car.
4. Say that this topic will involve students in finding out more about the Greenpower Challenge, identifying key features and preparing a presentation to justify the school's involvement.
5. This topic consists of three aspects. A decision will need to have been made by the teacher as to whether all students will do the three aspects or whether students will be divided into teams and then each aspect undertaken by a different sub-group. In this case the sub-groups would each contribute a particular component to the final presentation.

Outcomes

- Understanding and appreciation of the Greenpower Challenge to be met in this topic.

Investigate

In this episode students study how an electric car works, the components of the system and the function of each component. Students further their understanding, using a systems approach, of how a battery car works, how the charge and discharge cycles affect performance and how to get the best performance from such a vehicle.

Additional resources required

- Wind up torch (Flashlight)

Learning objectives

- Understand the charge and discharge cycles of a battery powered device.
- Consider the advantages and disadvantages of battery power.
- Understand what is meant by the capacity of a battery and how it is affected by efficiency.
- To apply ideas about energy transfer to understand how a car design might be made more efficient.

Learning activities

1. **Show students a wind up torch (flashlight) and ask them for an explanation as to how it works. Draw out contributions and develop the following points:**
   a) There is a charge process, which involves the handle and the battery. In this process, energy is transferred from the person, via the hand crank, to the battery where it is stored.
   b) There is a discharge process, which involves the battery and the bulb. In this process the energy is transferred from the battery to the bulb, where it is transferred to the environment as light and heat. (See activity 7 to further explore the law of conservation energy.)
2. **Ask students to work in small groups and consider these questions:**
   a) What would happen if the bulb was replaced with one that carried more current?
   b) What would happen if the battery was replaced with a larger one that held more charge? (Assume bulb is the original one.)
   c) Could you power a radio this way? A toy car? An electric drill?
3. **Take feedback and draw out the points that the larger the battery, the more charge it will hold and the longer it will run something for. The more current the output uses, the faster it will run down. Such a mechanism is well suited to hand held or portable devices that use relatively small amounts of current. Current flows around a circuit and is measured in amps. It is made to flow by the potential difference, sometimes referred to as voltage, which is measured in volts. The drill uses more current so will be less successful. The car needs to move the power source which will limit its effectiveness.**
4. **Ask them to suggest how energy is transferred as the torch is being used. Draw out that when the torch is being used this energy is transferred as light and heat to the surroundings.**
5. **Now show a picture of a Greenpower car, explain that it is battery powered and ask students to identify the energy transfers taking place. Draw out that some of these are useful, such as motion, and others are not useful, such as heat from friction in moving parts. Use the student support sheet 'Thinking about energy' to reinforce these points and use a 'Sankey' diagram to represent the transfer of energy to useful and wasteful outputs.**
6. **Explain that with a Greenpower car the charge cycle involves rechargeable batteries being charged from the mains, and the discharge cycle involves the batteries powering the motors. Say that the discharge cycle is important to study – going for a high speed involves draining the batteries quickly.**

Learning activities, cont'd

7. **Explain that the capacity of a battery is measured in ampere hours. The MRT35T battery used in the Greenpower cars has a capacity of 35Ahr (ampere hours) measured at the 20 hour rate. This means that the battery will deliver 1.75A over a 20 hour period at 200C. The efficiency of a battery is lower at higher discharge rates. For this reason, if the battery is discharged at 17.5A it will be discharged well before the end of the Greenpower Formula 24 race (90 minutes). In other words, a Greenpower car designed purely for high speed will have run out of energy long before the end of the race.**

Outcomes

- To be able to explain the difference between the charge and discharge cycles.
- Identify how energy is being transferred in a battery powered car and the need to reduce wasteful transfers.
- Understand why discharging a battery quickly may not be an efficient use of energy.

Communicate

Students draw upon a range of data provided in their research and produce a diagrammatical representation of key features, peer-assessed with regard to the clarity and effectiveness of communication.

In this episode students draw together the key points from the previous episode and consider how to communicate them effectively. They need to decide on the most important features and how these can be depicted. Groups will peer-assess the work with reference to how well this has been done.

Learning objectives

- To identify key features of an electric vehicle's power system.
- To represent those in a clear and effective way with reference to audience and purpose.
- To provide quality feedback to peers.

Learning activities

1. **Students should consider the important features of the electric car system and how this can be best represented. Explain that they are not expected to communicate all of the information they have found but to focus on the key features and to consider how well these have been represented. Remind the students that the audience for the presentation will be the school governors and the purpose will be to convince them to invest in the school's entry into the Greenpower Challenge. Say that the finished pieces will be peer assessed against the following (or similar) criteria:**
   a) Relevant information identified and selected.
   b) Information presented effectively and accurately using text and graphics.
   c) Clarity of key features of an electric car.
   d) Identify how the Greenpower Challenge supports the STEM subjects
2. **They should be encouraged to do a rough draft of their presentation first and compare it with the criteria before embarking on the main piece of work.**
3. **Once satisfied that the work meets the criteria, students can then complete the main piece.**
4. **Work should be displayed and peer-assessed.**

Outcomes

- To have collaborated in designing and producing a clear and effective visual representation of an electric car's power system, suitable for audience and purpose.
- To have created a concise and effective presentation highlighting the learning benefits of the Greenpower Challenge
- To have peer-assessed similar work.

Develop

Students consider how scientific concepts such as forces and energy play a role in understanding and developing the design of cars.

This episode provides an opportunity for students to develop their understanding of the key concepts of forces and energy in the context of car design. The way in which this is used will depend significantly upon students' prior knowledge and understanding of these concepts.

Additional resources required

- Object e.g. ball
- Surface e.g. Bench
- Student support sheet 'Analysing the forces on a car'

Learning objectives

- To understand how the concept of forces can be applied to understanding the motion of a car.
- To apply ideas about balanced and unbalanced forces to explain motion.

Learning activities

1. **Take an object such as a ball, hold it in the air and allow it to fall. Ask students to suggest what forces are acting on the ball, the direction in which they are acting and what is happening to the speed of the ball. Draw out from ideas offered that:**
   a) There is a force – weight – vertically downwards, caused by gravity, which may be used to reinforce students' understanding of kinetic and potential energy.
   b) There is another force – air resistance – vertically upwards (if students are unconvinced by this, drop a sheet of paper, first flat and then crumpled up; students should see that the weight hasn't altered but the air resistance has, changing the motion).
   c) The ball increases in speed – it accelerates – as weight is greater than air resistance. Emphasise the point that unbalanced forces cause acceleration, and like a) may be used to reinforce students' understanding of kinetic and potential energy.

2. **Now put the ball on a stool on the bench (or similar arrangement) so that it is easily seen and stationary. Ask students to suggest the forces now acting and to describe the motion of the ball. Draw out from ideas that:**
   a) Weight is acting, as before.
   b) The ball is at rest.
   c) There is a reaction-force acting upwards. This is the point that some students will struggle with and may need to discuss further. You might focus discussion by asking questions such as:
      i) What would happen if instead of supporting the ball by a stool we tried to use very thin paper, such as a single sheet of tissue paper, i.e. that couldn't apply the reaction force?
      ii) If you stand on the ground, the ground is applying a reaction force to you. If you tried standing on something that couldn't provide that force (soft sand, mud, foam, balls in a ball pool) you would sink into it.
      iii) If you use a ping pong pall and an air blower you can support the ball in mid-air. The air is providing an upwards force.

3. **The key point here is that an object that is stationary doesn't necessarily have no forces acting on it. It means that the forces are balanced. Be careful with the phrasing of conclusions from this though: whereas it is true to say that the forces acting on a stationary object are balanced, it is not true to say that if the forces on an object are balanced it is necessarily at rest (balanced forces result in zero acceleration, i.e. steady speed in a straight line; that speed may be zero).**

Learning activities, cont'd

4. **Now show the students something that moves at a steady speed. A good way of doing this is to use something such as a toy parachutist, which clearly falls at a steady speed (after the initial acceleration); an alternative is a linear air track. Avoid situations with motion other than horizontal or vertical. Again ask students to identify forces and motion. Draw out that there is the force of weight acting vertically down, air resistance acting vertically upwards and that the speed is steady because these balance out. Make the general point that if forces are balanced the result is steady speed.**

5. **Introduce the idea of applying this to a vehicle such as the Greenpower car. Use the student support sheet 'Analysing the forces on a car' provided, which presents similar questions with the car as a context. Allow students the opportunity to develop responses, take feedback and reinforce the points above. Explain that the reason this is important is that understanding and minimising the forces opposing motion is critical to an effective design.**

Outcomes

- Students being able to explain how unbalanced forces cause an object to accelerate and balanced forces result in a steady speed.
- Students identify forces that oppose motion and understand the importance of reducing these.

Identify

Students look at the bodywork designed by schools participating in the Greenpower Challenge and identify the design factors they are working to.

This episode is intended to provide students with ideas about suitable body designs for a Greenpower Challenge car. This is designed to get students thinking about key design factors and working from the designs of others to develop a list of criteria. This then provides a basis for the next episode, which is to use those criteria to develop their own basis for the design of the body.

Learning objectives

- To understand how streamlining can reduce drag and increase energy efficiency of a vehicle.
- To identify the design features that will reduce drag in a car body.

Additional resources required

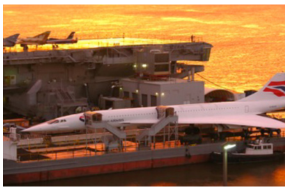
- Pictures of marine animals
- Designs for Greenpower Challenge cars
- Student support sheet 'Investigating streamlining and drag'
- Student support sheet 'Views of the Greenpower Challenge kit car'
- Materials for sketches i.e. paper, pens and pencils
- Formula 24 kit car can be downloaded from www.siemens.com/plm/academic/greenpower
- Optional: video clips with drag cars deploying drag chutes

Learning activities

1. **Show students pictures of various streamlined designs. These might include:**

   a) Sports car b) Speedboat c) Railway locomotive d) Concorde aircraft



2. **Ask students to suggest why the designers of those means of transport designed them the way they did. Draw out that it was partly to do with appearance but also to do with streamlining. Explain that objects moving through the air have to displace the air. If they can slip through the air with less resistance their movement will require less energy.**

3. **Show students pictures of marine animals. These might include:**

   a) Shark b) Eel c) Minnow d) Seal

4. **Ask students to suggest how movement through water is different to movement through air. Draw out that it is the same idea and that a streamlined shape reduces energy loss.**

5. **If desired, students could be shown video clips with drag cars deploying drag chutes. The cars are designed to be able to accelerate quickly (with very little drag) but the chutes slow them down (by having a lot of drag).**

Learning activities, cont'd

6. **Now show students pictures of designs for Greenpower Challenge cars. Explain that they are going to study these to identify how the designers tried to come up with a successful shape. In particular ask students to work in groups to answer these questions:**
   a) What features have the designers included?
   b) How might these reduce the amount of energy needed for the vehicle to move through the air?
   c) Why is weight a key factor when selecting material and shape?
   d) What might prevent a designer from coming up with a perfectly streamlined design?
   e) Why is a streamlined design critical for success in the Greenpower Challenge?
7. **Use the student support sheet 'Investigating streamlining and drag' to plan and run a practical activity enabling students to understand how drag can be decreased by effective design.**
8. **Take feedback and draw ideas together to produce a list of design features to bear in mind when designing a body for a Greenpower Challenge car. Display this for future reference.**

Outcomes

- To be able to explain why reducing the drag on a car body makes its movement more energy efficient.
- To identify design features that will reduce drag.

Design

Students use the criteria they have identified in Episode 5. They consider the implications for the selection of materials and develop some ideas for suitable body shapes by modifying a selected body style, either freehand or by using a CAD package, to produce a set of annotated images, presented to the class with key features highlighted. Note that entrants to Greenpower Challenge may either use the Greenpower Formula 24 kit car or produce a chassis and running gear or design their own structure (using the same batteries and motor). This episode assumes that the kit car is being used as the teaching materials use images of this. This episode is intended to provide students with the opportunity to design the outline of a body for the car which accommodates practicalities and maximises features such as streamlining.

A full detailed Solid Edge CAD model of the Formula 24 kit car can be downloaded from **www.siemens.com/plm/academic/greenpower**

This webpage also contains links to the free Solid Edge mobile viewers for the iPad and Android tablets and the viewer files for the Formula 24 kit car. Using either Solid Edge or the viewer will allow students to explore the kit car in more detail.

Learning objectives

- Identify key factors constraining the design of a Greenpower Challenge car.
- Develop and present ideas to show how these factors have been met.

Learning activities

1. **If necessary, revisit the characteristics of effective body designs for Greenpower Challenge cars to ensure that students are familiar with the design factors they are working to.**
2. **Present students with the student support sheet 'Kit car body design template'. Ask students to identify the features that this fixes as values. Draw out that this includes the number of wheels, the distance between front and rear wheels, the distance between the wheels on the same axle, the size of the wheels and the position of the driver.**
3. **Ask students to work in small teams, each with a copy of the Online Assembly Guide , to sketch an outline of a body design. This should reflect the various design factors and allow for practicalities such as the driver entering and leaving, the wheels steering and batteries being replaced.**
4. **Use the student support sheet 'Selection of materials' to support students in developing a design brief and a decision matrix to select a suitable material for the bodywork.**
5. **Each team should then talk through their design (a visualiser is a good way of displaying the designs to the class) with reference to how they meet the various requirements. Other teams should be able to ask questions and share observations.**
6. **Teams should then recommence work, bearing in mind ideas they have gathered from the plenary. It should be made clear that starting again is an option if teams want to radically alter their designs. Annotations are to be encouraged.**
7. **Completed designs should be displayed.**

Outcomes

- To have completed an outline design that accommodates a range of factors and meets the required brief; it should be presented in a way that others can understand.

Consider

Students consider the logistics of using the cars in a competitive situation, the features that are likely to lead to success and how these can be maximised. They prepare a presentation which will include key features, an estimate of the economic considerations and reference to non-financial factors.

This episode is intended to provide students with the opportunity to scope out the logistics, costs and wider benefits of preparing an entry for the Greenpower Challenge.

Learning objectives

- Explore and plan the various aspects of a development project from conception to production and testing of a competitive vehicle.
- Consideration of financial and non-financial considerations.

Learning activities

1. **Explain to students (or remind them if this has already been explored) about the nature of the Greenpower Challenge competition. Remind them, possibly with reference to wall displays from earlier episodes, of the various factors that might lead to success. Ask students to suggest the various considerations that should be made by a school that was planning to enter a car in the Challenge. Make this quite a wide ranging discussion and cover a number of areas including mechanical construction, design and construction of the bodywork, testing of the car and preparing for competition. They might also consider practicalities such as storage.**
2. **Divide the class into groups and allocate each group one of these areas. Nominate (or ask the groups to nominate) a leader who will lead discussions and report back. It may be useful to have excerpts from the technical handbook and the rules for entry, but ensure that groups aren't faced with a lot of written material to assimilate.**
3. **Ask for key points from each group and use these as a basis for wider discussion and development. Encourage students to look at ways of turning problems into solutions, such as the problem of storage being solved by displaying the car prominently to generate interest.**
4. **Ask for ideas about costings. Be prepared to have some information available but make it clear that it's a 'ball park figure' rather than a detailed sum that is being aimed at.**
5. **Also ask for ideas about non-financial benefits that might accrue. Draw out points such as the potentially positive aspects of students working as a team, both in the planning and the competing, and the learning accrued from the experience of designing and building a product.**

Outcomes

- Considered and detailed contributions to specific i.e. logistics, costs and wider benefits.
- Students will be able to provide general feedback on a range of areas.

Convince

Teams of students then make an overall recommendation, with reasons, as to whether the school should participate in the Greenpower Challenge and, if so, how to set things up to plan for success.

This episode is intended to provide students with the opportunity to make a case for entering the Challenge. This would be a very suitable activity to undertake by a school preparing to enter, especially if it was for the first time. However, if no such entry is being contemplated it might be advisable to modify this episode so as to avoid raising false expectations.

Learning objectives

- Contribute to the development of a suitable structure for a report.
- Develop one part of the report so that it makes a coherent case overall.

Learning activities

1. **Explain that this episode is about preparing a case for the school to make an entry in the Greenpower Challenge. Say that this would involve a significant investment on the part of the school in terms of finance, time and effort and that the Head Teacher needs to be convinced that this will be worthwhile.**
2. **Ask the class to suggest what sections need to be in the case that will be presented. Draw out ideas including:**
   a) What the cars do.
   b) What a competing team has to do to stand a chance of winning.
   c) What the school would need to do to prepare an entry.
   d) The resourcing implications including finance and time. To strengthen their case, students could look at ways to fund the project through fundraising and sponsorships.
   e) The benefits that the school and students will gain from a competitive entry.
3. **Divide the class into teams and allocate a team to each section. Decide on the format that will be used (written report, display, presentation, etc.) and explain that as the Head is a busy person it must make the points clearly and quickly.**
4. **Set the teams to work, initially identifying the key points to be covered and how they will be made. Run a mini-plenary in which each team outlines its part of the report and take comments and questions.**
5. **Complete the drafting and draw the components together.**

Outcomes

- Students will have made a contribution to the production of a convincing case.

NOTE:
You can download the complete standard Greenpower Formula 24 Kit Car modelled entirely in Solid Edge at the following webpage: **www.plm.automation.siemens.com/en_us/about_us/goplm/projects-competitions/greenpower.shtml**