3d printers club

3D Grand Prix

Coach Notes

greater cincinnati Stem collaborative
SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH

Developed for the Greater Cincinnati STEM Collaborative, 2018, Revised Fall 2018

Background on this unit:

This unit was first developed by educators from the Bethel-Tate and West Clermont School Districts for students in grades 5-8. This was made possible by the Greater Cincinnati STEM Collaborative and their supporting partners. As a result of its success with the students that piloted it, the unit has been revised several times and made available to other organizations throughout the Greater Cincinnati area.

In an effort to help guide an instructor through the logistics of this unit, "Coach Notes" is provided as a valuable resource. These notes are meant to clarify expectations as well as provide lists of resources and/or materials based on the authors' past experiences in teaching this unit. Of course, your individual students will have unique needs, so adapting the unit activities to fit your situation will bring success.

The strengths of this unit:

- Curriculum is standards-based and involves real-life problem solving.
- Twenty-first century skills are utilized.
- STEM (science, technology, engineering, and mathematics) skills are incorporated.
- The Engineering and Design Process is enforced.
- Students have the opportunity to use CAD (computer aided design) and 3D printers.
- Thinking skills are strengthened (divergent/evaluative/visual-spatial).
- Independent as well as cooperative activities are included.
- Students practice public speaking skills.

The mission:

Students become designers in this unit and will:

- learn about Sir Isaac Newton and the laws of motion;
- experiment with the laws of motion;
- use creative thinking skills to design a vehicle that demonstrates the laws of motion and is suitable for racing;
- build a prototype (model) of the vehicle utilizing the 3D printer; and
- participate in a racing competition with other students.

Before you begin:

- Decide if you will have the students create vehicles powered by rubber bands or if you will use a ramp to race the vehicles.
- Decide what CAD program your group will use.
- In order for students to understand the expectations that are in place, please ensure you discuss the rubric located in the back of the student coursebook with your students as you embark on this unit.
- We have included a sample letter in the Appendix that we recommend sending home with your students at the beginning of this unit. Communication helps to ensure success!
- Note that there are "checkpoints" throughout the unit, where students are encouraged to consult with you. These opportunities are important for ensuring that individual students are progressing appropriately.

Suggested time frame:

- Approximately 10-12 two-hour sessions and 3D Grand Prix Race Event
- In addition, there are opportunities for “Going Further” with extension activities listed in this manual.

Suggested Materials:

- 3D printer(s)
- computers
- plastic filament for 3D printers (assorted colors suggested)
- Internet access
- student course books
- flash drives (one per 3D printer)
- access to basic school supplies
- materials for physics experiments (see student coursebook pages 13-16)
- popsicle sticks to help with SCAMPER brainstorming
- materials for vehicle construction, such as:
  corrugated cardboard
  tagboard
  rubber bands (various sizes)
  paper clips
  wooden dowel rods (1/4 “)
  wooden spools
  wooden wheels
  duct tape
  hot glue sticks
  floral wire
  assorted types of paper
  fishing line
  yarn
  string
  masking tape
  foamboard
  index cards
- toy cars/vehicles for students to tinker with to see how they run
- tools: screwdrivers, wire cutters, saw, pliers, clamp,
- rulers, protractors, scissors, glue, markers, pencils, colored pencils
- calculators
- trifolds
- laminating machine (for Hero Cards)
- cardstock, construction paper
- space for printer to be housed as it is printing (The length of time that it takes a printer to print an object is often time-consuming.)

Unit Time Frame:
Please note that this is just a recommendation based on past teaching experience. Feel free to adjust the schedule to best meet the needs of your group. You may need to eliminate some activities.

Class Number	Activity	Page
1	Unit Pre-Assessment The Mission Begin Before the Beginning EDP	3-4 5 6 7
2	EDP STEP 1-ASK Sir Isaac Newton Laws of Motion More on Newton Physics Experiments 1-4 Energy Follow-Up Rubber Band Power	8 9-11 12 13-16 17-18 19
3	The Task EDP STEP 2-IMAGINE Brainstorming and SCAMPER The Grand Prix Warehouse Imaging Solutions EDP STEP 3-PLAN Source Reduction Sketching your Vehicle	20 21 21-22 23 24 25 25 26-27
4	Continue Sketching your Vehicle CAD and 3D Printing Mini Design Challenge: Hood Ornament	26-28 29 30
5	Continue Mini-Design Challenge/CAD practice	29-30
6	EDP STEP 4-CREATE, Warehouse Tab	31-34
7	Continue CREATE, Warehouse Tab	31-34
8	Continue CREATE, Warehose Tab EDP STEP 5-IMPROVE	31-34 35-37
9	Continue IMPROVE Unit Post-Assessment Entering the Race EDP STEP 6-COMMUNICATE Begin Tri-fold Graphic Organizer	35-37 38-39 40 41 41
10	Continue Tri-fold Create Hero Cards Begin Elevator Pitch	41 42 43
11	Continue Elevator Pitch Pit-Stop Finish all outstanding components	43-44 45 47-48
12	Practice elevator pitch Get all prepared for the big race!	
13	3D GRAND PRIX RACE Event	46,49

Unit Introduction (Course Overview, Pre-Assessment, The Mission, Begin Before the Beginning)

Coursebook Pages 2-6

The beginning of this unit contains an overview of the unit (pages 2 and 5) so that students understand what they will be learning over the next few months.

It is always helpful to gauge the knowledge that students come to us regarding 3D printing prior to the unit's start. A pre-assessment (page 3-4) is included should you wish to administer this to your students. At the conclusion of the unit you will find a post-assessment. We assure you that students will demonstrate growth as a result of their work.

Watching the online video "World's Fastest 3D Printed Car" is a great way to give your students a focus and help them catch excitement for the work at hand. In the video, engineer James Beswick states, "When you've built something yourself, and you can put it down and it works, and it works how you want it to… I don't think you can beat that feeling." We want our students to experience this! (See page 5.)

Another fun way to get younger students thinking creatively on this topic is to share the picture book *If I Built a Car* by Chris VanDusen. In this story, a young boy uses his divergent thinking skills to generate lots of ideas for improving his family's car.

Providing reading material on the topic at hand is another great way to build excitement and anticipation for a new unit of study. Feel free to create your own class library that houses books, magazines, and articles about engineering. We found the following books to be helpful:

- *Amazing Rubber Band Cars* by Mike Rigsby
- *A Beginner's Guide to 3D Printing* by Mike Rigsby
- *Isaac Newton and the Laws of Motion* by Andrea Gianopoulos and Phil Miller
- *Rubber Band Engineer* by Lance Akiyama
- *The Way Things Work* by David Macaulay

Encourage students to go online to search for more resources. We have listed a few websites that we have utilized with our students in the past on page 6 of the student coursebook. They may wish to record their discoveries or "ah-has" in the space provided on this page.

Discussion Starter

Your students will be using technology in this unit. Make sure they know that technology is an object or process that a person designs to solve a problem. Here are a few questions you could pose:

What examples of technology do you see around you right now? ***(Be sure students realize that even simple objects, like a paperclip or pencil, are examples of technology.)***
What problems were these objects designed to solve?
What challenges do you feel may have been faced by the engineers who designed them?

Engineering and Design Process
Coursebook Page 7

Engineering and Design Process:

The Engineering and Design Process (EDP) is a series of steps that engineers use in order to solve problems by designing solutions. This is a cyclical process, thus encouraging revision and improvement (Ask, Imagine, Plan, Create, Improve, Communicate). Throughout this unit, students are led through each step of the EDP. See Page 7 of the student coursebook for a picture of this cycle and questions that can be asked at each step. This website also gives a nice overview of the topic: http://www.eie.org/eie-curriculum/engineering-design-process.

Going Further:

It would be highly beneficial for your students to further investigate the EDP. Consider spending additional class time and utilize the "Going Further" attachments included for this section.

Sample EDP Challenge:

Design Parachutes for the Rover Landing

In order for the Lunar Rover to land safely on the moon and remain in working condition, a parachute was used to slow down the rate of falling to the moon's surface. In this activity, students are asked to design a parachute that will drop 20 grams of weight at the slowest rate.

Materials:

Paper napkins of different sizes
A variety of materials such as foil, fabric, trash bags, newspaper
A variety of strings such as fishing line, string, twine, yarn
3 oz. paper cups
masking tape
gram weights

Before class, create a prototype parachute for each group. The prototype should be made of a 10 inch square napkin for the "canopy" and four 25 cm long strings for the "lines." The strings are taped to the corners of the napkin and to the paper cup ("the basket"). This becomes the prototype that the students are to improve.

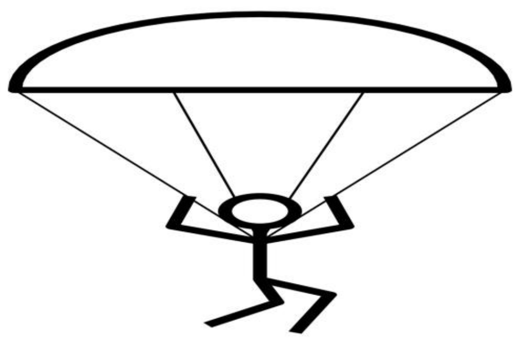
ASK the students the question "What changes could be made to this beginning prototype that would slow down its descent?" In small groups, students should IMAGINE possible improvements that could be made. Then students PLAN their designs on paper, including measurements of all parachute components. After the coach approves the group's model, they CREATE their models.

Once a new parachute is created, teams test their new parachute to the original prototype by dropping both off of a high place (such as the top of a staircase) at the same time. Students can then make observations on the performance of their parachute (and the performance of other groups' parachutes) and make revisions to IMPROVE their model. The students consider the initial question again "What changes could be made to the model that would slow down its descent?" This EDP cycle can be repeated three times, giving the students three tries, or can be repeated for a certain time period such as 20-30 minutes.

Some possible revisions include:

- The size of the canopy
- The material of the canopy
- The shape of the canopy
- The number of lines
- The material of the lines
- The length of the lines

In larger classes or groups, the teams can each be assigned one revision to make and share the findings with the entire group. Teams can then make another prototype based on the results of the class data.



EDP STEP 1-ASK (Sir Isaac Newton, Laws of Motion)

Coursebook Pages 8-12

It's important to begin any project by asking questions. One must know what is expected, and there is often background knowledge that needs to be gained before proceeding. In this unit, students need a basic understanding of physics and the laws of motion before tackling the design challenge that will be presented. The first section of the coursebook helps them explore these concepts.

Discussion Starter

This is a great point to find out how much your students know about physics. A good way to determine this is to create a concept map. Write the word "physics" in the center of a display device or chart paper. Ask the students what they know about physics, and then list their responses. This chart could be kept for future reference. You could add to it when students learn new material, and you could also look back at it to see if any misconceptions are brought to light. It's also rewarding to students to look back at a concept map at the end of a unit, and they are generally pleased to see how much they've learned.

At this point, your students need to explore Sir Isaac Newton's ideas about the laws of motion. The information on pages 8-12 of the student coursebook gives an overview of these laws. It will be important to explain these and discuss them with your students.

Going Further:

There is a multitude of online videos that can assist with your students' learning of Newton's laws of motion. Here are some suggestions that could be shared:

-Newton's 3 Laws with a Bicycle

-What's Newton's Laws Say

Thinking About Physics

Coursebook Pages 13-19

Once your students have a basic understanding of the laws of motion, it's important that they have a chance to experiment with them. This exploratory process will help them see how these laws affect our world, in preparation for applying them in the design challenge they will face. These activities may be done by individual students, in small groups, or as demonstrations with the group. If the demonstration approach is used, consider making the materials available for the students to use in a learning center on their own throughout this unit.

Thinking About Physics

Activity 1: The Coin in the Cup (student coursebook page 13)
This experiment is a wonderful demonstration of the first law of motion. The coin is at rest when it is sitting on top of the card and the glass. When the card is quickly removed, gravity takes over (the outside force), and pulls the coin into the glass. The coin is then stopped by the bottom of the glass. But why didn't the coin take off with the card? This is an excellent question to pose to your students, as they need to realize that the only force acting on the coin is gravity. Try extending this activity by adding more coins. Also, does the type of coin make a difference? What about the type of card used?

Activity 2: The Coin Tower (student coursebook page 14)
In this activity, the students will get a good look at inertia (an object's tendency to stay at rest, or remain unchanged). Be sure to supervise students carefully if they are performing this activity. When done correctly, one or two coins should fly out, and the rest of the stack will simply drop due to gravity. The stack will simply drop due to inertia, and there will not be much motion at all. The same principle is at work when a magician pulls a tablecloth from under objects on a table. Students should note that the first law of motion is demonstrated when the coin being struck moves, but the others simply surrender to gravity.

Activity 3: They're Off! (student coursebook page 15)
Your students have learned that objects tend to keep moving unless a force acts upon them. In this activity, the force acting on the objects is friction, which makes the jars slow down, instead of moving forever in a straight line. The students should observe that the jar filled with water moves down the ramp faster than the empty jar. The extra weight of the water evenly distributed inside causes more acceleration. In terms of inertia, the empty jar experiences a longer moment of inertia than the filled jar (due to the fact that a filled cylinder requires about half as much torque as an empty tube for changing the rate of rotation). This is an important point that will play a role in the design challenge to come. If your students experiment with rolling the jars on different surfaces, they will find

that friction plays a large role in the distance they will travel. How does changing the size of the jar affect the performance?

Activity 4: All Wound Up (student coursebook page 16)
This activity is a precursor to the rubber band-powered car the students may choose to design. They learn about the potential energy that can be stored in the rubber band, and how it transforms into kinetic energy when the band is released. They will see that greater movement is produced when more energy is stored up by twisting the rubber band. This activity provides a chance for students to "tinker" with the materials to see what produces the best results. It's important that they be given the chance to do this, as wonderful learning can result!

Pages 17 and 18 provide opportunities for acquired knowledge to be further emphasized. Review potential versus kinetic energy and have students write definitions for these words as well as inertia and friction.

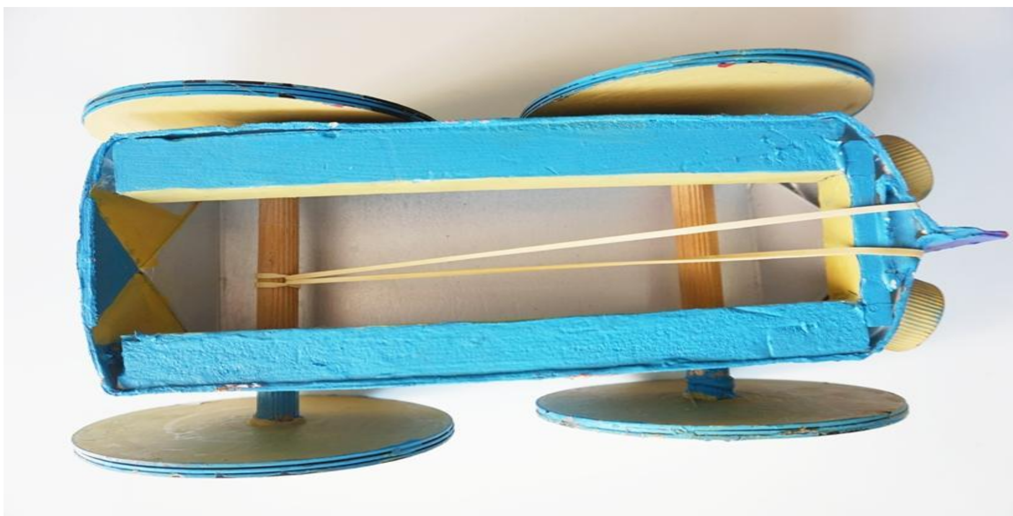
Rubber Band Power
Coursebook Page 19

Page 19 of the student coursebook describes the process of designing a moving vehicle that runs on rubber band power. This concept may be one that students will need to explore before designing. You will need to decide if you will permit "slingshot" designs in your 3D Grand Prix, or whether you want all students to employ "wind-up" designs. Also, you may need to revisit the "All Wound Up" activity students completed on page 16 of their coursebooks. This is another good opportunity for students to consider what they learned about Newton's Laws of Motion. Consider probing their understanding with questions like:

- How will the weight of my vehicle affect the ability of rubber bands to overcome its inertia?
- What will happen if I use more than one rubber band to power my vehicle?
- How will the properties of the various materials available affect the performance of my vehicle?

Going Further:

3D printed wind-up cars with tiny moving parts can be purchased. Students will find these fascinating, if you're willing to make the investment. Visit this site for a demo video and other information: *https://3dprint.com/47362/3d-printed-wind-up-car/*



The Task
Coursebook Page 20

Based on our experiences, we have discovered that oftentimes, as educators, we take things for granted. We expect our students to be able to gather data, analyze it independently, and draw reasonable conclusions from the data. Unfortunately, students are not often led through this process and therefore the results are not as desirable as we educators might have wished. This is a great point in the unit to stop, slow down, and ensure that students have internalized the physics concepts explored to this point. They will now be applying them to a design challenge, so their understanding will affect their success.

Page 20 of the student coursebook lays out the task the students will pursue. A discussion should take place here to make sure all students are aware of the guidelines for the challenge, and have a good understanding of the task, and how to apply the laws of motion to it.

EDP STEP 2-IMAGINE (Thinking Like An Engineer-Brainstorming, SCAMPER)
Coursebook Pages 21-22

Thinking Like An Engineer:

Before embarking on designing their vehicles, it's important for students to realize the role that creative thinking plays in the engineering design process. In this section, students will work on their divergent thinking skills as they strengthen their creativity. Utilizing tools such as brainstorming and the SCAMPER technique, students will begin to develop flexibility of thinking, a skill important for any engineer. Pages 21-22 in the student coursebook walk students through these two wonderful techniques.

Brainstorming:

Helpful resources include:

Brain Storming, The Book of Topics by Marty Fligor

Brain Storming II, Another Book of Topics by Marty Fligor

Primary Education Thinking Skills (PETS) published by Pieces of Learning

Discussion Starter:

Psychologist Paul Torrance is considered the "Father of Creativity," as he devoted much of his study to helping students think more creatively. He emphasized the importance of developing originality, elaboration, fluency and flexibility in our thinking. Visit these sites to find more activities to develop these skills:

http://www.bio-nica.info/biblioteca/VanGoundy2005101ActivitiesTeaching.pdf

http://minds-in-bloom.com/2009/10/creative-thinking-flexibility.html

http://www.jrimagination.com/blog/2011/11/11/the-powerful-fours-of-creative-thinking.html

SCAMPER:

Find a detailed explanation of SCAMPER on Page 22 of the student coursebook. However, In case you may not have had experience with this technique, here are some possible answers for the uses of a paper plate.

S -Use a paper plate as a **substitute** frisbee.
C -**Combine** a paper plate with rubber bands stretched across the center to make a musical instrument.
A -**Adapt** a paper plate for use as a sun visor by cutting out a portion and adding a strap.
M -**Magnify** a checker game by drawing a sidewalk chalk "board" and using paper plates as the checker pieces.
P -**Put** a paper plate **to a new use** by using it as a paint palette.
E -**Eliminate** half of the paper plate by cutting it and using it as a dust pan.
R -**Rearrange** Cut a paper plate in half and **rearrange** the parts to form a butterfly decoration.

Growth Mindset (An addition…)

Going Further…
Part of the creative process used by all engineers is to learn to embrace mistakes. It will be impossible to complete this unit without encountering a few failures along the way. This article discusses the importance of helping students turn mistakes into a positive experience:
http://www.edutopia.org/blog/teaching-students-to-embrace-mistakes-hunter-maats-katie-obrien

The Grand Prix Warehouse
Coursebook Page 23

The Grand Prix Warehouse will serve as the "store" where students will "buy" the materials for constructing their vehicles. There is a suggested materials list on page 23 of the coursebook, which could certainly be modified. However, one caution here: providing fewer choices of supplies often forces the students to become more creative in their designs. There is a "Warehouse Tab" sheet on page 33 where the students will eventually record what they have "spent." Suggested prices are listed, but if you have time, a good discussion could come from having the students price the items based on what they perceive as their "values" in the project. The prices are also based on the English system of measurement, but could be transitioned to metric if desired. The hot glue and masking tape are listed as free, simply because it's difficult to measure glue, and constant measuring of masking tape may prove to be inefficient. If your club is running short on time and/or adults to assist, consider doing away with pricing altogether. All of these materials and prices are flexible, based on your situation.

Going Further:

When engineers control the waste produced during a project, it is referred to as source reduction. Your students will want to consider this when designing their vehicles. An additional reminder about source reduction is included on page 25. To explore source reduction more, visit *Teach Engineering's* lesson on package design: https://www.teachengineering.org/activities/view/wpi_packaging_materials

Going Further Again:
The concept of providing fewer materials to students and forcing their creativity is called "limiting." This is often used in engineering, and is common in art as well. Perhaps this calls for a STEAM activity (science, technology, engineering, ART, and mathematics)!

Imagining Solutions
Coursebook Page 24

In this section, students imagine variations in design for their vehicles. This is their chance to apply the brainstorming and SCAMPERing techniques they learned. We have found that many times students have a very narrow vision when it comes to designing. They have one solution that persists in their thoughts. Students need to realize that there could be infinite possibilities when it comes to a design challenge such as this one. Encourage them to record several possible solutions in this section. Have them consider size, materials, simplicity, complexity, etc. They need to see the process involved in pulling ideas from numerous possibilities and creating something new. While keeping things simple is often the most beneficial, encourage students to not settle for the first design that comes to mind.

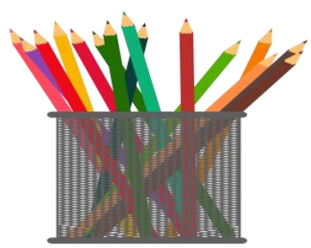
Students may also need a reminder that at least one part of their vehicle will be created using the 3D printer. You will need to decide what, if any, restrictions will be placed on this and communicate these to your students now. For example, does the 3D piece need to be a working part, or is a decoration for their car allowed? Will there be restrictions on the size of the part printed (for example, to conserve plastic filament if you're running low)?

Once students complete this section, consider having them discuss their ideas with a friend or family member. A checkpoint is included at the bottom for you to once again schedule some time to conference with your engineers.

Going Further:
If you have time, the "Marshmallow Challenge" is an excellent collaborative activity that reinforces the idea of staying open to different solutions to a problem, and not just sticking with the first thought that comes to mind. See the instructions and a view a TED talk from an expert here: *http://www.tomwujec.com/design-projects/marshmallow-challenge/*

EDP STEP 3-PLAN (Time to Plan, Source Reduction, Some Tips for Sketching your Vehicle)
Coursebook Pages 25-27

After preparing for sketching, students are now allowed the opportunity to consider the designs they imagined, and come up with a plan. Remind students that while this plan can be modified later, they should put thought into it now and try to realistically consider the effectiveness of their ideas. Space is provided for the plan, but larger/more graph paper could also be used here (search for "printable graph paper"). Encourage your engineers to sketch their plan in such a way that someone else would be able to pick up their plan and construct the vehicle. Also remind them at this point that at least a part of their vehicle will be printed on the 3D printer. A checkpoint is included here for you to sign upon completion of the plan. This is a great time to again ask probing questions to assess a student's understanding of the concepts at work here. It's not unusual for students to be "sent back to the drawing board" several times at this point if clarity is needed in the plan.



Sketching Your Vehicle:

Page 26 contains some invaluable advice for young engineers. Drawing is a favorite pastime for many of our students, but sketching scientifically and mathematically is often new. Considerations of scale, measurement, and geometric shapes can provide challenges. An example of a professional engineer's sketch is provided as an example. While we don't expect this level of expertise of our students, this will provide them with an excellent model. Page 27 provides students with graph paper that they could begin to use.

Going Further:
Sketching together in class in preparation for this exercise may prove beneficial. Some suggestions for sketching subjects include: Lego creations, chess pieces, toy cars, and other 3D printed creations.

STOP AND THINK!
Coursebook Page 28

In this section, our engineers are encouraged to take a step back and consider their design through some self-questioning. We don't want our students to overlook obvious logistical concerns. Placing students in small groups for discussion at this point can be valuable. Any changes they want to employ should be recorded here. Once students are set with their plans, the signature of a parent or guardian should be obtained. Your success as a coach will depend upon good communication with your students and their families. This will be appreciated! A checkpoint is included as a follow-up after parent/guardian signatures are in place.

Computer Aided Design and 3D Printing
Coursebook Pages 29-30

At this point in the unit, you will have options for the CAD program your students will use:

TinkerCAD.com – This free website provides an excellent introduction to CAD for younger and older students alike. The shapes are easy to manipulate, and very little instruction is needed. Please be aware that log-in options include using a Google or other social media account, registering with an enabled email account, or registering with a fictitious email account. If students register their own email account, we strongly recommend recording them along with passwords, as someone will inevitably need this information (because they are forgetful!) in the future. There is also a space for students to record this information on page 29.

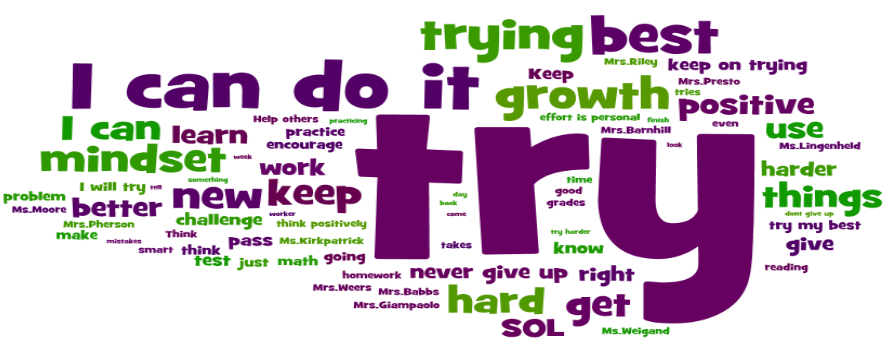
Blockscad3d - Brings the coding world into the 3D printing experience.

SketchUp – For a more professional and powerful CAD experience, SketchUp is a good choice. We recommend this for experienced designers or older students. There is a greater learning curve here, so your students may need additional time to "play" and become familiar with this software. This software is downloadable at www.sketchup.com.

For many students, coaches, and teachers this may be the first time using a 3D printer. While students are more than willing to "jump into" CAD, we have found that providing a little background and support in the beginning goes a long way. Should time permit, we strongly recommend embarking on a class tutorial before designing for an engineering challenge on CAD. For example, have everyone in class design a hood ornament using CAD, sticking with the vehicle theme. See Grand Prix Mini Design Challenge: Creating a Hood Ornament on page 30 of the coursebook.

To assist you with the ins and outs of 3D printing should you be new to it, we have included a website at the bottom of the Computer Aided Design and 3D Printing section. It includes a glossary that you may find beneficial.

As your students begin to utilize the CAD program, encourage them to continuously look at the object three dimensionally. Many young inventors find this a new experience and focus on two dimensions instead. It will take some time for them to find their own level of comfort with the program. Encourage a growth mindset (see publications by Carol Dweck) and trial and error. Above all, have fun!



EDP STEP 4-CREATE (Creating Your Vehicle, Warehouse Tab)
Coursebook Pages 31-33

Your young engineers will likely be very eager to begin creating their vehicles at this point! Sometimes they get impatient with the important groundwork that needs to be in place before this step! Students will “shop” at the Grand Prix Warehouse and begin construction of their designs. Be sure to have them record what they “buy” so a total cost for their vehicles can later be determined (see coursebook page 33). There is space for you to initial this for verification purposes. Simultaneously, students will also be using CAD software to design and submit their part(s) for 3D printing.

Be sure to encourage students to document their daily/weekly progress on the pages provided. Such documentation is helpful as a student looks back to evaluate him/herself. It also makes student evaluation easier. Some coaches have even given an award at the 3D Grand Prix based on the students’ meticulous completion of these logs.

During this step, be prepared for mistakes and frustration from your engineers. It’s part of the process! They will likely need to change parts of their plans, which is fine as long as they record what they change in their coursebooks. Encourage your students to embrace their mistakes as learning experiences! Allow them to struggle through the rough points of this phase!

Finishing Touches, EDP STEP 5-IMPROVE
Coursebook Pages 34-40

Finishing Touches:

Students will enjoy this step of making their vehicles more attractive. Hopefully they have a working design and they are ready to make improvements in the way the vehicle looks. Some coaches allow students to use paint, stickers, and other supplies from home here, as long as they don't affect the working mechanisms of the vehicles. There is a box provided on page 34 for students to record their ideas as they brainstorm ways to finish off their creations.

EDP Step 5-Improve:

Pages 35-37 are designed to give students time to practice with their vehicles and make needed improvements. In pilots of this unit, students found it very difficult to avoid human error in calculating speed. However, we have left these pages intact for those groups who want to try this in order to give students a foundation for calculating speed. A more successful approach was using a smartphone or tablet app. A favorite proved to be the app "Speed Clock – Video Radar," available from iTunes for Apple devices (approximately $1.99). There are many other speed apps available, but accuracy varies.

The time frame for this part of the unit is flexible. Students will be able to make improvements as time allows. Trial races are an excellent activity for students who finish before others, and may allow you more time to assist students who are struggling. For students who need more, there are some engineering websites listed at the top of page 40.

3D Grand Prix Unit Post-Assessment:

Students will remember taking the pre-assessment at the onset of this unit. This post-assessment (pages 38-39), almost identical to the assessment given at the beginning, should make your engineers pleased with all that they have learned about 3D printing, the Engineering and Design Process, physics, Laws of Motion, and much more!

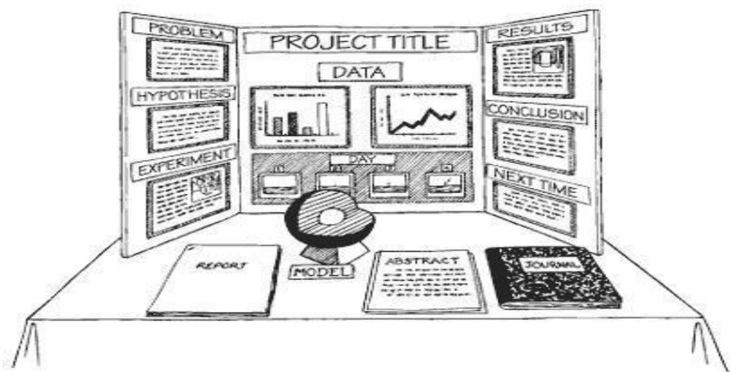
Entering the Race:

There is an application for entry into the 3D Grand Prix on page 40. This provides an opportunity for students to bring closure to their project as they prepare for race day. It can also be used as an assessment tool for your students' understanding of the big ideas from this unit.

EDP STEP 6-COMMUNICATE (Tri-fold Graphic Organizer, Hero Cards)
Coursebook Pages 41-42

Tri-folds:

As the coach/teacher, you will need to consider the exact requirements you have as far as your Grand Prix is concerned. We have found that giving students a tri-fold allows them to consider the space for which they will be responsible. Creating a visually appealing tri-fold is a skill that does not often come easily for students of this age. We have included a tri-fold graphic organizer (page 41) that you will want to strongly encourage your students to use before doing anything to the actual tri-fold. Students can think of what their whole displays (not just their trifolds) will look like and sketch this in the tri-fold graphic organizer.



Hero Cards:

Hero cards are a wonderful addition to the displays, should time permit. They are given out by racing teams to promote their driver, car, and the companies that sponsor the team. Encourage your students to find examples online of hero cards and have them create their own. Information can be fiction or nonfiction! Consider having students include info about their car, successful races, driver stats, logos of sponsoring companies, racecar/team colors, the vehicle number, pictures of the driver/car, and other relevant information. (See the *Appendix*.)

In the past, we have laminated these cards and attached them to our tri-fold displays with Velcro so that they may be easily transported and removed to be read. This also makes a nice memento for the families that attend your Grand Prix. Students can see an example and brainstorm ideas on page 42.

Creating Your Elevator Pitch and Write Your Elevator Pitch **Coursebook Pages 43-44**

One of the skills that this unit addresses is public speaking. In order to help students be prepared to present at the 3D Grand Prix we have included these sections. Students are encouraged to write a brief (no more than 60 seconds) speech that tells an audience all about their vehicles. An elevator pitch should contain a hook, details about the vehicle, and a request. (See page 43 for a detailed explanation of these concepts.) The bottom of page 43 provides websites where students can get more guidance before creating their own pitches.

Students will find a graphic organizer on page 44 to help them organize their thoughts for outstanding elevator pitches. Encourage students to obtain a witness' signature once they have completed their writing. Remind them that practice makes perfect!

Pit-Stop:

This exercise is invaluable as students have the opportunity to assess others' work and to receive feedback on their own before "the public" views their displays. See the sheet that accompanies this activity on page 45. Encourage praise and constructive criticism. Provide an opportunity to make changes based on the feedback the students receive from one another.

Race Day:

Your engineers will no doubt be very excited for their races! For documenting race day, a data chart is included on page 46. As the coach/teacher, you will need to spend some time planning how you want to organize this event. Some points to consider are:

- Should students' families be invited? They will no doubt want to come, and you will likely need the extra hands!
- How will the logistics of the race be handled? Do you want all students watching as each vehicle races? Will small groups of students be competing all at the same time in different locations? Each group of

students presents its own needs, so tailor this event to your group. In our pilots, we were concerned with students having too much "down time" if they watched individual vehicles or heats racing. So, we accepted help from parents, and had groups of students all racing at the same time.

- What awards will be given? In our pilots, awards were given for greatest speed, greatest distance traveled, and for the most economical vehicle. In addition, some coursebooks were selected as excellent examples of documentation of the process followed throughout the unit. Awards could also be given for using a growth mindset, best use of a 3D printed part, learning through failures, visually effective trifold, outstanding hero cards, use of realia in displays, and superb elevator pitches.
- Display "What I learned from the 3D Grand Prix" (page 48) at your event. Laminate the cards and present them to your engineers after they have been read by your guests. (See the *Appendix* for examples.)
- Encourage race fans to fill out the "Finish Line Feedback Form" (page 49). Place these at the displays of your racecar engineers along with pens/pencils and have your visitors leave notes of encouragement on them. What a powerful message this will send your students!
- Will other activities take place on race day? Consider having a guest speaker, refreshments, and/or student presentations as a part of race day! It could become a grand affair!

> A great moment from one of our pilots: After the awards were presented, the students were given time to simply play with their vehicles in the school gymnasium. There were lots of great photo opportunities, and the students found it tremendously enjoyable!

3D Grand Prix Rubric:

Reflection upon one's work and self-evaluation are important for students to grow as learners. We have provided a rubric for this purpose on page 47. The students should complete this with encouragement to be honest with themselves. You may want to make additional copies and complete one for each student from your perspective, or you might choose to write in the coursebook in a different color of ink. If your situation allows for an individual conference time with each student, perhaps even including their parents or guardians, it would be recommended.

Discussion Starter:
Your students will benefit from a group debriefing session after the races are completed. This will provide closure, and will help students know how to approach projects in the future. Consider asking: What went well during this unit? What challenges did you face? How did you overcome these challenges? What would you do differently if you could go back and repeat this design challenge? What should we change if we do this unit again?

Congratulations! Being a teacher/coach is not an easy job, but you did it! Take time to reflect on your experience with this unit. You no doubt worked incredibly hard, spent countless hours helping students, and perhaps even spent some sleepless nights thinking about how to best support your young engineers. Rest assured that you have had a remarkable impact! Thank you for taking on this challenge to impact STEM education today, and the lives of our students for years to come!

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