Facilitation Guide: Glowforge 500 (Exploring Physics with Gravity Racers)

Challenge

Students will create a miniature racer to compete against classmates and the clock. They will work through Design stages to develop, manufacture, and refine their racers. Throughout the process, they will use manufacturing principles to design, test, and correct elements of their miniature racers and maximize performance.

Rationale

Deceptively simple, gravity-powered racers are a perfect introduction to manufacturing and production. In races that come down to milliseconds, every design detail can be the difference between triumph and defeat. Students will research design elements and manufacturing techniques that maximize performance, then iterate their racer to correct product flaws and maximize performance.

Introducing engineering and physics concepts can help students improve their racer's speed and performance. This fast-paced learning opportunity helps students develop a range of essential skills and apply concepts such as resistance, drag, mass, and center of gravity.

Glowforge is an innovative classroom tool that allows students to create custom parts for their racers and experiment with various new design techniques. Additionally, the Glowforge App provides an intuitive interface that is easy for students to use, helping them to develop design skills that can be applied in a range of contexts.

Standards

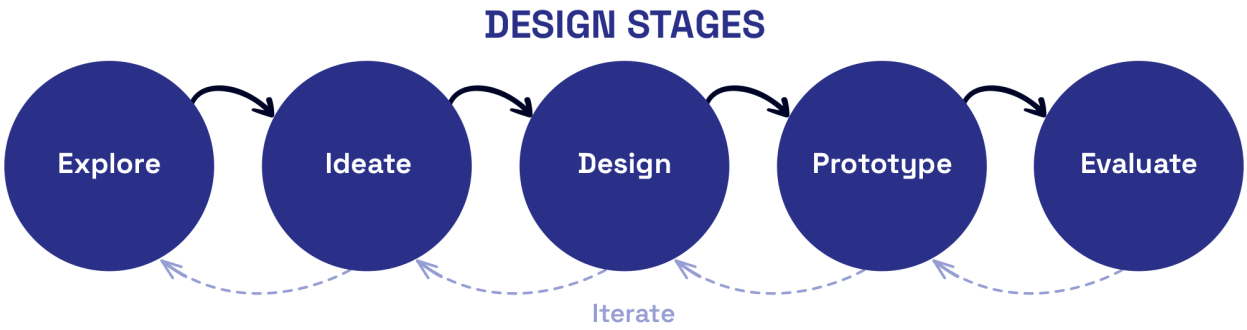
Common Career Technical Core Standards

- MN-PPD 1 Produce quality products that meet manufacturing standards and exceed customer satisfaction.
- MN-PPD 1.5 Inspect the product to verify that it meets specifications.
- MN-PPD 2.1 Research new manufacturing processes.
- MN-PPD 5.2 Propose changes to improve products and processes.
- MN-PPD 5.4 Inspect product for deviations from customer and product standard(s).

ISTE Standards for Students

- Knowledge Constructor 1.3 d Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions.
- Innovative Designer 1.4 Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.

Facilitation Steps to Support the Design Process



Explore

In this stage, students will focus on researching manufacturing techniques to maximize their racer's speed, performance, and aesthetic appeal. To ensure that students have the knowledge and skills they need to complete this stage, use the following steps:

1. Provide students with question prompts from the Explore stage of the challenge to inspire their research and help them consider how they can demonstrate manufacturing concepts to improve their miniature racers.
2. Determine what track your students will use. Here are some options:
    - Have the students design a track as part of their experience. Think about using materials that you have lying around and using Glowforge to create embellishments like flags, fans, or a track name.
    - Build a track like the one featured in this video.
    - Connect with a local Boy Scout troop to borrow the track they use for their Pinewood Derby.
    - Use tracks designed for toy cars.
3. Share any specifications that you want the students to follow for the challenge. Explore regulations for the Pinewood Derby and Soap Box Derby for inspiration. Your specifications might include the following:
    - Weight restrictions
    - Number of wheels
    - Dimensions of the track

4. Generate awards categories that the students can vote on during the Evaluate stage. Students can create custom awards using the Student Designed Awards activity. You can get started with these ideas:
    - Looks Most Like a Real Racer
    - Looks Least Like a Real Racer
    - Most Colorful
    - Fastest-Looking Racer
5. Develop a format for the race. Think about how you can support your students as they test and refine their racers. Here are some ideas to get started:
    - Integrate time trials into the Prototype stage. Consider having students complete at least three time trials where they log their racer's performance and make small adjustments to improve their racer design.
    - Create a bracket system to rank the racers times. Consider how you can create a double elimination bracket so that each student competes multiple times.
    - Consider awarding race superlatives. You could have categories like wildest looking racer or fan's choice! Create a system where racing superlative winners can deduct time from their race results.
6. Encourage students to share their findings and discuss what they've learned during this stage.
    - If students are working in groups to complete this design challenge, have different groups partner together to discuss what they discovered.

At the end of this stage, have students reflect on the research they did to learn more about making the fastest mini racer. Encourage them to consider the race specifications that you created.

Before moving on, students should consider if there are any other resources or manufacturing techniques that would be helpful to explore. Once they are finished, students will continue to the Ideate stage to brainstorm designs for their racers.

Ideate

In this stage, students will experiment with different ideas for their racers. This stage allows students to explore as many ideas as possible without judgment. Remind students to use manufacturing techniques and digital tools to create unique designs, creative elements, and speedy components for their racers. To ensure that students have the knowledge and skills they need to complete this stage, use the following steps:

1. Provide students with question prompts from the Ideate stage of the challenge to help them brainstorm.
2. Encourage students to brainstorm ideas using one or more methods.
    - Allow students to brainstorm individually or in small groups to utilize multiple perspectives.
    - Provide students with different ideation strategies to help them begin.

At the end of this stage, students will have generated multiple ideas for their racer and be able to narrow their focus in order to develop a design that is speedy and creative.

Before moving on, students should consider which ideas will help them manufacture a fast racer by addressing the race specifications and principles like resistance, center of gravity, mass, and drag. Once they are finished, students will continue to the Design stage where they will select one or two ideas that they will develop further.

Design

In this stage, students will develop their ideas from the Ideate stage to draft a detailed plan for their racer. Students should focus on one or two ideas to better understand their needs and final design before printing. Encourage students to consider the materials they plan to use, how they will produce the pieces, and their assembly plans. To ensure that students have the knowledge and skills they need to complete this stage, use the following steps:

1. Provide students with question prompts from the Design stage of the challenge to help them design.
2. Inspire students to experiment with Glowforge to create parts or embellishments they might need for function or visual appeal. Ask students to:
    - Consider various materials they could use with Glowforge to create aesthetic or functional components for their racer.
    - Explore the Glowforge design catalog to modify or enhance designs that might be useful.
3. Introduce, review, or model available design software options, including the Glowforge App.
    - Assist students as they create sketches or digital mockup of their racer. Consider having students use CAD software like SketchUp or AutoCAD to create detailed 2D and 3D designs.
    - Remind students that Glowforge can engrave from JPG or PNG image files and cut or engrave from SVG and PDF files. This means students can create something in popular software that they already use, convert it to one of the supported file types, and print using Glowforge.
    - Students can import a hand drawn or digital design to be etched using the Glowforge App's trace feature.
    - Review page 28 in the Glowforge Educator Guide for more software tools and information.

At the end of this stage, students will have a detailed plan for their racer design, including sketches or digital mockups, as well as an idea about how they will maximize their racer's speed by leveraging engineering and manufacturing principles.

Before moving on, students should consider if they would like to change anything about their design. Once they are finished, students will continue to the Prototype stage where they will select and test one of their fully developed racer designs.

Prototype

In this stage, students will use their design plan to manufacture a physical racer. They'll select one of their fully developed design plans, print the necessary elements with Glowforge, assemble their racer, and test its performance on the track. To ensure that students have the knowledge and skills they need to complete this stage, use the following steps:

1. Model how to use Glowforge in a safe and efficient manner.
    - Review the Glowforge safety guidelines.
    - Remind students of any applicable classroom or school policies.
    - Use this video to demonstrate how to use Glowforge.
2. Provide students with question prompts from the Prototype stage of the challenge to help them develop their prototype.
3. Give students the time and resources needed to produce the Glowforge elements of their design, assemble their pieces, and test the elements of their racer.
    - Create a classroom print schedule to ensure that all students are able to produce the elements they need efficiently.
4. Provide students time to conduct their time trials on the track. Remind them that they can use their racer's speed and performance to inform product or process changes.
5. Encourage students to share their types of modifications and results with each other.

At the end of this stage, students will have a finished racer that is ready for the big race. Students should have tested and adapted their racers to ensure that they have a design that can finish the course.

Before moving on, students should review their finished racer to ensure it maximizes speed and performance and has creative aesthetic elements. Students may need to test multiple times or return to earlier stages of the design process before moving on. Once they are finished, students will continue to the Evaluate stage where they will receive feedback on their finished racer and compete with others.

Evaluate

In this stage, students will evaluate their racer design and receive feedback from others. Feedback can be provided in pairs, small groups, or as a whole class. Encourage students to reflect on their process and consider their alignment to their original specifications and design plans. To ensure that students have the knowledge and skills they need to complete this stage, use the following steps.

1. Provide students with question prompts from the Evaluate stage of the challenge to help them reflect on their racer.
2. Encourage students to share and discuss their ideas to generate feedback from their peers to refine and enhance their racer.
    - Students can use the question prompts from the Evaluate stage to guide their discussions.

3. Provide students with question prompts to help them reflect on the feedback that they received. These might include:
    - How can you further improve and refine your design?
    - If making additional changes to your racer, which of the design process stages will you return to?
4. If applicable, provide students with time to complete a learning reflection, self-assessment, and/or peer critique.
    - Use the provided Assessment Suggestions for more ideas.

At the end of this stage, students should have reflected on the strengths and areas for improvement of their racer. Students should determine whether revisions are needed, then return to the appropriate stage in the design process to adjust their design. Consider assessing student work using one of the Assessment Suggestions or extending the challenge using provided Extension Activities.

Once students have finalized their racer, it's time to head to the track and race towards the finish line!

Supplemental Supports

- For newer Glowforge users, demonstrate how to use your Glowforge and its design features, including the design software, engraving capabilities, and cutting functionality. Check out the Glowforge Educator Guide for more ideas.
- For a fast-tracked version of this challenge, consider starting with the Making Moves activity. Once students create their race cars, they can customize and compete with classmates.
- The Glowforge 500 challenge is a perfect opportunity to explore simple coding projects to help manage the races. Take some time to review or share the following possibilities:
    - Arduino Pinewood Derby Timer : 3 Steps (with Pictures)
    - Designing The Best Pinewood Derby Finish Part 1 and Part 2
- For students who want to dig deeper with physics, share one of the many academic research papers or videos focused on designing the perfect pinewood derby car:
    - The Physics of the Pinewood Derby by M. Devine
    - Pinewood Derby Physics by Rhett Allain
    - Pinewood Derby Physics E. Roger Cowley
    - The extended version of Mark Rober's pinewood derby video

Assessment Suggestions

Overall Learning Reflection

Learning reflections allow students to reflect on their learning experiences, identify key concepts, and explain how they have grown throughout the design process. Ask students to

write or record a video about what they learned throughout the challenge. Students can incorporate feedback elements from the Evaluate stage to describe their strengths and areas for improvement.

Self-Assessment

Self-assessments allow students to reflect on their learning through portfolios, presentations, or learning journals that involve evaluating their own progress and identifying areas for improvement. Consider providing criteria to students prior to beginning the challenge that can be used by the student to reflect on their progress throughout the challenge. The criteria may include:

- Speed and design: How well did I demonstrate manufacturing techniques that maximize my racer's speed and performance?
- Aesthetics and creativity: How well did I use visual design elements to customize my racer?
- Use of the design process: How well did I develop, test, and refine prototypes as part of a cyclical design process?

Educator or Peer Assessment

Educator or peer assessments allow educators or students to review the quality and effectiveness of the finished racer. The assessment can be based on specific criteria, such as its performance on the track, or use a more open approach like a gallery walk for giving feedback on creativity and aesthetic design. Some criteria to consider may include:

- Performance: Did the racer perform well on the track?
- Creativity: Did the racer convey creativity or personality effectively?
- Design: Did the racer effectively utilize design software features?
- Specifications: Did the racer meet all manufacturing specifications?

Extension Activities

Design challenges often inspire students to think about what's next. For some, this could mean connecting with people within the manufacturing, engineering, or automotive industry or applying their skills in new ways. Here are a few ideas for how you can help students extend this challenge:

- Engineers have to adapt to constantly changing constraints. Challenge students to redesign their racer based on new specifications or have them change the scale of their designs without impacting other characteristics. This could mean doubling the length of their racer without changing its mass or reducing the weight of their racer without impacting its size. Learn more about scaling designs on Glowforge.
- Gravity alone can power racers, but adding other forms of propulsion can lead to more opportunities to get creative and highlight innovative design features. Watch to see how one engineer got his racer up to 40 MPH! Keep safety in mind when your students use other forces such as simple motors or air propulsion to jump start their racers.

- Downhill racers aren't just for kids. The Columbus Dispatch challenged engineers from Battelle Labs, Ohio State University's Center for Automotive Research, and other local groups to compete against each other in an adult pinewood derby. Have students propose a challenge to local manufacturers, engineers, woodworkers, makers, or automotive mechanics to see who can design the fastest racer.

If your students enjoyed this challenge, they might also enjoy Reinventing the Ordinary, an Art and Design challenge that focuses on re-using items or materials creatively to create a racer completely out of upcycled materials.

Ready to take students to the next level? Try the Capstone Challenge Sustainable Strategies for Circular Design, where students apply their manufacturing skills to create a sustainable product.