THE SPEED OF STEM

SCIENCE + TECHNOLOGY + ENGINEERING + MATH

The Physics of Lightweighting

TEACHER AND AMBASSADOR GUIDE

About The Dow Chemical Company

Dow's STEM mission is to build the workforce of tomorrow by empowering teachers, motivating student achievement, developing careers, and collaborating with communities to transform STEM education into a driver for innovation, manufacturing, and economic prosperity.

To live out this mission, Dow has created STEMtheGAP™—a growing and constantly evolving series of initiatives to support and advance STEM education. While stakeholders, target audiences, and focuses may vary, every initiative is designed to inspire conversation about STEM education, collaboration to develop innovative solutions and, as a result, transformation that will enable our nation and the world to surmount the challenges of the 21st century.

For more information on Dow's STEMtheGAP™ initiatives visit, www.dow.com/company/citizenship/stem.

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About Richard Childress Racing

Founded in 1969, Richard Childress Racing (RCR) is one of the largest and most storied organizations in NASCAR automobile racing competition. RCR currently fields three teams in the NASCAR Cup Series and five teams in the NASCAR XFINITY Series.

On their 17-building, 52-acre campus in Welcome, North Carolina, RCR's 530 team members build race cars from the ground up in a fully-integrated vertical manufacturing operation. With a culture focused on innovation, their engineering team utilizes cutting-edge technologies to continuously improve the performance of their race cars.

Their headquarters is also home to ECR Engines, a subsidiary of RCR that provides high-performance motors to our and other Chevrolet teams in NASCAR's top three national series. ECR uses advanced technologies for research & development and engine production that has earned it more than 250 victories across multiple national motorsports series and championships in the XFINITY, Camping World Truck, and ARCA Racing Series

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Evaluation of the safety of chemicals used in this module

A Safety Data Sheet (SDS) is the main document scientists at Dow use to assess the safety of chemicals. The SDS lists any hazards associated with the chemical, including potential hazards such as what might happen if the chemical is dropped or if it comes into contact with air or water. Before carrying out an experiment, a Dow scientist refers to the SDS for every chemical he or she is going to use. This allows the scientist to decide what personal protective equipment to wear and where to carry out the reaction. Dow uses a color-coding system for every chemical. All of the chemicals in these modules belong to the green category, which is the category associated with the lowest level of risk. Dow recommends and includes appropriate safety precautions in the Stay Safe boxes in both the Teacher and Ambassador Guide and Student Guide.

Lightweighting Module

How to Use This Guide

Welcome to your Lightweighting Teacher and Ambassador Guide. This Guide contains all the information you need to teach The Physics of Lightweighting Module produced by The Dow Chemical Company in collaboration with Richard Childress Racing.

The following features in this Guide will help you teach this module:

Safety Moment
Science is fun but can also be dangerous. Emphasize safety advice to your students.

Module Overview

Students will be participating in a series of activities based on a model-based inquiry framework that explores:

• Newton's Second Law (F = m*a)

• Strength and weight correlation or non-correlation

LESSON	ACTIVITY	LENGTH
Part 1: Newton's Second Law	Crash Testing: Crash 2 wooden 'cars' with various added masses to see where the impact takes place	8 minutes
Part 2: Material Strength	Impact Testing: Compare the strength of material by observation after impacted by a force	8 minutes
Part 3: Application	Racing: Compare times of two identical cars with differing mass on a straight and oval track	8 minutes

Lightweighting Module

Recommended Roles for Ambassador and Teacher

The table below provides suggestions for the role of the ambassador and teacher during this lesson. The ambassador and teacher should discuss this table before the lesson and modify as appropriate to their preferences and needs.

	TEACHER	AMBASSADOR
Preparation	• Set up classroom for demonstration and group work • Print out student copies of worksheets • Contact ambassador and inform of time constraints and special needs • Ensure adequate space is available for the racing activity • Review background information	• Contact teacher to arrange time and location for set up • Inform teacher of set-up and break down time • Ensure all materials are prepared and ready for transportation • Set up materials for demonstration • Have a general plan for timing
Getting Started	• Introduce ambassador • Explain what will happen during the lesson	• Explain the role of a Dow STEM ambassador • Introduce the module • Remind students of safety rules in the laboratory
Activity	• Maintain classroom procedures, keep students moving from one station to the next • Check in with groups as they work through the stations • Ensure students follow safety procedures • Ensure students follow cleanup and disposal procedures correctly	• Execute the demos/activities • Provide guidance and connections to what you do but no answers • Ask leading questions as you go through each activity • Ensure students follow safety procedures
Review and return of materials	• Make sure all equipment has been returned and put back into their proper locations and containers • Inform students that additional time will be given to complete questions and discuss concepts • Transition to ambassador for wrap-up • Thank the ambassador after for his/her time	• Explain what s/he does and relate it to scientific practices that students used in the lesson • Address concepts such as developing and using models, basing ideas on evidence, and confronting misconceptions as time allows • Answer questions

Lightweighting Module

Pre-class Preparation

1. Print out a copy of the Student Guide for each student.
2. Ensure adequate space is available. For part 3, two spaces are needed: 15 ft x 2 ft for the straight track and 10 ft x 6 ft for the oval track.
3. Prepare classroom. If using 3 separate stations, assemble parts at each station. If using a demo-style with volunteers, assemble Part 1 on table, set Part 2 aside after assembly and assemble tracks on floor to the side, if possible.
    a. Set up the barrier for Part 1 and make sure the rubber band is replaced between the cars (~5 minutes).
    b. Assemble tube for Part 2 (~2 minutes).
    c. Assemble the straight and oval tracks for Part 3. The first Start/Finish line from the straight track will need to be used for the oval track. Therefore, the oval track will appear to be unfinished. Move this piece after the straight track races are completed (~15 minutes).
    d. Turn on the cars and controllers (instructions in Part 3) and change batteries if needed.

Introduction

1. The teacher should introduce the ambassador (without giving away his/her job title or what he/she does). The ambassador should explain what a Dow STEM ambassador does.
2. The teacher should ask the students to write down the ambassador's name and what they think a scientist does in a typical working day.
3. The teacher should explain the structure of the day and the role of the ambassador.
4. The ambassador should introduce the module: Why/How Dow worked with RCR to develop the activities, what are the activities, what to expect. An introduction is included in the student packets (see below).
5. The ambassador should remind students of the laboratory safety rules.

Safety Moment

- Emphasize the individual student's responsibility for following safe laboratory procedures.
- Encourage students to report breakage and accidents as soon as they occur.
- Activity-specific safety precautions will be discussed at the beginning of each part.

Lightweighting Module

Why is lightweighting important?

One of the most important challenges facing the auto industry today is how to improve fuel efficiency of cars. This is driven by a few things, including regulation and customer desire to spend less money on gas. One way to do this is to make cars lighter. As will become clear from this module, reducing mass is one way to reduce the amount of 'force' required to push a car. This leads to better fuel efficiency because gas is what provides the force that makes a car go. Fuel use goes down approximately 7% for every 10% reduction in the weight of the automobile. This leads to less carbon dioxide emission, making cars more environmentally friendly.

What does Dow do to aid in lightweighting?

Dow makes a wide range of materials designed to help make cars lighter. For example, Dow makes carbon fiber-polymer composites to replace heavier metal parts in an automobile. Carbon fiber-polymer composites have the same strength and stiffness as steel but are considerably lighter. Another example that has been in the news lately is the 'glue' that sticks together the new aluminum framed Ford F150 truck. Aluminum is much lighter than steel, so making cars out of aluminum helps reduce the weight of the vehicle. However, welding aluminum presents many challenges. Dow helped make these new cars possible by providing a super-strong glue for bonding the aluminum parts together so that these new cars were just as safe as the steel frame ones.

Why is lightweighting important to RCR?

As explained above, keeping cars lighter increases the fuel efficiency of cars. This is very important to race cars, especially considering how using fuel efficiently can be the difference between needing to take another pit stop with the potential of losing track position and staying out on the track and moving up. Lightweighting also reduces the amount of force on the tires, which is better for the cost of driving as well as better for the environment. As with the fuel consumption, keeping the tires on longer means potentially fewer pit stops.

Part 1: Newton's Second Law

Lesson Overview

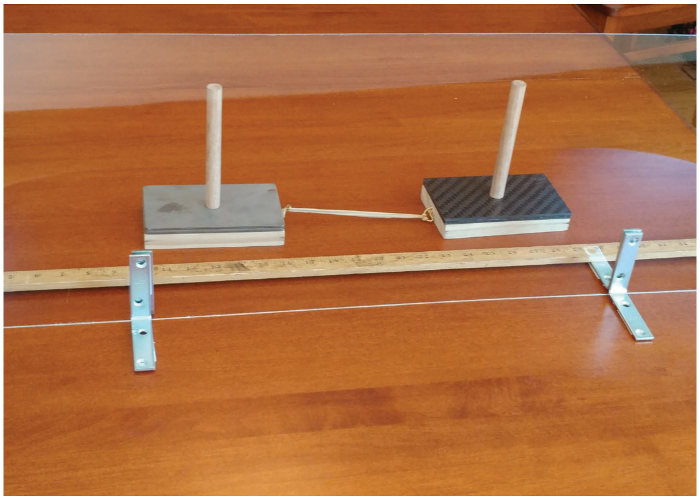
Newton's second law states that force is directly proportional to mass and acceleration. That is, if the same force is applied to objects of different mass, the object with smaller mass (or the lighter object) will undergo greater acceleration.

Materials

- Plexiglas barrier
- Metal brackets to stick to a table to hold up Plexiglas
- 'Cars' (wooden blocks with dowel rod sticking up and a hook on the side) connected by a strong rubber band(s)
- Meter Stick
- Extra Rubber Bands
- Weights to add to the cars: wooden blocks, steel, composite

Pre-class preparation

1. Assemble Plexiglas barrier (see picture) and place meter stick in front.
2. Inspect the hook – make sure it is firmly set in the wood.
3. Replace the rubber band(s) between the cars. This may require unscrewing the hooks slightly to get the rubber band around it.
4. Practice letting go of the cars at the same time a few times.



Safety Moment

- Pinch point hazard: keep all fingers/ hands away from point of impact
- Debris: With crash testing, there is a risk of debris or rubber band pieces flying off. Keep students observing the demo on the opposite side of the Plexiglas barrier to prevent injury
- Composite, wood and steel pieces might cause 'slivers.' Do not rub hands on the pieces – especially the edges.

Part 1: Newton's Second Law

Part 1 Introduction

1. Briefly discuss Newton's second law.
2. Explain the crash test: we're going to crash these two cars connected by a rubber band to identify where the impact will take place.
3. Have them write their hypotheses for the "Develop a Hypothesis" portion:
   a. We will be using simple "cars" attached by a rubber band to observe Newton's second law in action. Will two cars of equal mass meet in the middle? Will one travel more than the other?
   b. What if the "cars" are different mass? Will the "cars" meet closer to the heavier or lighter car?

Crash Testing (8 minutes)

1. Take 2 wooden blocks, each with a dowel rod in the center of the block, connected by a rubber band. Name one 'Car A' and the other 'Car B' for consistency with the table for recording the data.
2. Starting at the center of a meter stick, pull the 2 blocks apart to an equal distance and let them go at the same time.

   *Another option is having 2 students pull the 2 blocks apart to an equal distance and let them go at the same time. This is not recommended since 2 students have a difficult time letting go at the same time.
3. Observe the point at which the two blocks collide on the meter stick and have students record the results in Table 1.

Table 1

TRIAL	MATERIAL ON CAR A, WEIGHT OF MATERIAL	MATERIAL ON CAR B, WEIGHT OF MATERIAL	LOCATION THAT THE BLOCKS MEET
1			
2			
3			
4			
5			

4. Add steel blocks to the top of the two base blocks.
5. Repeat steps 2 and 3. Record results in Table 1.
7. Replace one of the steel blocks with a composite block
8. Repeat steps 2 and 3. Record results in Table 1.
9. Repeat with other combinations. Have the students pick some combinations. Record results in Table 1.

Part 1: Newton's Second Law

Review Questions

These can be done after class individually, or as a group if time permits.

1. Are things of the same size always the same weight?

   Answer: No! Weight and size are not the same.

2. What did you observe as you added more weight to one side?

   Answer: The blocks collided closer to the heavier side

3. Which material was the heaviest? Answer: The steel

4. Which material was the lightest? Answer: The composite

5. How does this relate to fuel efficiency?

   Answer: Newton's second law says that $F=m*a$, so it takes less FORCE to move a lighter object. What we're doing when we burn fuel is creating a force to move a car. The lighter the car, the less force needed, so the less fuel that needs to be burned.

Part 2: Material Strength

Lesson Overview

Even though polymer composite materials are lighter, they can be just as strong as steel materials of equal size. In this activity, we will be comparing the strength of materials when they are impacted by a force, called "impact testing."

Materials

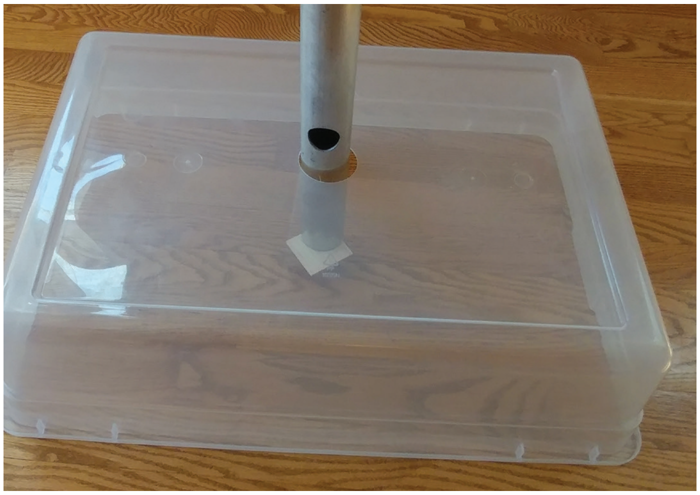
- Aluminum pipe with holes cut in every 6"
- Clear plastic container with a hole in the bottom for the bottom of the pipe
- A stainless steel ball to drop - 3/kit
- Plaques of 2 different materials 2" x 2" x 0.1" depth (Plexiglas, aluminum, composite, balsa wood - 0.125" depth) - several/kit

**Note for ambassador - replace balsa wood, plexiglas and possibly aluminum each time*

Part 2: Material Strength

Pre-class preparation

1. Assemble aluminum pipe
2. Place secondary container upside down on bottom of pipe
3. Grab a stainless steel ball and a few plaques of each type out of the supplies box to place near the demo



Safety Moment

- Pinch point hazard: use caution when dropping the ball into the pipe so as to not pinch fingers
- Debris: Impact testing requires impact of two materials. Keep all fingers away from the bottom of the tube. Ensure the guard is in place before dropping the ball.
- Composite, wood and steel pieces may have cause 'slivers.' Do not rub hands on the pieces – especially the edges.
- Use caution with the edges of the plaques – they may be sharp.
- PPE: Use cut-resistant gloves when picking up broken pieces of Plexiglas to prevent cutting fingers. Do not let students pick up broken pieces.

Part 2 Introduction

1. Briefly discuss that lightweighting is necessary, but we do not want to lose strength in the process of making things lighter.
2. Explain the impact test: we're going to drop a stainless steel ball from various heights to see at which point the plaques are affected.
3. Let them hold the materials and have them write their hypotheses for the "Develop a Hypothesis" portion:
    a. Feel the materials to be tested. What material do you expect to be the strongest?
    b. What do you expect to be the weakest?

Part 2: Material Strength

Impact Testing (8 minutes)

Testing the hypothesis (procedure):

1. Place a plaque block of balsa wood at bottom of the aluminum pipe.
   **ambassador holds pipe in place.*
2. Cover the bottom with the clear plastic box.
3. Have a student drop the ball from the lowest opening on the pipe (6”).
4. Inspect the material for damage.
5. Replace the plaque and repeat steps 1-4 moving up one ‘slot’ (6”) each time until material breaks or shows indentation.
6. Record height at which the material breaks in Table 2.

Table 2

TRIAL	MATERIAL TESTED	HEIGHT OF BALL DROP	RESULT OF IMPACT TESTING
1			
2			
3			
4			
5			

7. Repeat steps 1-6 for the Plexiglas, aluminum and composite.
   **Balsa wood and Plexiglas break fairly low – go up by 6” each time. Aluminum and composite should not break – for time’s sake, go up by 18” until you hit the top. Observe a dent in the aluminum at higher points.*

Review Questions

These can be done after class individually, or as a group if time permits.

1. Are ‘weight’ and ‘strength’ the same thing? ____________________

   Answer: No! Sometimes lighter materials are as strong as or stronger than heavier materials?

2. Why is this important for cars? ____________________

   Answer: It means that we can improve fuel efficiency while not sacrificing the strength of the car and therefore keeping everyone safe!

Part 3: Lightweighting Application

Lesson Overview

This activity will demonstrate how lightweighting impacts racing, and how we can use physics to understand the result. You get to be the racecar driver… We will observe Newton's second law by racing cars!

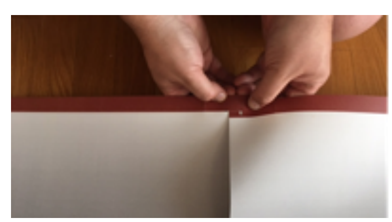
Racing – Straight Track

Materials

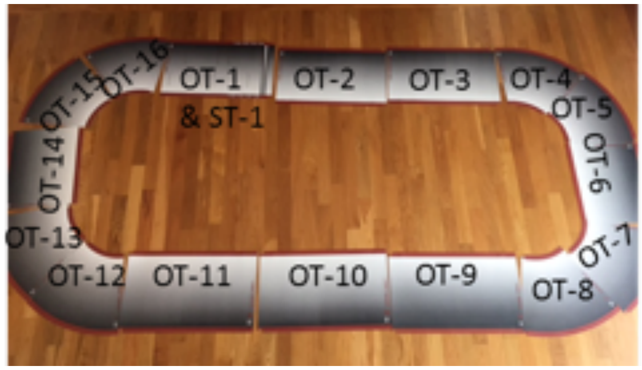
- RealFX Racing track with 2 start/finish lines
- 1 unweighted RealFX Racing car
- 1 weighted RealFX Racing car

Pre-class preparation

1. Assemble the straight track:
    a. Lay out 8 pieces (labeled ST 1-8) – As shown below
        i. A start/finish line from oval track needs to be used
        ii. Note: "Sensor Track" label will be covered once pieces are assembled
        iii. To assemble fit tabs in the slots
    b. Shorter track can be assembled by using less pieces or substituting two B sections with two U sections
        i. Shorter tracks will decrease the difference in times between cars and make explaining the exercise more difficult



Part 3: Lightweighting Application



2. Assemble the oval track
    a. Lay out 16 pieces (labeled OT 1-16) – As shown below. Labels are on the back of the track pieces. OT-1 & ST-1 will be on the straight track initially.
        i. Note: "Sensor Track" label will be covered once pieces are assembled

3. Replace batteries in the remotes and cars, if needed
4. Pair vehicle with remote control
    a. Press power button and release, listen for "Welcome to RealFX Racing, and switch on your vehicle"
    b. Turn on vehicle, listen for "Vehicle and handset paired, and select vehicle mode"
    c. Press the practice mode button, listen for "Practice. Position vehicle on starting grid, and press the check button"
    d. Place the vehicle on the track, then press the green check button. It will say "3,2,1 go" but you don't have to go right away
    e. Repeat for 2nd car (Do not turn both vehicles on at exact same time)

Safety Moment

• Pinch point hazard: keep all fingers/hands away from the wheels of the cars

Part 3: Lightweighting Application

Straight Track Racing (3 minutes)

Straight Track Introduction

1. Explain how you're going to compare the time it takes for each car to travel from Start line to Finish line to calculate the average speed.
2. Explain how the remote control works and how the cars stay on the track
3. Have them write their hypothesis for the "Develop a Hypothesis" portion:
    a. Which car will have the higher average speed on the straight track, the heavy car or lighter car?

Test your Hypothesis (Procedure)

1. Pick 2 students to drive the cars and give them the remote only
    a. Driving tips:
        i. At the start pull the trigger fully towards you
        ii. There is no need to turn the vehicle
        iii. The handset gives the time, so listen closely
2. One car at a time, give a practice run, then 2 trials
3. Record the times given by the handset in Table 3.
    a. The first run you will hear the time from the handset. Pick up the car and replace it at the start line for a 2nd run
    b. On the 2nd run (and subsequent trials), you will hear two times. Ignore the 1st time you hear when vehicle crosses the start line and record the 2nd time you hear after the car crosses the finish line

Table 3

RACER	TIME – RED CAR	AVG. SPEED – RED CAR	TIME – YELLOW CAR	AVG. SPEED – YELLOW CAR
Class Average				

Part 3: Lightweighting Application

4. Repeat steps 2 and 3 on the straight track with the second car and student
    a. Typical times for each car are below. If times are outside this range, consider changing the batteries.
        i. Red Vehicle – Light weight: 1.74 – 1.78 Seconds
        ii. Yellow Vehicle – Heavy weight: 2.19 – 2.21 seconds
5. Calculate average speed in meters/second: track distance is 3.5 meters. (Can be done afterwards)

Racing – Oval Track

Oval Track Racing (5 minutes)

*Move the Start/Finish line from the straight track to the oval track.

Oval Track Introduction

1. Explain how you're going to compare the time it takes for each car to travel from Start/Finish line around the track to the Start/Finish line to calculate the average speed.
2. Explain how the remote control works, changing the force to apply to each car, steering and how the cars stay on the track if they go slow enough to get around the corners.
3. Have them write their hypothesis for the "Develop a Hypothesis" portion:
    a. Which car will have the higher average speed on the oval track, the heavy car or lighter car?

Procedure

1. Pick 2 different students to drive the cars and give them the remote only
    a. Driving tips:
        i. At the start pull the trigger fully towards you
        ii. If you go slow enough, there is no need to turn the vehicle. However, we're racing so use the wheel to keep the car on the track. Also use the trigger to slow down around the corners.
        iii. The handset gives the time, so listen closely
2. One car at a time, have the student practice driving around the track. Have the other students prepared to start writing. After a few times around (when the times seem more consistent), announce 3 times for the other students to record.
3. After a few times around (when the times from the remote seem more consistent), announce 3 times for the other students to record the times in Table 4.

Part 3: Lightweighting Application

Table 4

RACER	TIME - LAP 1	TIME - LAP 2	TIME - LAP 3	AVG. TIME
Class Average				

4. Repeat steps 2 and 3 with the second car and student and record the times in Table 5.
    a. Typical times for each car are below. If times are outside this range, consider changing the batteries.
        i. Red Vehicle – Light weight: 3.9 – 4.2 Seconds (if they're good!)
        ii. Yellow Vehicle – Heavy weight: 3.5-3.9 seconds (if they're good!)

Table 5

RACER	TIME - LAP 1	TIME - LAP 2	TIME - LAP 3	AVG. TIME
Class Average				

5. Calculate average speed in meters/second using the average time in the tables: track distance is 3.6 meters. (Can be done afterwards)

Part 3: Lightweighting Application

Review Questions

These can be done after class individually, or as a group if time permits.

1. Were the calculated average speeds of the two cars different on the straight track? If so, explain why?

2. Were the calculated average speeds of the red car different on the straight track vs. oval track? If so, explain why?

3. Were the calculated average speeds of the yellow car different on the straight track vs. oval track? If so, explain why?

4. Did the results confirm your hypothesis?

5. What are some ways we could improve lap time?

Wrap-Up

Bring the class back together, if needed, for discussion of the various results.

1. Part 1: Were each group's results consistent? Discuss inconsistencies and possible reasons for the inconsistencies.
2. Part 2: Did the plaques all break at approximately the same height? Discuss any inconsistencies.
3. Part 3: Were the groups' data fairly consistent? Was the Red car (lighter) faster on the straight track and the oval track or only on the straight track? If the yellow car (heavier car) was faster on the oval track, why? Discuss lightweighting and how it can affect handling on an oval track. *Remember, NASCAR tracks are not flat around the corners to help keep speeds higher in the corners.

Clean-up

1. Take down Plexiglas barrier and clean the table where the adhesive was on the brackets.
2. Put all materials from Part 1 in the box.
3. Disassemble the aluminum pipe and place Part 2 materials in the box. Dispose of the broken Plexiglas pieces appropriately so the sharp edges are not a risk to anyone else.
4. Carefully disassemble the straight and oval tracks and keep the pieces in order to help the next person.
5. Switch off the cars and remote controls.
6. Make sure all materials are gathered and brought back to the STEM office.

THE SPEED OF STEM

SCIENCE + TECHNOLOGY + ENGINEERING + MATH

Thank you to everyone who contributed to the Speed of STEM Learning Modules, helping to bring to life the importance of STEM in the sport of racing.

The Dow Chemical Company

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