8th Grade STEM DESIGN CHALLENGE
CORRESPONDING ENGINEERING DESIGN PROCESS STAGE IN RED

Unit 4: Laws of Force and Motion
Topic: Designing a Zip-Line Public Transportation System
Subject/ grade level: STEM/ Grade 8

Materials:

Students in teams of 2-3

- Design logs
- Handouts
  - "ForceStations" handout
  - "Math in Science" © handout- Part 2: Newton's Second Law only (pg. 2-3)
  - "ForcesExitTicket" handout
  - 21st Century Skills rubric for project grading
- Websites
  - PHET online simulation of forces: http://phet.colorado.edu/en/simulation/forces-and-motion-basics
  - PHET online simulation in Spanish: http://phet.colorado.edu/es_PE/simulation/legacy/forces-and-motion
  - Free Body Diagrams link: http://www.physicsclassroom.com/class/newtlaws/u2l2c.cfm
  - Distance vs. Time graphs: http://www.sfponline.org/Uploads/71/distance-vs-time-graph-worksheet.pdf
  - Concept transit cars: http://thecreatorsproject.vice.com/blog/8-mass-transportation-ideas-that-make-the-hyperloop-look-boring
- Scissors
- Tape
- Fishing line
- Balloon
- Straw
- Masses
- Design logs

For stations

- 2 spring scales
- 2 rubber bands
- 1 weight
- 1 electronic scale
- 1 wooden block

TEKS

Science

∗Ⓡ SCI.8.6C Investigate and describe applications of Newton's law of inertia, law of force and acceleration and law of action-reaction, such as in vehicle restraints, sports activities, amusement park rides, Earth's tectonic activities, and rocket launches**.**

Ⓡ 8.6A Demonstrate and calculate how unbalance forces change the speed or direction of an object's motion.

Ⓟⓢ SCI.8.2C Collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers.

Math

Ⓟⓢ 8.1B Use a problem-solving model that incorporates analyzing given information, formulating a plan or strategy,

determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution.
8.5H Identify examples of proportional and non-proportional functions that arise from mathematical and real world problems.

ELPS
C1C Use strategic learning techniques such as concept mapping, drawing, memorizing, comparing, contrasting, and reviewing to acquire basic and grade-level vocabulary.
C2I Demonstrate listening comprehension of increasingly complex spoken English by following directions, retelling or summarizing spoken messages, responding to questions and requests, collaborating with peers, and taking notes commensurate with content and grade-level needs.
C3J Respond orally to information presented in a wide variety of print, electronic, audio, and visual media to build and reinforce concept and language attainment.

CCRS
Science
2A7C Use calculators, spreadsheets, computers, etc., in data analysis.
8C2A Understand forces and Newton's Laws.

Math
8C1C Formulate a solution to a real world situation based on the solution to a mathematical problem.
10A2A Connect mathematics to the study of other disciplines.

Cross-Disciplinary
1B3B Gather evidence to support arguments, findings, or lines of reasoning.
1C3B Collect evidence and data systematically and directly relate to solving a problem.

Lesson Objective(s):
Students will construct models of mass transit and analyze the important factors in measuring the motion (time and distance) of an object.

Big Idea(s):
- Motion is achieved when unbalanced forces are applied.
- The amount of mass and force affect the motion of an object.
- Distances and time are necessary to calculate speed.

Differentiation strategies to meet diverse learner needs:
A Spanish version of the "Force and Motion" simulation is at the following link:
http://phet.colorado.edu/es_PE/simulation/legacy/forces-and-motion

IDENTIFY NEED
The teacher asks, "How many of you have ever been travelling somewhere and have been stuck in traffic for a long time? What are some of the causes of traffic?"

Formative Assessment (in design logs):
Students write down their responses and share in groups. (*Possible answers: too many people travelling, inefficient roads, car accidents, etc.*)

The teacher should lead a conversation about how public transportation can help alleviate some congestion, but how Houston has flooding issues that continue to make a widespread public ground level public transportation system problematic.

Scenario for students to work through:
Students are told that they all work for a large transportation engineering firm that has been contracted by the city of Houston to create an elevated public transportation system to travel directly from downtown Houston to the Galleria.

The expectations of this project are as follows:
Working in teams, students will design a zip-line vehicle that is able to travel across the length of the room (or from chair to chair) using only the materials given: scissors, tape, fishing line, a balloon, straw, and a mass. The mass selected will represent the weight of the passengers and should be the same for each group. **The objective is for the vehicle to reach the other end in the fastest time possible using only the materials given to them.**

RESEARCH THE PROBLEM

Have students view and complete a series of stations to investigate different types of forces- tension, normal, and friction- by completing the "ForceStations" handout (in-depth directions here). See the stations materials lists below. Minimal materials are needed to conduct this lab and it serves as a great way for students to be introduced to the common forces covered in general physics.

Station 1: Tension Forces. Students investigate how a spring scale records mass and force.
Materials needed:
2 spring scales
2 rubber bands
1 weight

Station 2: Normal Forces. Students investigate normal forces by reading a scale.
Materials needed:
1 electronic scale
1 wooden block

Station 3: Friction Force. Students utilize a computer simulation. They move objects back and forth across the screen to investigate how the friction force changes as an object moves.
Materials needed:
Forces and Motion PhET link on "Friction": http://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html (English here, Spanish version in materials list) and differentiation above.)

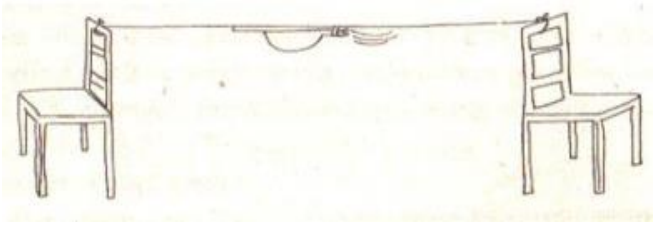
Differentiation:
The activity should be geared towards encouraging students to operate in learning mode, not performance mode. Ask them some of the following key questions at each station:
1. "What can you discover about the physics involved?"
2. "What connections do you find?"
3. "How does what you saw make sense?"
4. "How can you explain what you have discovered?"

Formative Assessment:
Have Teams complete the "ForceStations" as they move through the stations.

DEVELOP POSSIBLE SOLUTIONS

Teams will devise and test out different design options. Students should investigate the impact adding a mass to represent passengers will have on their speeds.

Setup the class in the following manner: Tie two lines across the room parallel to each other with 2-4 feet of space between them. It is up to you if you want lines to be parallel to the ground or slanted (whether they have to go up or downhill). You want them spaced close enough so that it feels like two parallel racetracks, but far enough that the students' vehicles do not bump into each other.



Or, you can have teams set up their line using chairs like pictured.

Differentiation:
Once teams have made adequate progress making and testing their designs, the teacher should bring the class together to discuss the norms of building. Provide questions like the following:

1. "What are some ways your teams are using the balloon?"
2. "Did we notice any issues with how to place the balloon on the straw?"

(**Teacher Note:** Having teams share out the norms will give them the opportunity to learn from others.)

Formative Assessment (in design logs):
Have the teams record the time and distance data for 3 trials of their first design. (**Teacher Note:** Be sure to go over how you want students to organize this data and how to use this data to inform future changes.)

SELECT THE MOST PROMISING SOLUTION

The teacher should lead a class discussion as to the cause of the motion. Possible questions follow:

1. "What caused the vehicle to move?"
2. "How can you describe the movement of your vehicle?"
3. "What caused it to move faster or slower?"

(**Teacher Note:** The teacher should be sure students understand the important point: that all movement requires an energy, or force, to start and end movement.)

Formative Assessment (in design logs):
Teams will make their last round of changes, decide which design is the best, and then create a sketch of their final design.

CONSTRUCT A PROTOTYPE

Have teams construct their design in its final, testable form.

Differentiation:
To help students evaluate the effectiveness of their prototype, provide them with the following scaffold to complete in their design logs:

What are you trying to learn from your prototype?

Formative Assessment (in design logs):
Have teams explain in their logs the step-by- step process they used to construct their final prototype.

TEST AND EVALUATE PROTOTYPE

Students should test this final version by recording the time and distance data of three more trials. Have teams also graph this final set of data.

Differentiation:
The following link provides extra help for students having difficulty with interpreting and creating distance vs. time graphs: http://www.sfponline.org/Uploads/71/distance-vs-time-graph-worksheet.pdf

Formative Assessment (in design logs):
Questions like those below will help teams evaluate their final designs.
1. "Did the shape of the balloon affect how far (or fast) it travels? Why or why not?"
2. "Did the length of the straw affect how far (or fast) it travels? Why or why not?"
3. **"**Did the angle of the string affect how far (or fast) it travels? Why or why not?"

COMMUNICATE THE DESIGN

The teacher will reinforce the idea of balanced and unbalanced forces in the design challenge by stating the following: "As scientists and engineers, we need to be able to quantify and communicate how much force is being applied to objects. How do you think we can communicate this information?" The teacher will introduce, discuss, and demonstrate how to create free body diagrams at the following link:
http://www.physicsclassroom.com/class/newtlaws/u2l2c.cfm

Differentiation:
The teacher and the teams can do some of the odd or even practice examples found at the link above together and discuss the answers as a class to ensure understanding of the depicted diagrams.

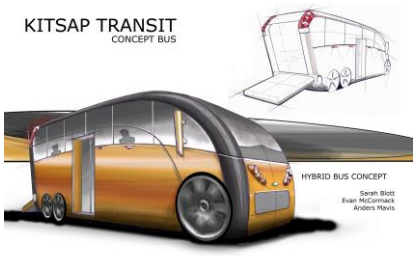
Formative Assessment (in design logs):
Students will complete the "ForcesExitTicket" handout to summarize what they have learned about free body diagrams.

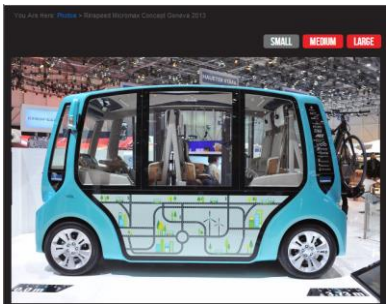
Extension:
Students will be challenged to draw a free body diagram for their zip-line, both at rest and moving. Then, in a class share of their designs, teams should share their diagram and elaborate on 1) what caused their vehicle to move, 2) a description of the movement of their vehicle, and finally 3) the causes behind their vehicle moving faster or slower.

REDESIGN

Tell students the following:
"The city of Houston has decided that the zip-line design may be too expensive to implement city-wide and has hired our engineering firm to redesign our mass transportation designs to replace the zip-line."

Differentiation:
To stimulate creative idea generation, share some images of concept transit cars like the following by conducting a Google search. One great website to explore is http://thecreatorsproject.vice.com/blog/8-mass-transportation-ideas-that-make-the-hyperloop-look-boring to stimulate thinking! (Manually put link in browser, if necessary.)





Formative Assessment (in design logs):
Have students draw a sketch and write a paragraph description about their new concept transportation car/system and its features.

MATH CONNECTION

Teams can calculate forces and accelerations based on the formula, F=m x a.

Formative Assessment:
Teams can complete the math examples provided in the "Math in Science" © handout. The "Part 2: Newton's Second Law," section focuses on F=m x a.