Engineering Design Challenge

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The E in STEM: Meaningful Content for Engineering

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Phase I - Research and Planning

In this hands-on exploration (NASA's On The Moon), I'm asking my students, aka, grandkids, to design and test a spacecraft that will help them land on a specified target on the moon (Big Idea) using energy and the principles of motion to help astronauts travel a certain distance, and to land safely on a specific target. They will have to build and test prototypes that will not only help astronauts to hit the specified target on the moon but endure and withstand the conditions of entering the moon's gravity. The group of students I will be working with range in grades 4th through 7th (ages 9 through 11).

I plan on focusing on the Kentucky Science Standard 07-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. Another Kentucky Science Standard 07-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

In addition to science standards students will also use the ELA Common Core Literacy Standard RST.6.8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks and WHST 6-8.1 Write arguments focused on discipline content.

Students will also use the following math standards MP.2 Reason abstractly and quantitatively, 6.RP.A.1 Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities, and 7.RP.A.2 Recognize and represent proportional relationships between quantities.

Engineering Standards used in this project will include:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Students will work their way through the “mission” of launching a rocket to land on a specific target on the moon. Students will also design and build a spacecraft that helps the astronauts (marshmallows) land safely on the moon. Students will need declarative knowledge about the moon such as how far away it is, that it's a natural satellite in space, and other characteristics of the moon such as that its gravity is one-sixth the gravity on Earth, and very little atmosphere. Students will also need to know the basic parts of a rocket such as the fins, nosecone, and body. Students will also need an understanding of potential and kinetic energy and what might affect the amount of potential and kinetic energy of objects in motion. When students design their spacecraft, “the lander” they need declarative knowledge about gravity, how quickly things fall as related to speed and moon’s gravity. They will need to understand the concept of force and what might affect how hard or soft an object might land as well as a basic understanding of Newton's Laws of Motion.

Students will also use procedural knowledge that ranges from well structured to ill structured as they build the rocket to travel various distances and then adjust their design so that the rocket will go the desired distance and land on a specific target. Some variables they may choose to adjust are the length of the straw, fins/no fins, position of fins on the rocket, the number of fins to attach, the amount of air to put in the engine of the rocket, the angle of the string to direct their rocket, the mass of the object traveling to the moon, etc. When students design and build the spacecraft, the lander, they will also use procedural knowledge to think through the steps necessary to ensure that their spacecraft doesn't fall too quickly or dump the astronauts out of the spacecraft. Students will need to determine types of materials to use that can absorb the energy but still get the astronauts to their target safely.

One other possible activity that might work well with the two previously mentioned activities described above is the "Touchdown". In this activity, students are using their knowledge of the amount of power required to get their rocket to the moon and the structure of their lander to help them land their astronauts (marble) safely on a target. Here students are using the previous knowledge and data collected from their straw rocket as well as how to cushion the astronauts landing to ensure that the spacecraft and astronauts land on the target zone taking into account the amount of energy (potential and kinetic) will allow them to hit the target zone and prevent the forces encountered from injuring their astronaut.

Phase II

For my engineering project I modified the "On the Moon" activity by Design Squad to meet a variety of ages. My grandkids were my sample students ranging in ages from 9 to 11. I wanted the journal notebook to be simple enough that everyone could do it, but I didn't want it to be overwhelming. I purposefully didn't include data tables for students to record quantitative observations because of the ages but I will have measuring tools available for them to use and let them decide on how and when to use the measuring tools and whether or not to use tables to organize their data. I was trying to avoid a "canned" activity where everyone arrives at the same answer in the same way. When activities are "canned", students don't often think for themselves. They are just following steps and there is very little variation in the designs. I wanted kids to ask their own questions and explore their own designs with very little guidance from me. I did prompt and guide some because I didn't want the tasks to be too difficult that the kids would get discouraged. Here's a link to my student notebook journal I created to help students to record their observations and notes about their rocket.

https://docs.google.com/document/d/19EvS6uOpiHNn74Ckn8IEi2PmVqPXgYgxcIB1pvJQ1Yg/edit?usp=sharing

I attempted to draft the student journal to follow the basic design process using the NASA Model. My project was divided into two tasks. The first task asked students to first build a rocket that was powered by a balloon, and the second task asked kids to build a cabin to house an astronaut and help that astronaut to land safely on a specified target on the moon.

Reflection

Using the NASA Model, I asked my grandkids to think about a rocket like what NASA would use to launch to the moon. The standards I wanted kids to be able to discover were related to kinetic energy and potential energy and how distance can affect this energy (PS3-2, PS3-5) as well as understand Newton's First Law of Motion (PS2-1). In the activity, we discussed types of energy (kinetic and potential) involved as well as how distance and gravity affects objects and how gravity is different on the moon. We also discussed a little bit about Newton's Laws of Motion. This activity could use a lot of math, everything from basic measurement to calculating the amount of kinetic energy or even calculating the amount of force. Using the NASA design model, kids were first asked a question (s). Then they were asked to imagine a design that might help them answer their question by drawing it out which also served as their plan to construct/create their model. For the most part the kids liked illustrating their models but needed prompting to include labels as well as measurements. My grandkids also didn't want to share their ideas with their siblings. So, I think a future modification might be to make them a team from the beginning where they are forced to work together and assign roles. I didn't this time because I wanted each person to be able to visualize their own ideas.

They then tested it out, made improvements, and retested their models. I wanted my grandkids to feel free to think out of the box and try their ideas without influence from me. I did offer suggestions at times that they could accept or reject. So, how did the activity work out? I think overall it did go well, but I did have some difficulties trying to get my grandkids in student mode versus “We’re at grandma’s house” mode . My grandkids (Gabriel, Anabelle, and Madalynn) are very curious by nature and they are also very competitive with each other. They naturally tested out their design and modified it constantly. They didn’t like planning it out before constructing or recording things on paper.

I started the activity with the idea that they could just “play” with materials and just create with the focused question, “How can I build a rocket with given materials like a balloon, straws, string, paper, and some other odds and ends. My grandkids were very excited to get started and we discussed their ideas and how rockets were designed in the real world. I used some of the literature from the Design Squad to guide them in their discussion. I made the mistake of laying all the supplies out at once which meant the kids were focused on that and not on writing their ideas on paper during the image and create part of the NASA model. They did great imagining and trying to create their idea of a rocket physically. The mechanical aspects related to motion of the rocket did cause some frustration. I believe the frustration was due to lack of experience with rockets and not enough background knowledge. This lack of experience and background meant they couldn’t get a concrete idea of what or how a rocket performs in the real world.

In their “play” period they noticed that the rocket didn’t really have a specified direction. The rocket traveled vertically up and down or in a circular motion. We discussed this and I asked them to record what they observed and challenged them to get their rockets to travel in a particular direction. We also discussed what we could do to give the rocket more specific direction. They reasoned that it was too light or lacked enough power. This is when the grandkids decided to attach a paper towel roll to their drawings to add mass and to look more like a rocket.They also added a guide wire to help the rocket travel a specific path to counter the effects of gravity. They tried a straight no slope path and a slanted slope path. Older kids could actually measure this and see how slope affects the speed of their rocket. Gabriel was going to add a nose cone and fins, but decided against it when he saw that the girls had simply run a fishing wire through their straw to guide the rocket in a particular direction.

Things became frustrating at this point. The kids wanted their rockets to perform as expected but it wasn't. The rocket would have too much power or not enough. They also lacked teamwork and didn't want to take time to hear each other out. Very little verbal communication took place among them. Each wanted their rocket to be the one to travel the specified direction and to have enough power to reach the desired destination first. Recording their findings was also an issue. No one wanted to write down what happened and what they changed on the rockets to improve the rockets performance. I had to get the kids to put their rockets down to get them to put anything down on paper. They wanted to continue to test and make modifications, but it was taking a lot of time and the kids were getting tired.

To keep the project moving toward the end goal, I ended up telling them to just move on to the next task of building a cabin (papercup) to help astronauts (marshmallow) to land safely on a particular target without falling out. I explained that sometimes this happens in the real world but just taking a break from a task can help. I had envisioned in the second task for the kids to build a cabin to support the astronaut as a separate engineering component and if time permitted I would allow them to construct the two different models together as a final piece. However, the kids ended up automatically attaching their cabin to the rocket they had constructed in the first task. The kids thought that their rockets were very unique in design, but in reality the kids rockets were very similar in design. There were some slight variations such as Anabelle had covered the end of her paper towel tubes to prevent air from escaping. They may have not communicated verbally with each other but did take time to stop and make observations of each other's rockets which I could see they internalized and used to make modifications to their own rocket and cabin. Gabriel's and Anabelle's astronaut kept falling out of the cabin as the rocket moved along the path. Madalynn's cabin and the astronaut did reach the target. Madalynn believed her rocket was the most successful because she had added a jetpack to the cabin. However, her astronaut didn't actually tip out to land safely on the target. Gabriel had tried adding a trap door that was supposed to drop the astronaut out when it reached its target, but the astronaut kept falling out just after the rocket launched. Anabelle's astronaut also had similar issues like Gabriel's design and sometimes the rocket would get stuck in the middle of the course because air wasn't being released consistently. Madalynn's rocket and astronaut did make it all the way to the target but didn't actually land as expected on the target. She thought her rocket design was more successful than the others because she added a jetpack to it.

If I use this current activity as an exploration, I wouldn't change a lot, but I would try to do a lot of modeling and guiding students through it to show what good observations look like and students can practice this with me until they develop a natural tendency to do this. I discovered my grandkids did not have a lot of experience. Unless a student is naturally an organizer and detail oriented, I believe students need repeated exposure to good data keeping and many experiences where they apply the engineering process. I would definitely work on communication skills and probably do selective grouping so that I could mix up the personalities somewhat. I would definitely modify it by teaching more background information and adding more sections to the notebook so that it was more structured and organized until kids have a better understanding of data and the recording of the data. I would also emphasize the vocabulary they should use by writing about three to five terms on the board so I can see if they understand and can apply.

The design process does help and I think it is less intimidating.The scientific method seems to be somewhat linear and restrictive in thought and flow. Whereas the design process is circular and when something isn’t as expected you make note of it and almost immediately make modifications. So overall, I believe my grandkids did have an understanding about how distance could affect kinetic and potential energy as well as how inertia influences the motion of an object to change direction or speed. Even though they didn’t quite achieve the goal of landing their astronaut safely and they didn’t write everything down, they did talk to me about their models and they could see that not only speed and distance affected the amount of energy but that mass impacted this energy as well.