Turning and Flinging: Simple Machines in the Classroom

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ENGR 2020/3030/4040

4/25/06

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ABSTRACT

Students enrolled in a multidisciplinary service learning engineering design course work in groups to make working prototypes of hands-on experiments in STEM (Science, Technology, Engineering, and Mathematics) areas for K-12 teachers. The module to be discussed addresses the topic of "simple machines," geared for a 3rd-grade classroom but adaptable to other age groups. The student-designed materials involve plastic gears used on separate platforms designed to allow the young students to place and move components in specified or experimental locations. Students could change the positions and relationships of the components to have variety of outcomes. As a starting point, two to five different configurations would be used by the 3rd-graders to become familiar with how the various machine components work. Then, the students would be free to innovate the gear arrangement as they wished. An additional project involved the use of catapults. Students were given a list of materials to build one, develop the idea of the lever. This lesson was meant to be inquiry-based such that children would be free to ask questions and use their own creativity to build their catapult. A competition of accuracy was be implemented to increase motivation. Students in the class were asked for oral and written responses to observational questions throughout the process. The lesson was evaluated by having students link the scientific method and knowledge of simple machines to their design processes and stating their results. The classroom trials proved successful but there were several flaws such as the need for more time, to keep their attention, for a visual aid or example demonstration.

Introduction

Teachers are important, yet they are busy individuals. They have to maintain a class, teach a curriculum, grade papers, organize events, and educate the children of America. Although teachers would love to try new, innovative projects, they often don't have the time to brainstorm, design, and experiment with new ideas or projects that they could use in the classroom. This is where we come in.

Our main objective for this class was simple: develop projects using the engineering design process that will be used in a K-12 classroom. In addition to this overarching objective, our group set several sub-objectives that included the following:

- Identify a topic that can be designed for use in the classroom
- Research the topic
- Brainstorm activities that we could use that would educate students about the topic
- Design the prototype(s)
- Link to MICLIMB
- Test the prototypes in a group setting
- Test the activities in a classroom setting
- Evaluate the results and make recommendations

We were able to satisfy most of these objectives. The only one we were not able to fulfill was the objective concerning the testing of the prototype in a small group setting. This was not possible due to scheduling conflicts and a lack of time to organize a group testing.

Background

Simple machines, every day we use them and every day they make our lives easier. In their simplest form these machines need only human muscle power from which an ordinary human can move several times their weight. In addition to this, simple machines have prevented injury and have reduced the amount of time and energy spent on a task. There are six simple machines that are widely acknowledged and they include the wheel and axle, the pulley system, the wedge, the screw, and the inclined plane.

Each machine works differently from the others. The wheel and axle, described as a central wheel attached to an axle, works such that when you turn the wheel, you also turn the axle. The principle behind this simple machine is that it takes far less force to turn the wheel then the small axle and since the wheel is larger then the small axle and in addition, a turn of the wheel often results in several turns of the axle. The pulley system, described as a pulley combined with a rope, is a simple machine that reverses the direction of force applied to it. For instance, when you pull down on the rope, the object attached to the other end of the rope goes up. The wedge, described as two inclined planes that are connected together to form a "V", works by causing a change in the direction of the force applied to it such that the force moves perpendicular to the inclined planes. The screw, described as a central post by which an inclined plane is wrapped

around it, works by converting a rotary motion into an up-and-down motion. The inclined plane or ramp can be described as a flat surface that is inclined at an angle and works by reducing the amount of force needed to move an object upward (essentially how a ramp works).

In order to teach students the importance and the relevance of simple machines, we intended to devise and administer two experiments that students could do that would help demonstrate this concept. Our first idea involved gears on a platform and the second idea involved using the idea of simple machines to build a catapult.

Methodology

The first proposed design involves plastic gears on separate platforms. They are designed to allow students to place components in specified and experimental locations. Each gear has a base which corresponded to it and could freely be joined with others. This allows for many different configurations. To focus more on the visual relationships with gears, we would provide example configurations. We will stress the extreme differences such as high to low and multiple gear setups. Along with the given examples, time will be allotted for the students experiment off script and learn on their own.

They would then be asked observational questions like, "Why does one gear rotate in one direction while another spins in an opposite direction?", "When a large gear turns a small gear, what happens?", and "Can you find other ways to make gears spin faster or slower?" Also, we would attempt to get them to realize that the speeds and forces change by having a discussion about what gears can be used for.

The second idea proposed involves students creating their own simple machines. At first, we found a lesson plan that had students making their own device that would open a door from across the room. We liked this idea, but as we went further into the project, we realized that this might not be the best idea to use in a classroom. Some logistics made this project not as appealing for classroom use, such as not enough door handles for students to use and/or not having the correct types of door handles available in the classroom. Also, we thought that this project would be harder to tie into direct concepts that the students would need to learn.

Instead of the original proposed idea of a simple machine that would open a door, we came up with a new proposal for a simple machine that would act as a catapult. The basic principals of this project would remain the same – have students create a simple machine to complete a specified task. With this project, we can have students create their own catapults (within small groups) that are designed to launch jumbo marshmallows. We would give the students some materials that would allow them to create the machines and then when they were done constructing they would be allowed to test the machines and determine which group had the most successful design. After these steps had taken place, we could go into a lesson on simple machines and levers and reinforce what the

students had learned about these topics through their experimentation. The ideas for this project came from the website http://www.edheads.org/activities/lesson_plans/sm_03.pdf

Meeting with Teacher

On February 21, 2006 our group met with Ms. Engels-VanEck. At the meeting we received background information on the students in the class such as the number of students in the class, math skills of the general class, the general class dynamics, as well as some of the materials that we would be able to use. In addition to this, she made a request from us that we try to incorporate the scientific method into our activities. Ms. Engels-VanEck also approved of our ideas for a gear activity as well as the catapult activity. She suggested that we incorporate some sort of competition into our activities since her students are very social and like to compete against each other. This would also help to keep their attention, which she said we might struggle with if we tested on a Friday. She let us take a textbook that the students were using home and Jenna went to meet with her the following week to get more materials from her classroom.

Experiment Set-Up and Group Prototype

After our meeting with the teacher, our group split up the work to be done between our three members. Andrew developed the gears project and Jenna developed the catapult project. Jarred developed the lesson plans needed for both experiments. Due to time constraints, our group was unable to test our projects before our actual classroom testing.

The decision was reached that we would focus only on catapult and the gears activity and abandon the pulley portion of the gear experiment due to lack of time. The individuals of the groups tested their projects on a one-on-one basis.

Budget

The budget for the gears experiment was:

- $39.95 for the set of gears
- $0.00 for the drive to teach

The budget for the catapult experiment:

- Our total cost for the catapult project kits came to $37.88
- Each kit cost $6.31 to produce (Six kits in total)

Classroom testing

Our classroom trial went very well as we were able to hold the attention of the students and we feel that they took something away from it. Some of the things that we did notice include the fact that on the gears project some of the students had a hard time keeping track of which gear was the follower gear and which one was the leader gear. Another thing that we failed to do involved the fact that we did not emphasize how important it was to line up the gears (have the lines drawn on the gears match up such that they are parallel). Our idea to separate the class into groups of four worked out brilliantly and due to the difficulty of counting the rotations of the gears, students were forced to work together and we would often hear the entire groups counting the rotations of the gears. We also had some concerns that we went over the material a bit too fast and our failure to have an example gear project to demonstrate, caused difficulty and led to several questions that could otherwise have been averted. Time was also a factor, as we now believe that an activity like this requires more then 40 minutes to successfully complete.

The catapult project also went over very well as the class quickly became abuzz in terms of discussing how to develop the catapult. The complexity of the project did cause some hesitation as it seemed to us that the class was not used to such an open inquiry project. The students did walk away from the project with a sense of what a catapult is as well as information about what not to do with them (i.e. two spoons did not work out as well as one spoon). Many of the materials in the kit were used, although many of the designs came out similar in appearance. Since an outside observer in the class told us that the groups did not consult together, we concluded that this design came about independently. What surprised us the most was how enthusiastic the students became as they even started standing on top of their desks. There were issues with leadership within the group (i.e. who was in charge) and we also noticed that the students were greatly concerned with the appearance of their catapults as some groups tried to make their catapult resemble an animal. One other thing to note, was that the decision of the group to hold off handing out the marshmallows that were to be launched in the competition ended up being beneficial to all and the competition overall proved to be an excellent motivator for the students.

Conclusions

We concluded that the concepts that we presented were very workable with what Ms. Engels-VanEck had in mind. Both projects seemed to fit well within her curriculum and we could introduce the simple machines topic around the same time that she wanted to introduce them with her class. We ended up being overzealous in our quest to educate the students on the complexity of a specific few simple machines. As a result, we had less time then we expected to complete each project if we wanted all our objectives to be achieved.

Recommendations

For those who would like to carry out these projects in the future, we suggest that either more time be allotted for the projects, or try to the break the projects into more than one time block. The students that we worked with took longer than expected to get rolling, but when they did, there was no stopping them. Reading over the instructions with the students and going through the worksheets step by step (possibly on an overhead projector) would help as well. This would help to clear up the confusion that the students had and lets the students see the purpose of the project. It would also help to have more visual aids to help the students better understand what was going on within the projects.

Acknowledgements

Jill Engels-VanEck
Dr. Andrew Kline
Dr. Betsy Aller
Dr. Mark Jenness
The American Science Foundation

Suggested Websites (References):

www.Edheads.org

www.mos.org/sln/Leonardo/InventorsToolbox.html

http://www.fi.edu/qa97/spotlight3/spotlight3.html

Appendices

- Lesson Plan for Catapults
- Lesson Plan for Gears
- Student worksheets for catapult activity
- Student worksheets for gears activity

Lesson Plan for Simple Machines: Catapult

Grade Level: Grade 3 and up

Subjects: Physical Science

Duration: 40 minutes

Description: Students will be given a kit of materials from which they will develop a catapult capable of launching a marshmallow at a given target using knowledge of the simple machines.

Goals: Students should be able to identify the different types of simple machines as well as understand how simple machines are used in the real-world.

Objectives (MICLIMB only):

1. (C) I.1.m.2) Conduct a scientific investigation
2. (C) I.m.1) Be able to answer a scientific question by gathering and analyzing evidence
3. (R) II.1.e.1) Observe the importance of evidence in making decisions
4. (R) II.2.e.1) Illustrate scientific concepts through creative expression
5. (R) II.2.e.3) Describe how technology is used in everyday life
6. (PMO) IV.3.e.4) Identify and use simple machines and describe how they change effort

Materials:

(Materials in kit)

- Rubber bands
- Paper clips
- Spoons
- Craft sticks
- Index cards
- Straws
- String
- Styrofoam ball
- Clothes pins
- Tape

Vocabulary:

- Work – something done whenever a force moves an object through a distance
- Compound machine – a machine that uses one or more simple machines

- Simple machine – one of six kinds of tools with few of no moving parts that make work easier
- Lever – simple machine made of a bar or board that is supported underneath at the fulcrum
- Fulcrum – the point on which a lever is supported and moves
- Inclined plane – simple machine that is a flat surface with one end higher than the other
- Screw – a simple machine used to hold objects together
- Pulley – a simple machine made of a wheel and a rope
- Wheel and axle – a simple machine that has a center rod attached to a wheel
- Gear – a wheel with jagged edges like teeth
- Wedge – a simple machine used to cut or split an object

Procedure:

***Intro*:** (*Note to teacher*: this is designed to be a supplemental activity to a previous lesson on simple machines)

Simple machines are used in everyday life; it is recommended that you ask students what they have observed simple machines used for, what are simple machines, as well as any other things they might know about the topic. Afterward, mention that today's lesson will cover two types of simple machines: the lever and the gear.

Lesson focus / setting up the experiment: The lever is an important tool used today by all societies around the world from the farmer who uses a stick to move a boulder to the see-saw used in the playground. Students will be given a kit of materials from which they will be asked to develop a catapult capable of launching small marshmallows at a target. You can also role-play if you like, using a situation such as you are the engineer for a king and he needs you to develop a catapult capable of knocking down the castle walls of the enemy (something you can integrate into a medieval history lesson).

Encourage the students to use the scientific method as they try to develop catapults since it may be helpful for them. It is also possible to turn this lesson into a competition with the group that hits the target wins or the group that launches the marshmallow the farthest wins.

***Evaluating the data*:** Encourage students to write down their design thoughts on a piece of paper, draw and label pictures, then have the students write down the eight (or six) steps of the scientific method and have the students tell what they did for each step.

It is recommended that you look over their design worksheets, check and see if they applied the scientific method to their work, and test to see if their models are appropriate.

Assessment: This is an experiment that is designed to get students to think about simple machines and how they are used to do work and reduce the effort that we exert on objects. Students can also see that simple machines can be made from a variety of different materials and have many different uses

Suggested Websites (References):

www.Edheads.org

Lesson Plan for Simple Machines: Gears

Grade Level: Grade 3 and up

Subjects: Physical Science

Duration: 40 minutes

Description: Students will be given a set of gears and pulleys, from which they will construct several assemblies of gear/pulleys and then evaluate the machines.

Goals: Students should be able to identify the different types of simple machines as well as understand how simple machines are used in the real-world.

Objectives (MICLIMB only):

7. (C) I.1.m.2) Conduct a scientific investigation
8. (C) I.m.1) Be able to answer a scientific question by gathering and analyzing evidence
9. (R) II.1.e.1) Observe the importance of evidence in making decisions
10. (R) II.2.e.1) Illustrate scientific concepts through creative expression
11. (R) II.2.e.3) Describe how technology is used in everyday life
12. (PMO) IV.3.e.4) Identify and use simple machines and describe how they change effort

Materials:

- Pulleys
- Gears set
- Platforms for gears and pulleys

Vocabulary:

- Work – something done whenever a force moves an object through a distance
- Compound machine – a machine that uses one or more simple machines
- Simple machine – one of six kinds of tools with few of no moving parts that make work easier
- Lever – simple machine made of a bar or board that is supported underneath at the fulcrum
- Fulcrum – the point on which a lever is supported and moves
- Inclined plane – simple machine that is a flat surface with one end higher than the other
- Screw – a simple machine used to hold objects together
- Pulley – a simple machine made of a wheel and a rope
- Wheel and axle – a simple machine that has a center rod attached to a wheel

- Gear – a wheel with jagged edges like teeth
- Wedge – a simple machine used to cut or split an object

Procedure:

Intro**:** (*Note to teacher*: this is designed to be a supplemental activity to a previous lesson on simple machines)

Simple machines are used in everyday life; it is recommended that you ask students what they have observed simple machines used for, what are simple machines, as well as any other things they might know about the topic. Afterward, mention that today's lesson will cover two types of simple machines: the lever and the gear.

Lesson focus / setting up the experiment: Gears are important in history, from ancient times onward. They mainly serve as ways of transferring the direction of force and can either amplify or reduce force. One of the more memorable uses of gears comes from their involvement in clocks and their use in the early industrial age.

Display in front of the class several gear configurations that have been pre-assembled. Show the students how to count the revolutions of the gears and the best way to spin them and explain how when a larger gear is placed next to a smaller one, the smaller one will move differently. From there, it is recommended (depending on grade level) an engineering way to look at the ratios, along with an explanation of what a radius is.

Then, have the students break into groups and work with the gear configurations. After 15 minutes, it is recommended that you go around to the groups and see if they have any questions about those configurations and what you discussed earlier. After this, if time permits encourage students to explore possible gear configurations of their own design using the scientific method as a guide.

Evaluating the data**:** The best way to evaluate the students especially since there is a instructional lecture/experiment at the beginning of the lesson, it would be best to use the enclosed handout.

Since you also have the option of making this experiment open-ended, it is recommended that you look over their design worksheets, check and see if they applied the scientific method to their work, and test to see if their models are appropriate.

Assessment: This is an experiment that is designed to get students to think about simple machines and how they are used to do work and reduce the effort that we exert on objects. Students can also see that simple machines can be made from a variety of different materials and have many different uses.

Student Worksheet

Build Your Own Catapult!

We will be having a competition to see who can create the most accurate and creative catapult.

<u>Materials Needed</u>:
-Kit with all of the materials you will need inside.

<u>Goal</u>:
-Each group will be making a catapult from the materials in their kit. The goal is to make the catapult able to launch mini marshmallows accurately onto a bulls-eye poster on the floor in the middle of the room.

<u>Procedure</u>:
-Brainstorm with your group what you would like your catapult to look like.
-On the design worksheet provided, write down ALL of the ideas that you come up with.
-Decide as a group which design you want to create.
-Write down how you will create this design and draw a picture if you'd like!

<u>Rules</u>:
1. The marshmallow must be touching the catapult before it is launched. (NO hitting the marshmallows like you are hitting a baseball and using the catapult as a bat!)

2. No throwing or eating the marshmallows!

3. Be creative and use your imagination! It's o.k. if each group's catapult looks different!

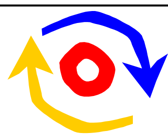
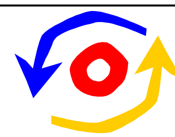
Design Worksheet

Results

How Close did you get to the target?

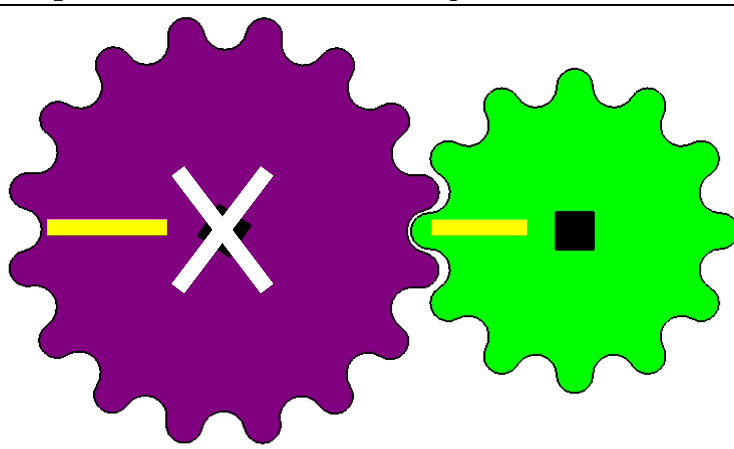
Were you happy with your catapult? Do you think that it worked well?

Key:

Clockwise:  **Counter-Clockwise:** 

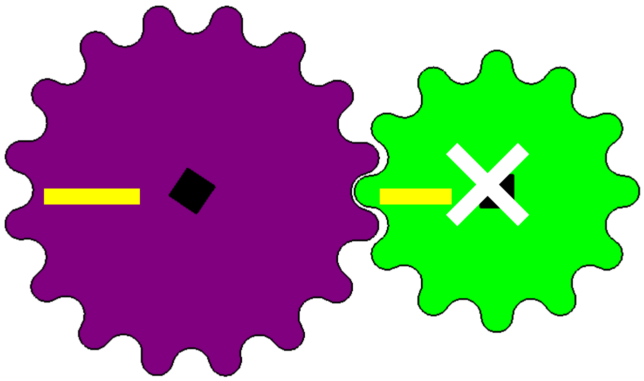
Leader: The gear you spin
Leader gear is marked by an X
Follower: The gear(s) which spin as a result of other gears' spin
Revolutions: Number of times a gear spins all the way around

After every new picture, re-construct the gears to match

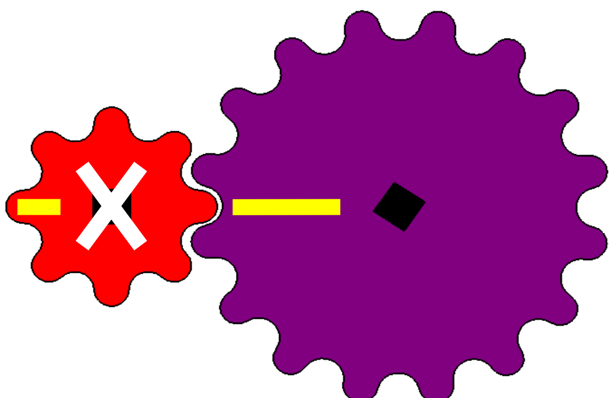


Which direction does the "Follower" gear turn when you rotate "Leader" gear clockwise?______________________________________

Rotate the "Follower" gear 6 times. How many times does the "Leader" gear revolve?____



Rotate the new "Leader" gear 6 times. How many times does the new "Follower" gear revolve?______________________________________



If you rotate the Leader 6 times, how many times does the Follower revolve?

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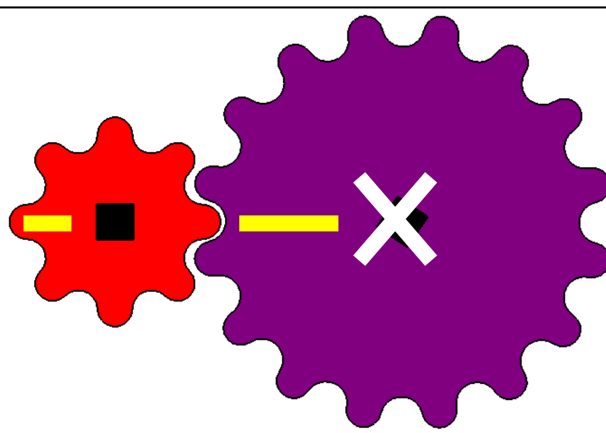
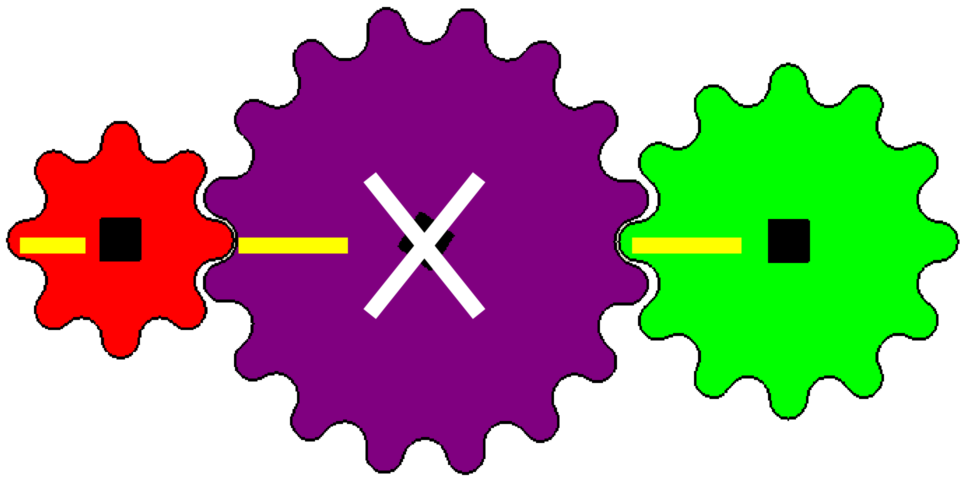


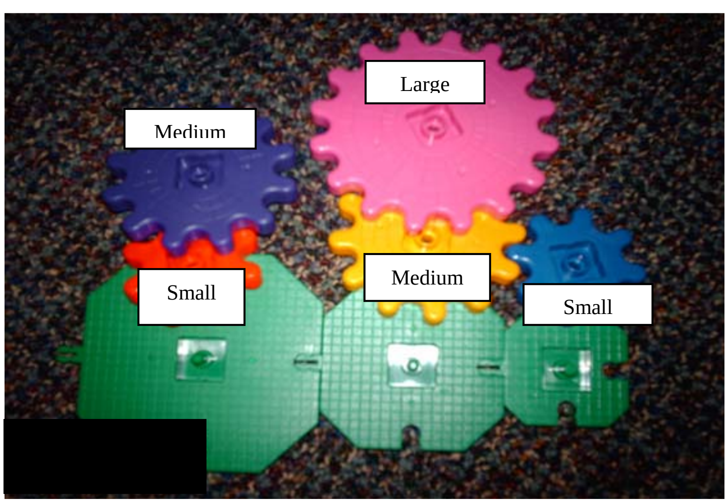
If you rotate the Leader 6 times, how many times does the gear on the Follower turn? ____

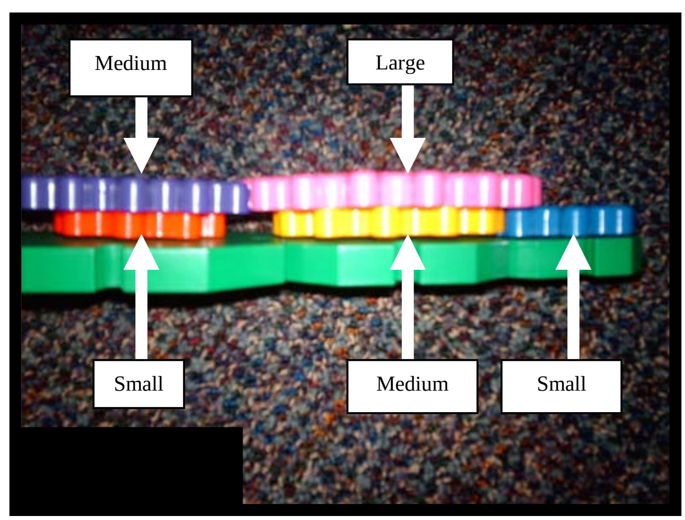


One at a time, make each gear the Leader and spin it 6 times. Record the revolutions of the <u>Left</u>, <u>Right</u>, and <u>Middle</u> gears.

	Left	**Middle**	**Right**
Large		6 times	
Medium			6 times
Small		6 times	

Stack the gears as shown in the pictures:





What do you notice about the gear's revolutions?

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What other combinations of gears can you make?