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Simple Machines: Promoting Student Application and Reflection

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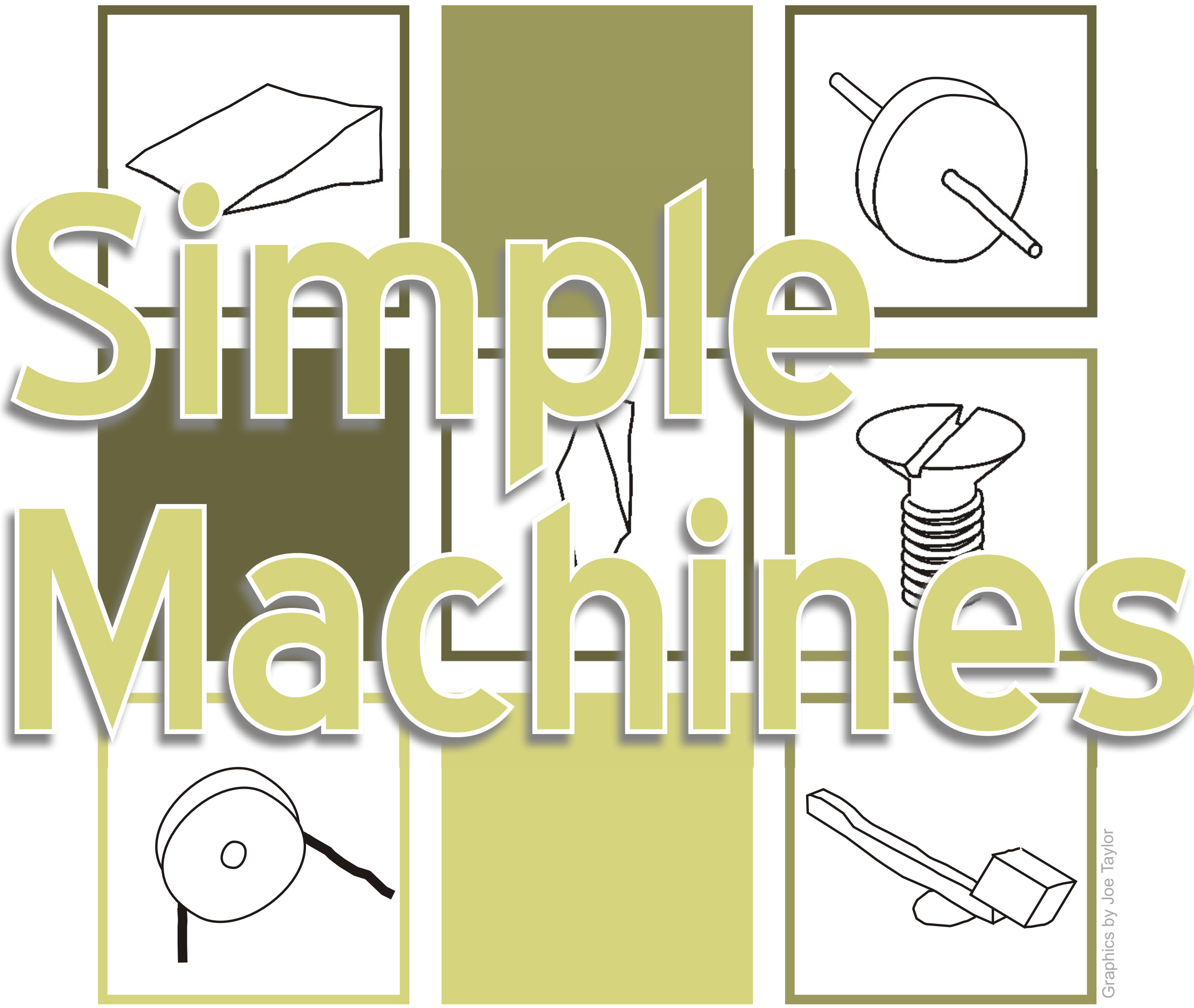

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PROMOTING STUDENT APPLICATION AND REFLECTION

Sarah Borzo

ABSTRACT: Simple machines are a common elementary grades science topic. This article describes how I frame my simple machines unit using a problem and have students reflect on their initial designs as we learn about each machine. The students then apply their learning by preparing proposals for how they might use simple machines to aid in the building of a pyramid. *This article promotes National Science Education Standards A, B, and E and Iowa Teaching Standards 1, 2, 3, and 5.*

Reaching all students is a challenge every educator faces. I have found that students connect with science activities that are inquiry-based. I designed my third grade unit on simple machines in light of my understanding that students benefit from the opportunity to engage in inquiry-based learning in an authentic, real-life context (Krajcik and Rivet, 2004). The inquiry nature of the unit is important because scientific inquiry encourages students to "actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (National Research Council, 1996).

Motivating Students

I start the unit with a problem that promotes critical thinking, provides insight into student thinking and motivates students. I present the students with a challenge:

- "How could we get a heavy box of books to the top of a high shelf?"

I first encourage several volunteers to attempt to lift a cardboard box filled with books to the shelf. The students quickly realize the weight of the box and the height of the shelf will prevent them from quickly solving this problem.

Because the students cannot lift the box by hand, we discuss factors that prevented us from being able to lift the box. The students usually decide that the weight and size of the box, the height of the shelf, and their own height and strength are the primary factors preventing them from being able to lift the box individually.

Generating and Discussing Ideas

After discussing the nature of their difficulties, I present students with their next challenge: to design a device that would overcome the obstacles of size, weight, strength, and height and enable them to get the books from the ground to the shelf. The device has to be something that could be used by third graders and could be made using things found in the classroom or school. I give the students at least ten minutes to work in teams of five to discuss, design, and draw their contraptions. While student groups discuss, I appoint a recorder for each group and pass out blank transparency sheets. The recorder lists the required materials and draws the device the group creates. After handing out transparencies, I try to visit each group several times to not only monitor progress, but to ask questions to get the students to think more deeply about their designs and the clarity of their drawings. Some questions I ask include:

- "Why do you think your idea will make the task easier?"
- "I'm not sure what ______ is, how could you make sure the rest of the class will understand your drawing?"
- "What part of your device do you think will cause the most problems?"
- "What part of your device do you think is the most important? Why?"

As I walk around and listen to student discussions, I work to tailor my questions to the student drawings or the discussion that I overhear. Rather than pointing out problems or providing my own ideas directly, I ask the students carefully posed questions to help them assess and think more deeply about their ideas. When they answer a question, I encourage the other members of the group to evaluate the response. My role during the group brainstorming is to encourage discussion amongst group members and pose scaffolded questions to help move groups forward in their designs.

When I believe groups have had enough time to get some of their ideas on the transparency, I call for the students' attention and ask what good audiences do. The students almost always say that good audiences listen, but to help them understand my expectations I ask, "What things does an active listener do?" We make a quick list ranging from looking at the speaker to asking questions. I then remind students that my expectation is that they provide comments about what they like about the idea, and then ask questions about things they did not understand or problems they see.

After discussing expectations, each group presents their ideas. They verbally describe how the machine would work and how it would help accomplish the goal of moving the box from the floor to the shelf. After each group's presentation the class shares what they like about the proposal and ask questions. After giving positive feedback, students are invited to make respectful constructive criticism.

To close the first day, I ask students to think about what they know about machines. I have students talk quietly to a neighbor and share ideas. I then call on groups to share their ideas with the class. I record all student answers, both accurate and inaccurate, on a large tablet to be utilized during every science lesson for the remainder of the unit. Student ideas often include:

- They have wheels
- They run on electricity
- They help us do work
- They are made of metal
- They have many parts

This list helps me to understand the students' current thinking about machines, which informs my decision making for the remainder of the unit. The list also gives us something to refer to and add to throughout the course of the unit. We begin and end every class by reviewing our list and editing it as students see fit. As the unit progresses, the list serves as a record of the class's growing knowledge and understanding.

Depending on available time and resources, giving students the opportunity to build their machines or make smaller versions of their machines to see how well they would work can provide more concrete experience with machines for future discussions. I keep the students' drawings to refer back to as examples of the simple machines we will be discussing. When learning new material, helping students make connections to what they have already done or already know helps them build their understanding and make important new connections. Yet, the teacher must actively encourage students to make those connections.

Introducing the Machines

Many elementary level science curricula involve introducing students to six simple machines (Figure 1). Although specific strategies to introduce each simple machines lie beyond the scope of this article, I try to show the students each of the simple machines in action. I introduce one machine per day. While the students observe the simple machine, I ask,

- "How is this machine making the task easier?"

If students struggle I ask,

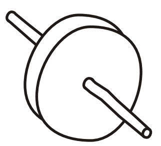
- "Why can't I do this task without the machine?"

During these discussions I look eagerly around the room to encourage students to respond. Rather than responding quickly to student ideas, I look to other students for additional comments. My goal is for students to discuss their thinking with each other rather than always seeking confirmation from me. Yet, I must encourage them to respond to my questions and to each other. If students are not thinking about each others' ideas, they are not gaining as great of insight as possible. If a student has a particularly interesting, or thought-provoking idea, I ask the class,

- "What do the rest of you think of that last idea?" or
- "How does that idea fit with what else we have talked about?"

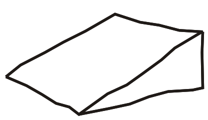
FIGURE 1
Overview of six common simple machines

1. Wheel and axle



Students observe a skateboard to discuss the arrangement of a wheel and axle design. Students later construct their own wheel and axle using wooden dowels and Play Doh.

2. Inclined plane

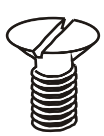


Two wooden boards are set up at different angles. Students are given an object and predict which will be more difficult to drag up each board. Students also predict which board will allow a marble to travel down faster and farther.

3. Wedge

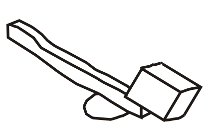
Students observe a kitchen knife slicing an apple into sections, and discuss why the design of the knife makes this task easier. Students are treated to apple slices, and discuss how their teeth act as a wedge.

4. Screw



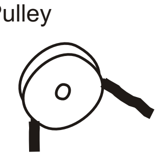
Students attempt to insert a screw into pre-drilled holes in a board, and discuss ways that work or do not work. Students observe the design of a screw and consider why it must be turned.

5. Lever



Students are given a box of books that are too heavy to lift. A wooden board and concrete block are provide, and students are challenge to design a lever that requires the least effort to life the box.

6. Pulley



Students examine their school's flagpole and observe a pulley. Students construct a pulley using wire coat hangers, spools, and yarn. Messages are attached to the yarn with paper clips to observe how a pulley can be used to move the messages across the room.

I also use these demonstrations and discussions as an opportunity to introduce students to the concepts of gravity, friction, motion, speed, and force. When demonstrating a machine, I ask the students what force is working against our goal. For example,

- "If we want to lift the box, what is holding the box down?" or
- "If we want to slide the box to the other side of the room, what makes the sliding difficult?"

These questions lead to discussions on gravity and friction, respectively. I also have students think about the applied effort (force) compared to the output force (although not in those words). For example, when talking about levers, I ask students,

- "If I had a teeter totter with an adult on one side and a third grader on the other end, why doesn't the teeter totter work?"

Promoting Continual Student Reflection

After discussing the simple machine of the day, we return to our original list about machines to review and edit. I ask the students,

- "What things should we add to or remove from our list about machines?"

Depending on our discussion for that day's machine, the students may add a new force to be overcome, the name of the new machine, or uses of the new machine. It is imperative that the students decide which ideas are crossed off and which remain in order for the list to serve its purpose as both a tool for deconstructing prior knowledge, and as a record of growing understanding.

In addition to revisiting our list about machines, I may have students revisit some of their creations from the first day of the unit. If a group's initial idea made use of the day's featured machine, I show the drawing on the overhead and ask students to discuss with partners how the day's machine is used in the device. I also have students think about how they could improve the use of the machine within the device based on their new knowledge. Again, I remain open to student ideas, look eagerly around the room, and wait to respond until other students have had a chance to comment so that I can encourage students to creatively think using what they had learned that day.

I also have students write in their science journals about how the latest simple machine could help them move the box and draw pictures depicting the machine at work. To make the experience as concrete as possible, I leave the box of books out at all times during science class for students to return to and examine. Frequently, while revisiting the box dilemma, students lift, push, pull, and turn the box before returning to write and draw in their journals. This ability to consistently physically engage with the dilemma proved to be beneficial for concept application.

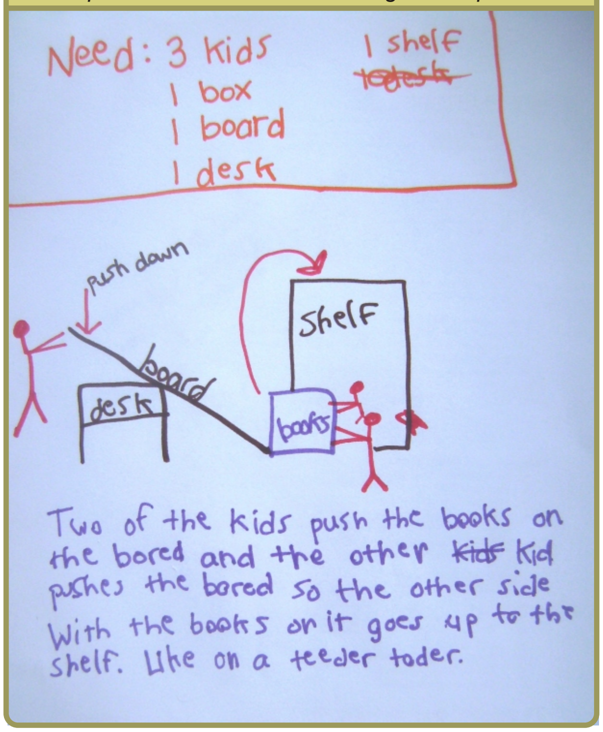
After discussing all of the machines, students work in small groups to analyze the list and their experiences to determine what overall purpose simple machines serve. At this point, the students usually decide that the purpose of machines is to help do work and save people energy. This discussion helps me determine if the students are ready to move on to the unit assessment.

Assessing Students

My goal is to provide an authentic assessment in which students apply their understanding to a novel problem. I display a large model of a pyramid and ask students to observe it and think about what obstacles ancient Egyptian pyramid builders faced. I then ask,

- "How do these problems compare to our box dilemma?"

FIGURE 2
Sample of student's lever drawing and explanation.



The students note that "both were jobs that were too hard to do with just our bodies". I then present the assessment challenge: students will work in teams to create a proposal for how they would build a pyramid using three simple machines of their choice. (I opt to focus on three machines instead of all six because it requires a greater degree of critical thought they have to choose which three would be best suited for the task.) The groups have to explain why they selected each machine and how they would use them, and then create a diagram to accompany the proposal. Each team uses a large sheet of poster board, markers, and crayons to create a visual aid. This portion of the assessment encourages students to demonstrate their basic learning and allows me to assess their knowledge, comprehension, and application skills.

On the final day of the unit the teams present their proposals. I tell students I am watching from the perspective of a wealthy Egyptian while the rest of the class serves as my advisory committee. The class takes notes while each team presents, and we ask questions at the end of each presentation. The posters are left up around the room for later reference. After each group presents, every student independently writes a recommendation for me. The recommendation includes which group should be selected and why, including specific discussion about each of the three machines used. This portion of the assessment requires students to apply their thinking and allows me to assess their ability to analyze, synthesize, and evaluate.

This two-part assessment has a group component and an individual component and is designed to encourage higher order thinking. My assessment strategy was informed by the understanding that "knowing science content is not memorizing facts, but rather being able to use content in different contexts" (Krajcik, McNeill and Reiser, 2008). Students share knowledge and ideas which they then apply to a novel problem. Individually they analyze and assess the ideas presented in class and select the proposal that makes the most sense to them. Finally, they must support their decision. The activities throughout the unit are designed to help students deeply process the science content through meaningful reflection. The unit assessment encourages students to demonstrate their critical thinking skills and their deep understanding of simple machines.

My appraisal of past student work on the assessment demonstrated the students' deep understanding of content and their ability to transfer that understanding into practical application. The machine choices students made in groups were logical and the rationales they provided were insightful and reflected a thorough understanding of how machines help us overcome obstacles. The individual analysis of other team's proposals clearly demonstrated their ability to engage in higher order thinking, and I was impressed to see that students talked explicitly about how motion, gravity, speed, friction, and force influenced their evaluation of the proposals and helped them arrive at a decision.

Final Thoughts

In order to be successful in an inquiry-based curriculum, students must have "both domain specific knowledge and knowledge of the general practice" (McNeill and Krajcik, 2006). Addressing inaccurate prior knowledge and documenting new understanding are important daily tasks, but providing ongoing contextualization for new concepts is also critical because utilizing content knowledge in general practice strengthens student learning (Rivet and Krajcik, 2008). Applying their knowledge in a new context not only allows me to better assess student understanding, but furthered student thinking about the simple machines we discussed.

This activity promotes much more than deep understanding and application of content. Critical thinking, communication skills, self-reflection, and confidence are each heavily emphasized. Additionally, having students consistently reflect on their thinking by revisiting their initial ideas encourages students to modify their thinking in light of new experiences and helps them understand that learning is a process rather than a destination. These valuable life lessons and goals for our students must never be ignored.

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