Math Students Build Trebuchets (in Trenton!)

IN MEDIEVAL TIMES, ONE OF THE GREATEST CHALLENGES TO A WARRIOR WAS BREAKING THROUGH FORTRESS WALLS. GETTING EVEN CLOSE ENOUGH TO ATTEMPT TO CLIMB THE WALL WITHOUT BEING SHOT BY ARCHERS PROVED TO BE QUITE DIFFICULT, SO THEY BUILT MACHINES THAT COULD HURL WEAPONS OR ROCKS LONG DISTANCES OVER OR THROUGH CASTLE WALLS.

The trebuchet is one such machine –

it was "designed to throw heavy rocks long distances to create breaches in castle walls." Invented by the Chinese and used in the West starting around 1280, the trebuchet proved to be a highly effective and destructive weapon for its time. Even though this weapon is now extinct, it still holds a tremendous amount of educational value for math, science, and technology students.

At Hedgepeth-Williams Middle School in Trenton, New Jersey, Susan Shields' 7th grade math class decided to build their own trebuchets. PITSCO donated a classroom set of trebuchet kits to Ms. Shields' class. The approximately 20 students worked in groups of four to build and test their individual trebuchets to see who could launch their projectile (i.e. ball of clay) the farthest.

tre • bu • chet:

(*trá-bu-shay*) a fifteenth century military engine used for hurling heavy weapons and rocks.

Trenton and the Center for Math, Science and Technology

Henry Harms, from the Center for Math, Science, and Technology (M/S/T) at The College of New Jersey (TCNJ), has been working with Ms. Shields' class as they are transitioning to Connected Mathematics™. Connected Math was developed at Michigan State University and is a program that encourages students to work in small groups, utilizing more hands-on activities than traditional math courses. (See *Ties Magazine*, March 2004 for more on Connected Math.) Mr. Harms works with this class throughout the school year as part of the Teachers as Leaders and Learners grant whose main focus is to support the Trenton School District's math and science teachers.

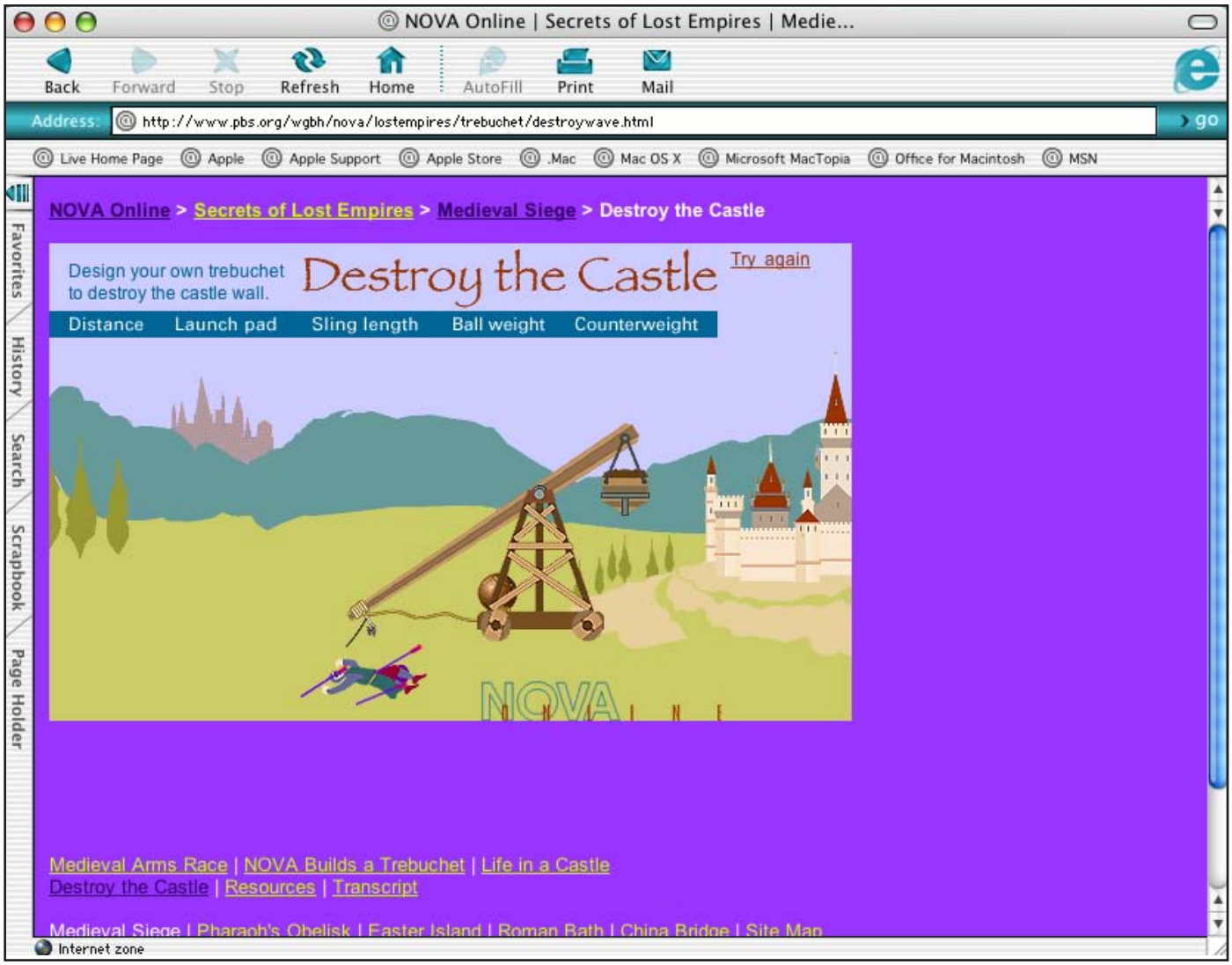
Making Connections

To put the activity into context, Mr. Harms provided some background information on the trebuchets to enhance the students' understanding of their historical significance and to distinguish them from catapults, a device with which more students may have been familiar. The difference between the

Ms. Shields assists the students with their construction.

Students followed step-by-step directions provided in the trebuchet kit.

Mr. Harms makes small cuts in the trebuchet base so students can add the hook that holds the arm.



NOVA Website – "Destroy the Castle" – The attacker is shot with arrows as he positioned the trebuchet too close to the castle walls.

trebuchet and the catapult is that trebuchets use gravity instead of springs or torsion as their motive force. Trebuchets have a counterweight that once released, falls to the earth launching a sling which holds the ammunition. To understand its destructive power, in 1999, NOVA enlisted the Timber Framers Guilds of The United States and The United Kingdom to recreate two trebuchets. They fired a 150 pound projectile over 700 feet into a castle wall, producing impressive results. The video of that NOVA program makes an excellent scene setter for a trebuchet activity.

The students then explored the NOVA website, which includes historical information about trebuchets, information on the life size trebuchet they built, and a "Destroy the Castle" computer simulation that allows the students to choose specifications for the trebuchet and launch a projectile to crush the castle wall. Ken Maskell, the Ties Magazine Editor and TCNJ staff member from the Center for M/S/T, visited the class and connected a projector to demonstrate the NOVA website. The students experimented with the "Destroy the Castle" simulation and tried to make predictions for the most effective specifications for the trebuchet. In the simulation, the students must determine distance, launch pad (with or without wheels), sling length, ball weight, and counterweight (hinged or fixed).

What the students learned was that if the distance was too close to the castle, they got shot with arrows, just as real medieval warriors would if they didn't distance themselves from the castle walls. More importantly, they learned that a ball that is too heavy will fall short if they are far from the

castle and that the trebuchet can throw the ball further with wheels because the wheels allow the force to push the trebuchet forward rather than tipping it. Without wheels, the force causes the trebuchet to rear on its back legs, diminishing its power. They also learned that if the specifications are not correct, the ball can fall on top of the trebuchet, crushing it and possibly them, just as Cortez found when he built one for his siege of Mexico City. The first boulder he fired fell to the ground and destroyed the machine (Lienhard, John H. No. 593: *A Modern Trebuchet*. All of these findings led to the ultimate lesson... this activity is not simply about tossing a ball – it's about making proper calculations, observations, and adjustments.

The Process

Over a two week period, the students built their own trebuchets and made modifications to make the device effective. The students constructed the basswood trebuchet, using the PITSCO kit that included paper clips, a brass tube, string, cloth for the sling, and washers for the counterweight. They followed step-by-step directions and were encouraged to help each other. They also received some assistance from Ms. Shields and Mr. Harms. One benefit of this activity is that it caters to a wide spectrum of ability, allowing all of the students to participate without worry of proceeding ahead or lagging behind. The students who were further ahead in the construction helped others who were having difficulty, reinforcing the importance of teamwork. They could also make modifications to their trebuchet to make it more complex, so they could still be

One student attaches the arm to the holder in preparation for adding weights.

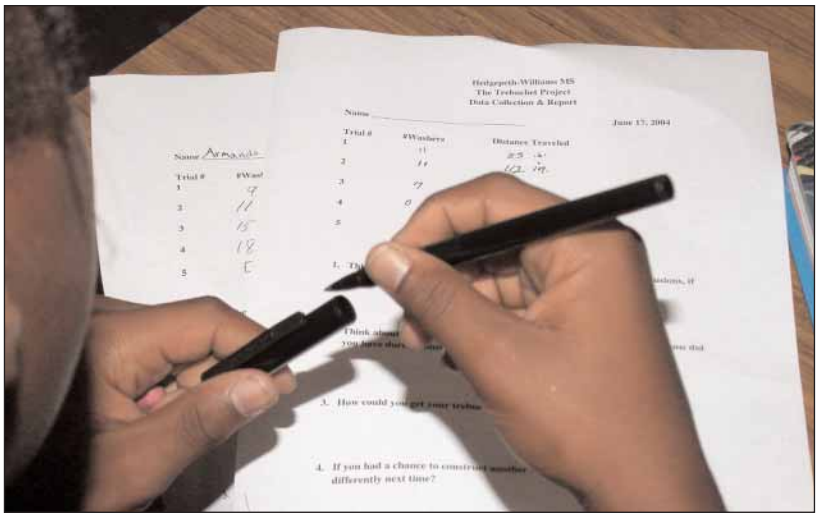
These students are completing the final step – tying and attaching the sling.

productive while others were catching up to them. "Some of the students found good solutions to problems they encountered," stated Ms. Shields, "and shared them with those who were struggling."

Once the students completed the construction of their trebuchet, they tested them using a ball of clay as their projectile. Their goal was to launch the clay as far as possible. Ms. Shields had some Popsicle sticks that they set up as "fort walls" for the students. She said in the future, with more planning, she would stage "battles" between opposing "armies." The activity was not just a fun competition, but a lesson in math – they had to make predictions as to how far they could launch their ball, take measurements, and then modify their trebuchet to make it more efficient.

They recorded their test data on worksheets, analyzed it, and made calculations for solutions. The students correlated the distance the clay traveled to how much it weighed, the sling length, and the position and weight of the counterweight, and made further adjustments. Finally, they listed problems they encountered with the construction and testing of the trebuchet along with their solutions to those problems. In addition, the activity lends itself to various extension assignments, such as having the students do research on historical and technical aspects of the trebuchet, followed by writing reports on their findings.

Even though trebuchets aren't used today, the thought process and skills needed to build and operate one are used in the current design process and the development of a product. Learning math in an abstract sense does not allow



Students conducted tests and then recorded the data on a worksheet to correlate the number of washers to the distance the clay ball traveled. Students then had to answer questions explaining problems they encountered and their solutions.

students to apply or see connections to the real-world. The trebuchet kit, on the other hand, provides a real-world context with a connection to math, science, technology, and social studies.

Trebuchet Challenges

One of the more challenging aspects of building the trebuchets was attaching the sling. The sling, which held the ball of clay, was attached using pieces of string. Since the string was very thin, the students had to be patient while trying to attach and tie the sling. For many of these students, this activity was their first hands-on activity, while others had very limited experience. The students who experienced initial success assisted others who were struggling and all the groups were able to complete the device. Building the trebuchet also took a long period of time – they followed the complex step-by-step directions for a class period each day for two weeks, staying focused and determined to complete their task.

Ties to Science

The trebuchet activity is not only appropriate for math classes but is also beneficial for science classes. In Kissimmee, Florida, Rebecca Allen's 6th, 7th, and 8th grade science classes at Horizon Middle School also used the PITSCO Trebuchet Kit as part of their simple machines lesson. Ms. Allen introduces the idea of the trebuchet by showing a battle scene from the movie, *Lord of the Rings* where they are firing at a castle wall. In their case, instead of following the written directions, she uses PITSCO's Dr. Zoon Trebuchet Video, which takes them through the process of building the trebuchet. Ms. Allen feels this approach works well with a large class.

As in Ms. Shields' class, Ms. Allen's classes also test the distance, measure the string, and compare weight. They also focus on the range, resistance, constant variables, and force. The activity as a whole provides the students with the opportunity to go through the problem solving technical design process. Ms. Allen believes if she uses some of the terminology for the math, even if they don't go into depth, it will compliment the math program and make it easier for the students when they cover these terms in their math class. Ms. Allen's classes also build cars for and participate in the Junior Solar Sprint. She says this activity covers axles, pulleys, and wheels, but it does not cover levers adequately, so she believes the trebuchet activity is perfect for introducing levers to her classes. Overall, just as Ms. Shields found, Ms. Allen's students love the activity. Her only wish is to have real Orks for their battles with the trebuchet.

Trebuchet Benefits

The trebuchet activity was a positive one for Ms. Shield's 7th grade math class. Ms. Shields remarked that even students who had done very poorly in math class were really involved in this activity, even helping others. "My experience with the trebuchet kit was really wonderful, mostly because the kids enjoyed it so much," said Ms. Shields. She commented that the students couldn't wait to come to class and that they really looked forward to building the trebuchets. "The students loved it! They were totally involved in the activity," remarked Ms. Shields. Their enjoyment, for her, was by far the most rewarding aspect of the activity.

This student has added the counterweight and is ready to test.

Student measuring the distance the clay ball traveled in order to make adjustments.

Trebuchet Resources

The PITSCO catalog includes the Trebuchet Kit, individual or Class Pak, along with the Dr. Zoon Trebuchet Video – visit www.pitsco.com. Also, visit the **NOVA** website for information, a teacher's guide, resources, and the *"Destroy the Castle"* computer simulation. The ***"Destroy the Castle"*** activity also lends itself to a webquest. Portions of the NOVA special, *Secrets of Lost Empires II: Medieval Siege* showing the Timber Framers Guild building trebuchets in Scotland and knocking over castle walls are available on this website as well. The full special is available on VHS video for $19.95 through either **WGBH Boston**, or through the **PITSCO** catalog.

For additional resources, the **McMurry University Physics** page, provides links to various trebuchet sites, including *The Physics of the Trebuchet*, *The Grey Company Trebuchet Page*, *Siege-Engine.com*, *Anthony's Trebuchet Page*, and ***The Northern Exposure Trebuchet*** (built for the TV show). The **Virtual Trebuchet** website, is an excellent site where you can experiment with release points, weights and distances. Finally, for the high end math, visit the ***Algorithmic Beauty of the Trebuchet***.

Sue Shields is a full-time teacher in Trenton, New Jersey. She has taught 7th grade math, as well as alternative middle school. Prior to teaching in Trenton, Sue worked part-time teaching in private school, also teaching German to K-12 students.

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