Video Description (posted next to video)
In order to create a hands-on understanding of physics and engineering, my students designed and created custom automatons. What's an automaton, you may ask? It's a complex mechanical toy - just like the one featured in the movie HUGO. As part of a joint physics and humanities project, my high school seniors partnered with senior citizens from a local senior community center and designed, constructed, and troubleshot an automaton specifically for their senior citizen partner. My students learned and applied concepts ranging from torque, simple machines, and angular velocity to engineering design principles and the precision of an engineering proposal. Their project was accompanied by an engineering analysis of their piece as well as a series of writing pieces on their senior citizen (on which the automaton was based). Overall, my students were able to practice engineering, get involved with our local community, and to build a meaningful relationship with a local adult in need.

Lesson Objectives

- Develop a real-world need for understanding simple machines
- Simulate an environment of accountability similar to a workplace and/or institution of higher education.
- Keep my 2nd semester Seniors motivated, on task, and productive.
- Empower my students to create something that is both magnificent and meaningful.
- Allow student to discover concepts on their own, out of sheer practical necessity, before introducing those concepts academically.
- Instill a deep, practical, understanding of simple machines in such a way that they can better manipulate objects in their life.
- Give students a taste of engineering and the design process

Engage. How do you stimulate student engagement and prepare them for the lesson?

By the 2nd semester of senior year, student motivation can be at an all time low – especially in an applied science course. I was planning to teach the concepts through an engineering project but the complexity of the project required each student to have a personal drive to build something great. This is when my humanities teaching partner and I, in collaboration with a local Senior Citizen Community Center, created a project called Seniors Squared.

Seniors Squared is a joint effort between High Tech High and Senior Community Centers that aims to connect two groups that are often very isolated from each other - senior citizens and high school seniors. We felt that students have a great deal to learn from our community's aging population and hope that this project opened a conduit for that learning and experience.

Immediately after seeing the project outline, students visited the Senior Wellness Center to meet their senior citizen partner. Students were keenly aware that in addition to social activities, general volunteering, and educational activities, they were responsible for interviewing their senior partner, producing and publishing a piece of creative nonfiction and literary journalism that represents their partner's legacy, and producing a mechanical wooden toy, called an automaton, that represents their partner's legacy. Since these final deliverables were to be gifted to to each of our senior partners, the purpose of this first visit was to engage students by showing them that there was a real need for their work and that there was a person who was very excited about their upcoming work.

As students designed and built their automata, they weren't engaged for a good grade or because their teacher said so. They were engaged because their senior citizen partner was depending on them. Students were very aware that at the conclusion of the project, they would be not only gifting their finished project to their senior citizen partner, but also participating in a public exhibition of their work in front of their high school peers, senior citizens partners, parents, and the general public. Students were engaged because they were very motivated to create quality work. And to create quality work, you had to understand the physics.

Explore. What experience (lab or manipulative activity) helps to introduce/develop the lesson concept?

In preparation for this project, we started with a few mini projects. The first was building paper automata, based on the templates of Rob Ives. The second was building a unique, but very simple, wooden automata. These mini projects introduced, in a very hands-on way, what simple machines can do. Some preliminary troubleshooting of these projects also lead into quick one-on-one conversations about various physics concepts. More importantly though, these projects isolated the physical construction skills that would be required in the weeks to come. Students were slowly introduced to the various tools in our shop and worked together to solve the many problems that came up. When it came time to build their final automatons, students were excited about automatons, well versed in tool safety, and comfortable using the various tools in our small shop. From then on, they could concentrate more on the physics and engineering than on fabrication.

Explain. How do you present and clarify the concepts, demonstrate the skills, etc?

This project was one big laboratory exercise. The academics behind each concept grew organically out of the student's needs. For example, as the project developed, many students found that their projects didn't have the oomph to accomplish all they wanted to do. Since the only input to their automatons is a hand crank, this was a natural introduction to torque and the lesson was framed as a means of addressing their technical problems. The other concepts introduced as part of this project were framed in a similar way and only introduced after there was a real need for the information. As students began to reach the limits of what could be accomplished with levers on their projects, I introduced gears. When students had trouble getting the movements of their automaton to match what was described in their proposal, I introduced angular velocity. These conversations were a springboard for the academics that followed.

After a few days of preliminary introductions to each concept (as described above), we would take a day off of construction and talk about the concept in depth. For example, the first was a discussion of torque as it applies to levers. After the introduction to the concept, students were given a problem to solve. I presented a meter stick at the front of the class with a fulcrum at 75cm. Students were given 5 small masses and had to, analytically, find a unique way to balance the lever given a number of constraints. In order to obtain full credit, each group had two chances to balance the lever based on their calculations. As one group found a particular solution, the other groups had to find a unique one. To wrap up the concept, students took home a worksheet as homework. The next day we moved into the engineering applications of levers and discussed how it applied to our automatons.

These lessons became a basis for extremely in-depth, student-led, discussions and debates about how to proceed on their designs. Not a day went by where I (or a student) didn't refer to a lesson during their design and the successful changes they made to their projects were memorable illustrations of the concept they had learned.

Evaluate. What formative assessments do you employ to assess student understanding and probe for necessary reteaching?

Although quizzes and worksheets were the most direct assessment of student comprehension, working with students is where I get the best assessment of where they are. Since a significant part of our day is spent in independent work time, it frees me up to do small group instruction. For example, one group was using an eccentric cam to move a lever. They had attached the only spring they could find to the tip of the lever but it had proved to be too powerful for their purpose. When they asked for a weaker spring, I said I didn't have any, and instead used it as a teaching moment. Though it took the better part of their afternoon to get the answer they wanted, they were able to perform some preliminary calculations and were able to show that of all the variables involved (spring k constant, spring displacement, length from fulcrum to cam, length from fulcrum to spring, etc.) – there was only one that they had any real control of – the attachment point of the spring. They reattached the spring closer to the fulcrum and voila – it worked. And not only did it work, they understood why.

Extend. How do you connect the ideas in the lesson to other curriculum areas, or real-world applications.

As discussed above, this project was a coordination between my 12th grade physics class, my teaching partner's 12th grade humanities class, and a local organization called Senior Community Centers. The entire project stemmed from the relationships between our high school seniors and their senior citizen partners. Although we used these relationships as basis for our curriculum, we also hoped to provide some perspective for our students. Our students are in the midst of a great transition as they prepare to enter college as an independent adult. It was very interesting to watch them interacting with individuals that were at the other end of the spectrum - some of whom were beginning to become less independent. In addition - the health, happiness, and attitude of our senior citizen partners varied considerably and the sincere reflections of those individuals seemed to have a profound effect on our students.

Our project also forced students to be resourceful. Throughout the project students had to seek out experts in various fields. Some students would meet regularly with our art director for guidance in sculpting and decorating the figures on their automaton. Others were very active in online trade-groups that focused on automata. As for applying concepts to real-world applications, I made a significant effort to point out and discuss physics as I saw it day to day. While volunteering for Habitat for Humanity (building homes for low income families) - my students made a game out of recognizing physics. After failing to get a wheelbarrow over a curb - one student set off to find a ramp screaming "we need an inclined plane". When trying to grip a piece of pipe with pliers, one student said "use the pliers with the longer handles - you'll get more leverage." After digging holes for hours, the students were given access to a hole auger and began lovingly calling it "the screw".

Grant. Explain how you would utilize a $15,000 prize to improve your classroom (250 words or less)

The physical building of projects is an important part of any engineering or applied science course. However, the physical fabrication of parts can be an enormous stumbling block and I am much more concerned with a student's ability to design, troubleshoot, and conceptualize a project than I am their dexterity with a scroll saw. As such, I would use this prize to equip my classroom with some basic fabrication equipment such as a *Saw Stop* table saw or stationary sanding equipment that would allow students to quickly fabricate their own parts.

The cost of day-to-day construction materials and hardware is also an enormous barrier so I would like to make many common materials readily available for my students such as lumber, fasteners, polycarbonates, adhesives, and the like.

Also, our personal protective equipment is very limited. We are in dire need of a class set of high quality (scratch resistant) debris goggles, filtered masks, protective gloves, as well as a hepa-filtered shop-vac, class air filtration, and other items to prevent the inhalation of airborne particles.

Lastly, for concepts where a project isn't practical - I find it very useful to have a demonstration activity to start the day off. Some of these demonstrations I would be able to build myself, whereas others would be purchased. These demonstrations include: a class set of pulley systems, an air track to demonstrate kinematics, computer controlled timing/sensing equipment, and a projector to allow me to show online demonstrations to the class.

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Working with my humanities teaching partner, we came up with the idea of Seniors Squared - an intergenerational project that connected our high school seniors with the senior citizens at the local senior community center. Each group of 1-3 students met weekly with their senior citizen partner and as they got to know them, they authored a number of stories, articles, and other writing pieces that were bound into a book. As a companion piece to their writing, they were also tasked with creating a mechanical toy(Automata) that in some way represented their senior citizen's life as well as a *Journal* that outlined both the engineering and science that went into their construction. At the end of the project, the book and toy are gifted to the family of their senior citizen as a lasting legacy of their loved one. But this is about a STEMIE - so let me tell you about the project itself.

When planning out this semester, I was tasked with creating a curriculum that was primarily project based, helped

- It had to be founded on the principles of project based learning.
- I had to engage 2nd semester seniors in an applied science course.
- I wanted students to feel a need for the course concepts prior to their learning them.
- I wanted to be be confident that each student was walking away with a real understanding of their selected concept.
- I wanted a real reason for my students to do great work - something other than grades or 'because I said so'.