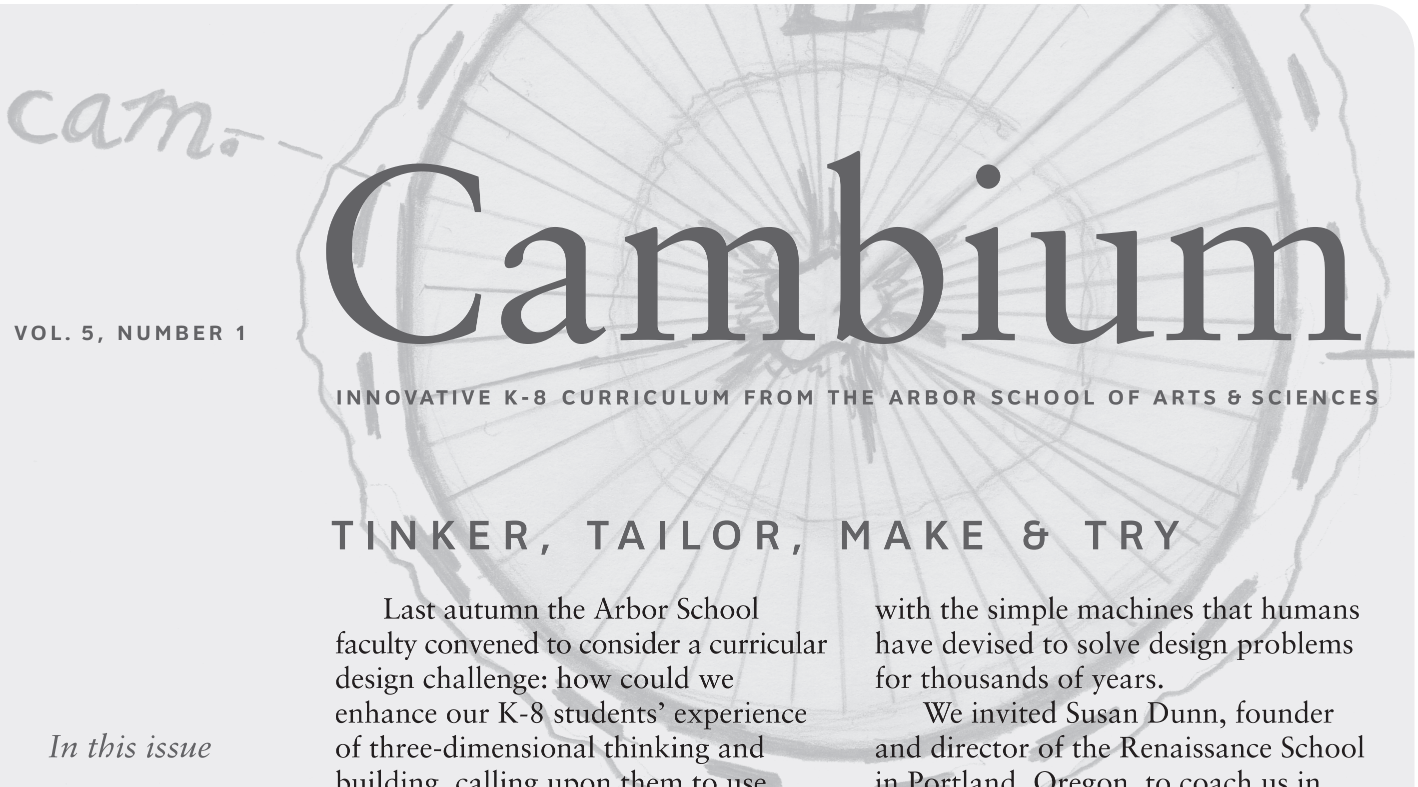

Cambium

VOL. 5, NUMBER 1

INNOVATIVE K-8 CURRICULUM FROM THE ARBOR SCHOOL OF ARTS & SCIENCES

In this issue

ARBOR SCHOOL
OF ARTS & SCIENCES

TINKER, TAILOR, MAKE & TRY

Last autumn the Arbor School faculty convened to consider a curricular design challenge: how could we enhance our K-8 students' experience of three-dimensional thinking and building, calling upon them to use their spatial sense and to take up real tools to solve problems with creativity and perseverance? Children at Arbor already have myriad opportunities to tinker and craft—freely in the Design Studio during recess; playfully in African workshops beading bracelets or carving log drums or making found-object toys; collaboratively in building sets for "A Midsummer Night's Dream;" formally in preparing a display to support an independent project. We intend that design thinking should permeate the curriculum. In addition to reports, stories, drawings, mathematical proofs, and paintings, our students gain and display understanding through the construction of models and through physical demonstrations. Music and movement are also often woven into each unit and become highlights of each culminating celebration. Supporting children in the cycle of questioning, testing, and evaluating as they build knowledge and understanding is a daily goal in all our classrooms. But it seemed to us that we could better support our students' creative visions and innate wishes to tailor their environment to their own specifications for work or play, in part by giving them concrete experience with the simple machines that humans have devised to solve design problems for thousands of years.

We invited Susan Dunn, founder and director of the Renaissance School in Portland, Oregon, to coach us in teaching design technology at our faculty retreat. She has placed design tech at the heart of her school's curriculum, and we were agog at the quality of the student work she shared with us and the beautifully clear explanations of challenges met and solutions attempted that accompanied the charming pieces. Susan led us into the process she undertakes with her students and soon had us scribbling our guesses about what hidden mechanisms might be creating the movements of a puppet's limbs, drawing hypothetical schematics and conferring with our tablemates about the exact location of pivot and attachment points.

What does bringing design tech into the classroom yield for children and their teachers? In her book *Design Technology: Children's Engineering*, co-authored with Rob Larson, Susan Dunn gives the following answer:

continued...

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> “Children involved in active exploration learn that they can influence their environment. They eagerly seek answers to real problems they pose, building and testing theories, creating, and organizing reality in a way that is meaningful to them. This theory of cognitive constructivism provides a perspective for viewing the child as an engineer of personal understanding.
>
> Direct experience allows the child to observe properties and functions of materials. Opportunities arise for sorting, arranging, and recording and form a basis for questions and responsive ideas. Sharing with others opens avenues for the exchange of perspectives. The child is then challenged to review her own ideas in light of new information.
>
> When a situation presents the child with ambiguity or inconsistency, she must make adjustments in her thinking, moving from a strictly sensory dependence to perceiving and constructing patterns and generalizations that might be applied to other situations. She creates an order in her world. Talking helps the child to sort out that order and its meaning. Listening to her as she works with emerging ideas gives insight into conceptual development. Information gained through sensitive observation of the child’s playful work opens opportunities and directions for further investigations.”

We decided to set ourselves the task of undertaking a major design tech project at every level of the school during the spring of 2013. We first made a list of the design challenges that we already pose for our students, the concepts addressed by those challenges, and the skills that are practiced in the process. We then examined our lists with an eye to what was *not* there. We looked for missing fundamental concepts, such as how do hinges work, and what constitutes an appropriate fastener, and for places where it was clear that more exposure and practice, or perhaps more direct skill instruction, would enhance our curriculum. We used the winter months to plan and build prototypes during faculty and team-level meetings, considering the appropriate degree of complexity for each age group and how we would embed the projects in our thematic curriculum.

The K-1 Primaries planned to augment their study of chickens by adapting Susan Dunn’s puppet as a flapping, hopping chick. An investigation of pulleys and gears fit easily with the 2-3 Juniors’ unit on time and clocks. The 4-5 Intermediates planned to immerse themselves in the Renaissance in the spring, and a study of automata, the mechanical toys that were rediscovered and flourished during that period, seemed a natural choice. Finally, the 6-8 Seniors found inspiration in their Humanities focus on China to design and construct seismographs. This issue of Cambium tells what unfolded in our classrooms as we lived the promise and perils of design tech. Admissions director Deborah Mandelsberg and Primary teacher Felicity Nunley also write on their observations in the Primary Junk Box, where design challenges are daily invented and collaboratively tackled—almost entirely without teachers’ help and with some fascinating ripples into the life of the classroom. We hope this collection of curricular tales will inspire you to try some iterative tinkering of your own.

–Sarah Pope and Peter ffitch

Dunn, Susan and Rob Larson. *Design Technology: Children’s Engineering*. London & Philadelphia: The Falmer Press, 1990.

TIME TO TINKER

JUNIORS BUILD WEIGHT-DRIVEN CLOCKS

by Peter ffitch, grade 2-3

Junior girls assemble paper-plate sundials on the lawn

As part of our study of time in the Juniors, we have always undertaken to design and build simple versions of the earliest clocks. Students use paper plates with pencils acting as the gnomen to make sundials, gathering evidence of the Earth's movement around the sun. They use paper cups and mason jars to experiment with Egyptian clepsydra, or water clocks. And they use plastic water bottles and sand to replicate sand clocks. As they face the challenge of building models that reliably measure a unit of time, students encounter many of the same problems that drove their engineering predecessors to keep looking for a better method for measuring the passage of the hours. But each of these models is fairly simple, has a limited set of variables to work with, and can be constructed with readily available materials. This year we decided to add one more design challenge to our thematic unit, a project that would ask our students to wrestle with the more complex physics of mechanical clocks. We did so because we saw the opportunity to engage our students in an investigation of pulleys and gears with a real purpose. We also saw wonderful opportunities for integrating geometry into our study.

Although it is our intention that students will build their design technology skills just as they develop all of their academic skills, with each year serving as a foundation for the next, we began our work this spring with the knowledge that not every brick was in place—that there were gaps in skills and knowledge that would have to be filled for students to complete the design challenges we were devising. The Juniors were going to be asked to work with pulleys and gears, two simple machines with which they had no formal practice. With our end goal—that each student be able to design and construct a timing device that incorporated weight-driven pulleys or gears—in mind, we began to unpack the concepts and skills that we would need to cover.

We began with circles. Having worked earlier in the year to define triangles, rectangles, and squares, our students were ready to make a good run at coming up with a definition for this geometric shape. It took them no time at all to define a circle as being closed, and as having a continuously curving line, but just how to differentiate a circle from an ovoid shape was more challenging. We teachers offered the rule that each point on the line must be equidistant from the center. We then explored this definition by tracing circles using lengths of string anchored at one end by a thumbtack and by drawing circles using two different types of compass.

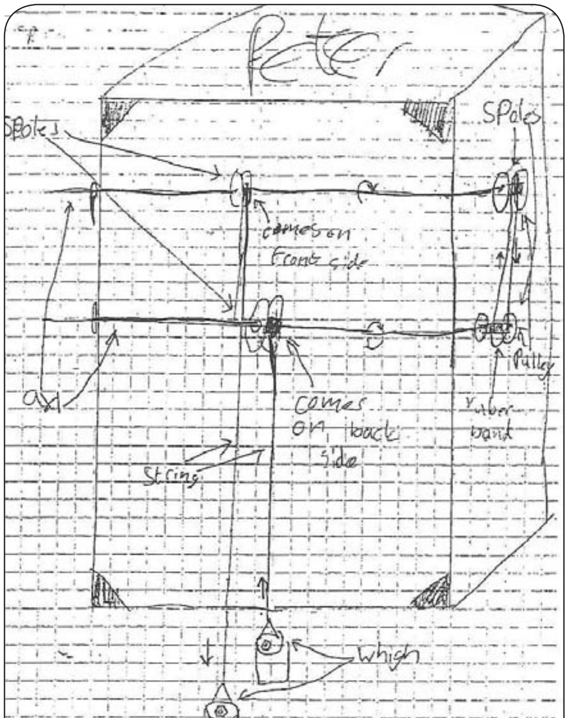
After drawing circles, we learned about the ways to measure them. As with the definition, the first part was conceptually easy for the children. Radius and diameter are easy to see and measure, and the relationship between the two is easily grasped, but measuring circumference presents more of a challenge, particularly for second- and third-grade children not yet ready to work with pi. To get over this hurdle, we had children draw and cut out matching pairs of circles from tagboard. Using a pencil as an axle to turn these discs into a set of wheels, students were able to measure circumference by marking the distance rolled in one revolution. As they worked, we began a class chart on which they recorded the diameter of their wheels and the distance rolled. It soon became apparent to the students that wheels of a greater diameter rolled farther in one revolution than the smaller sets, and that a wheel that was half the size would take two revolutions to equal the distance traveled by its larger counterpart. It was this relationship that we hoped children would begin to grasp, and we were pleased to see that understanding developing.

To take the next step in exploring rotational relationships, we needed to move from wheels to gears and pulleys. We set up a number of boards with arrangements of nails on which children could skewer spools of various sizes and connect them with rubber bands. Through experimentation, children began to see that a small spool would have to turn multiple times in order to turn the large spool around once. Students played with connecting more than two spools and with twisting the rubber-band belts so that the spools would spin in opposing directions.

With a growing sense of how pulleys can work in a system, our students were ready to experiment with the idea of having sets of pulleys turned by the force of gravity rather than manually. Traditional cuckoo clocks are powered in this way and we had just such a clock to demonstrate. To let the children explore the concept on their own, we attached the pulley boards to a series of posts so that the pulleys would be turning on horizontal axes. Students were then given lengths of string with paper cups affixed as baskets at each end. They experimented with wrapping the string around the pulleys and adding weight to the baskets so as to let gravity do the work of turning the spools. We asked that each student demonstrate that he could set up the string so that the spools would turn in opposite directions, and that he could measure the number of turns that the smallest diameter spool took in comparison to one turn of the largest one. Once students had mastered this, they began to add interest to these simple machines, adding extra spools with spiral designs that twirled as the weight dropped, for example.

After all of this messing around with pulleys and weights, our students began to wonder when they were going to get to put their newly developed understanding to some good use. "When can we make machines that really do work?" one student asked. Another Junior wondered if we might give him time to try to use what he had learned to make his own clock. This enthusiasm was just what we had been working toward, but we had one more piece of scaffolding to add before we set the students free to design and build.

When we began to plan this project, we built a model to test our own understanding, to test whether our design challenge would truly be within the range of our students' skills, and to show the students an example of what was possible. After some initial experimentation, we settled on an open box with two dowels driven in parallel through its opposite sides. Where these dowels exited the box on one side, each was capped with a pulley, and the two pulleys were connected by a rubber band. Inside the box, each dowel carried a spool to which we affixed a string attached to a paper cup that could hold weights. When the heavier cup descended, the pulley connection caused the lighter cup to ascend. To help the children think deeply about this simple machine, we began by showing it to them with all of its inner workings hidden. Able to see only that the exposed ends of the axles were turning and that one weight was dropping while the other was rising, students wrote and sketched what they thought might be happening inside the device. They asked questions in aid of testing hypotheses; we responded by incrementally revealing all of the workings. We then asked students to make a drawing of the machine that included all of the moving parts with labels and arrows to help explain the function of each.



As we demonstrated our model for the students, they were most interested in experimenting with the distribution of weight between the two cups, specifically wondering if they could regulate the rate at which the cups rose and fell, thereby also regulating the speed of the dowels' rotation. They were already imagining adding clock faces and hands to their own models.

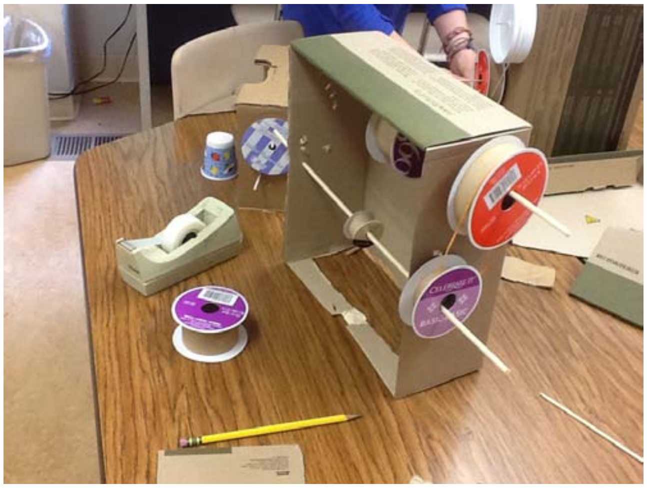
Later we repeated this process, but with a machine that now featured two weighted strings rolling and unrolling from separate spools on each of the two axles. With the inner workings again hidden, students watched as two weights rose and two fell. We were pleased that students began to refer to our earlier work with pulleys as they crafted possible explanations for the inner workings of this machine, and we were delighted when they came up with alternative design possibilities that would have worked as well as the design that we had used. Students again made a final drawing of this machine and were given the added challenge of writing an explanation of how it worked. This was a new kind of writing for most of our students, and it proved to be quite challenging. The students who had the greatest success described the machine's workings in a very linear fashion; their prose reminded us of the longer passages in *The House That Jack Built*.

Satisfied that our students were well armed with an understanding of the ways in which weight could be used to drive pulleys that are designed to do some work, we set them free to work—alone, in pairs, or even in small groups if they chose—on designing a weight-driven pulley device of their own. Our experience in the preceding weeks had revealed to us the challenges of making this device keep time, but we did still think it reasonable for our students to work toward making a device that could be used to measure a chunk of time, such as five seconds, in a repeatable way. We had gathered a collection of boxes, dowels, rubber bands, and jar lids to serve as pulleys, and our classroom soon became a busy workshop. We suggested that drawing should precede building, but many of our students needed to tinker first in order to sharpen their thinking.

As students built and tested prototypes, two challenges consistently arose. The first had to do with keeping the rubber-band belts on the pulleys once there was a load. Students dealt with this by gluing cardboard discs to their pulleys to create deeper channels. The second had to do with friction. As weight was added to the cups, this weight also pulled the dowels/axles hard against the cardboard holes. The resulting friction made it difficult for students to create a smoothly running machine and made it challenging to calibrate the weights so that each operation of the machine would take the same amount of time. Students worked to reduce friction by using plastic straws as sleeves to separate the axles from the cardboard.

After a number of work periods, during which many students made significant changes based upon the results of their testing, we asked everyone to incorporate their most successful ideas into a final model for demonstration and display. Many chose to collaborate for this final phase. We mounted their completed machines on the wall beside the cuckoo clock. We then gathered as a class to take a tour of the room, stopping at each station for a demonstration. Although not all of our students had achieved the goal of creating a device that could serve as a timer, all had met the challenge of connecting a series of pulleys that were driven by descending weights. These students also demonstrated an understanding of the relationship between pulleys of different sizes, most often choosing use a small pulley as

Torben, Vivek, Quincy, and Nadia hard at work on their weight-driven timing devices



the driver for a larger one, so that the larger one would turn more slowly. As students demonstrated their machines, they described their successes as well as their challenges. The new understanding gained from this final phase inspired some to begin again on their own time, even gathering materials to work at home.

While we will not return to this project with these students, we will keep some of the prototypes up in the room year round so that students can experiment with them and gain more experience with pulleys. We also created an outdoor installation using large wooden cable spools salvaged from construction sites. We mounted these spools on conduit axles driven vertically into the ground and connected the spools with rope. As students played with this construction, they experimented with the relationship between large and small diameter pulleys, and with the ways in which they could set up the rope to determine the direction that each pulley turned in relationship to the one driving it. It is this ongoing ability to play and explore that we hope will lead to our students' putting their understanding of these simple machines to work in creations of their own.

INGENIOUS MECHANICAL DEVICES

INTERMEDIATE INVENTORS CONSTRUCT AUTOMATA

by Charles Brod and Azure Akamay, grade 4-5

Humans have been creating mechanical toys since ancient times. There seems to be a universal delight in cunning animal or human figures that seem to move by themselves—from China to Greece, complex automata were presented to royalty as entertainment or used as tools to demonstrate scientific principles. Engineers in Baghdad devised automata for the palace complex as early as the eighth century, and tenth-century visitors to Byzantium reported that the emperor's throne incorporated singing birds, roaring lions, moving beasts, and water organs. A beautiful illuminated manuscript called *The Book of Knowledge of Ingenious Mechanical Devices*, written by the Muslim polymath al-Jazari in 1206, gives instructions for the construction of 100 devices: alongside clocks and water supply systems are a drink-serving waitress, a peacock-shaped hand-washing fountain with mechanical servants that pop out of the peacock to offer soap and towels, and a boat full of automatic musicians that could provide the entertainment at royal parties. In medieval Europe, the Count of Artois commissioned a pleasure garden at Hesdin that was famed for its automata until English soldiers destroyed it in the 16th century. And the Renaissance saw a surge of interest in automata, many beautiful and intricate examples of which have survived to this day: clockwork figures who appear to breathe and tilt their heads in contemplation as they write sentences—one built by Pierre Jacquet-Droz can be programmed to write any text up to 40 letters—in perfect script, a draughtsman who blows the dust from his pencil as he executes four different complex drawings, an organ player who makes genuine music on a custom-built instrument.

In short, these mechanical devices are laced through the history of civilization that Arbor Intermediates study every second year in their Inventions & Discoveries curriculum. When we set out to incorporate a major design tech project into those studies last spring to get our students thinking in three dimensions and investigating interacting parts and motion, the construction of automata seemed a natural choice.

Scaffolding

For students to succeed at this very challenging task, their teachers needed to develop plans of instruction as thorough as any mechanical drawing. In the weeks leading up to this exercise, our Intermediates had been studying levers and formulating the ratios between load and effort that operate in first class levers, but the concepts of cams and gear ratios would be entirely new to them. We knew the automata themselves would be intrinsically fascinating and the students would be keen to dive in, but first they would need foundational scientific understandings and hands-on practice with the basic elements of mechanical systems. Thorough planning and reflection on paper would be essential, as would the help of adults.

We began by establishing thoughtful aims and parameters. Plenty of pre-packaged design tech experiences are available for purchase and could have provided the understanding of and practice with simple machines we aimed for, but kits don't allow for inventiveness. Our goal was for the students to conjure and build something original and to feel the satisfaction of having encountered and overcome design challenges. We wanted to give the Intermediates the latitude of choice they would need to truly engage with the project and make it their own, but lay out just enough limiting factors that they wouldn't bite off more than they could chew or put their teachers through backflips trying to support wild flights of fancy. We decided upon one clear constraint: each automaton would have to be structured to fit within a pre-cut rectangular box. The student could orient the box however she wished and deploy any set of mechanisms within it, but the physical size of the materials would limit the complexity of the design. This also allowed the teachers and a generous woodworker parent to prepare a class set of basic materials ahead of time, cutting the four sides of each box to length and pre-drilling holes for screws. We also turned to craft stores for pre-made components—disks, dowels, gear wheels, and more—that would provide students with some common mechanical elements standardized to fit together. Most students would still have to modify or add to these components to carry out their vision, but fabricating every piece from scratch would have added much more time to this already protracted unit and would have created real bottlenecks in work flow and adult help to safely operate power tools. The second constraint we placed on the design of the automaton was that it had to illustrate something from the year's thematic curriculum. We planned for precise drawing, measurement, writing, and reflection at each step of the process to ensure each student would be traveling a well-lit path. And we allotted plentiful, full-afternoon work periods over many weeks.

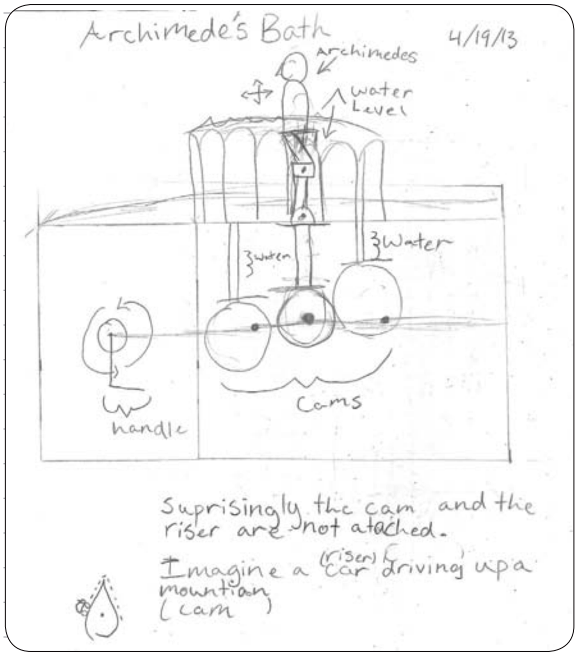
Setting the Stage

We introduced the design tech challenge to the Intermediates with the same exercise through which Susan Dunn, the author of *Design Technology: Children's Engineering*, The puppet investigation formed the first entry in a "Notebook of Mechanical Mechanisms"—about ten sheets of single-sided graph paper stapled into a packet with a bright cover—that we prepared for each student to log his subsequent learning about mechanical systems and his automaton planning.

had guided the faculty at our fall retreat: the puppet that lifts its arms and legs in response to pulling the ribbons dangling beneath. What mechanism is concealed within the puppet's body to create this motion? As we teachers had done, the students sketched their guesses and refined their drawings as further clues were dispensed. We emphasized technical terms—*fulcrum, load, effort*—as we discussed the motion of the limbs.

The next step brought in the model automata the teachers had constructed. In small groups, students watched as Archimedes stood up in his bathtub and the water level dropped or Odysseus's ship sailed toward a bobbing Scylla and Charybdis with a spinning whirlpool beyond. Again, the mechanisms weren't revealed and the Intermediates tried to guess what parts could be interacting inside the box to create the different kinds of motion. Being unfamiliar with cams, they couldn't deduce the more complicated mechanics as accurately as they had with the puppet. But the teachers' models were the launchpad for the week's work: getting to know cams, gears, and friction drive systems.

The following week, students had the chance to experiment. They broke into groups to mess around with pivot points (brad fasteners connecting paper strips in a variety of ways to create different kinds of motion); test cardboard cams of different shapes on a shaft; and delve into books of historical automata. This work helped prime the pump of inspiration as students began to see possibilities and connections with the arc of history they had experienced over the year.



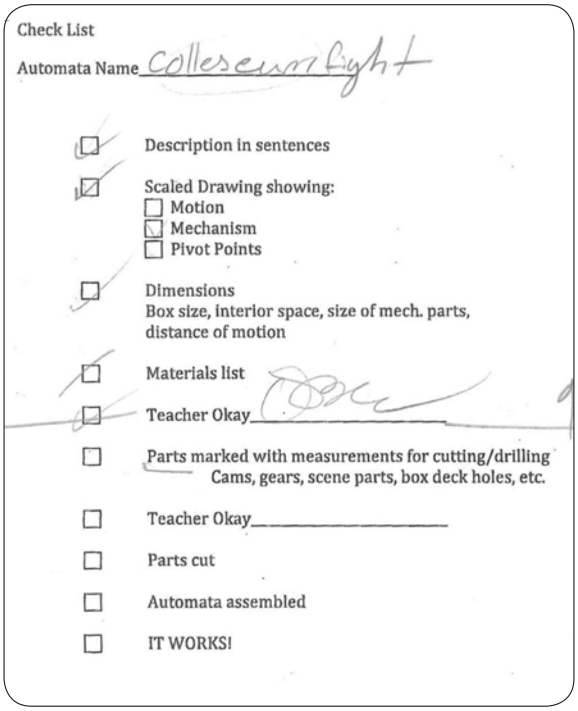
Suprisingly the cam and the riser are not atached.
Imagine a (riser) car driving up a mountain (cam)

Design

At last the students were ready to design their own automata, and we entered a four-week period of planning and building all afternoon three days a week. Most Intermediates were already fizzing with ideas for scenes from Greek myth, Roman conquest, medieval chivalry, or great moments in science and art. Each student received a checklist to guide her progress. Having described their intentions, eager draughtsmen took up their pencils and graph paper to puzzle out the precise mechanisms by which Circe would turn a man into a pig, Leonardo's flying machine would take to the air, and Copernicus would observe celestial motions as the stars and planets whirled above his head.

Some students approached the challenge from the other side, having become intrigued by the motion of a particular mechanism and developing the possibilities for what it might do. Watching his teacher's demonstration of using gears to translate motion from a horizontal shaft to a vertical shaft, causing a wheel to spin above the deck of the box, Jasper envisioned fixing a warrior figure on that spinning disk. His medieval knight would swing a sword to mow down a ring of spring-mounted enemies.

Students discussed their plans with teachers and began to encounter problems to solve. What gear ratio will produce the right speed for the whirlpool sucking down a hapless ship beside the Sirens' rock? Will the lion swing his paw at the gladiator more menacingly by means of a lever or a cam? They calculated precise measurements that would allow all the mechanisms to interact properly. They sourced the necessary materials, either from the bounty of components we'd assembled at school or from home. When teachers had given the green light to the final schematic, it was time to build.



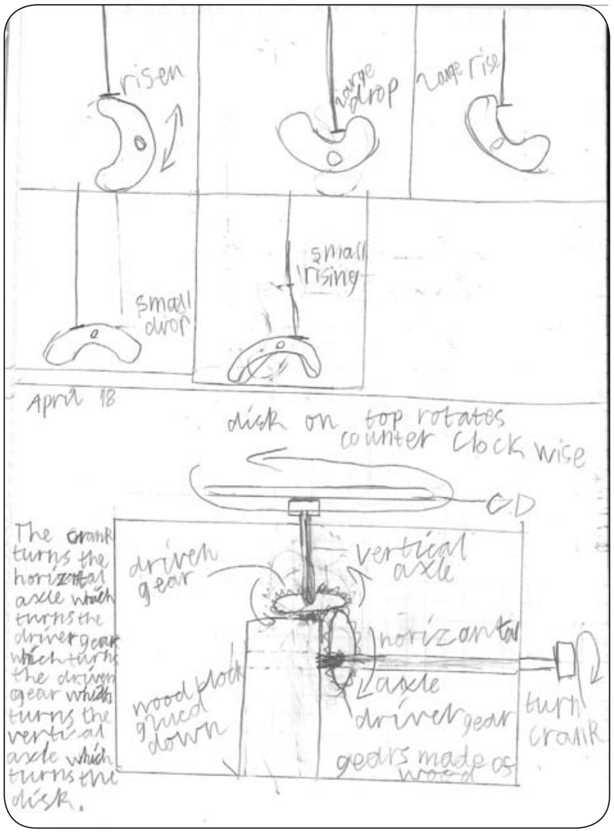
Check List

Automata Name Colleseum fight

- ☑ Description in sentences
- ☑ Scaled Drawing showing:
  - ☐ Motion
  - ☑ Mechanism
  - ☐ Pivot Points
- ☑ Dimensions
  Box size, interior space, size of mech. parts, distance of motion
- ☑ Materials list
- ☑ Teacher Okay__________
- ☐ Parts marked with measurements for cutting/drilling
  Cams, gears, scene parts, box deck holes, etc.
- ☐ Teacher Okay__________
- ☐ Parts cut
- ☐ Automata assembled
- ☐ IT WORKS!

Construction

During our work periods, the Intermediates focused on the mechanical aspects of the automata—decoration of the box tops and figures happened mostly at home and could be as elaborate or minimal as each student liked. Mechanically, there was plenty to do. The design challenge was an education in the qualities of different materials; most students had to overcome balsa wood disks that snapped when cut or popsicle sticks that split when drilled. They had to learn the skills to use a variety of tools—how to back a drill out of a hole, how to apply enough force to penetrate wood without breaking a fine-gauge drill bit, how to insert screws without stripping them, how to use a scroll saw, how to clamp small pieces of wood for drilling or cutting. To offer as much support as possible, we enlisted several parent volunteers to run work stations. We took advantage of fine weather to set up some groups outside, giving everyone more elbow room. A collective wisdom about materials, tools, and techniques began to grow amongst the Intermediates, who were quick to offer assistance and suggestions to frustrated peers.



Mechanical drawings by Lehua and Cole

Workflow would have been improved by even more explicit instruction on where to replace tools and materials you've finished with, taking only what you need, the importance of replacing a drill bit in its proper slot so as not to spoil someone else's precise plans with a wrong-size hole, etc. There's no such thing as too much organization when more than forty builders are sharing resources in a small space.

Enough Help

Trouble-shooting marked the next phase of construction, and each teacher had the delicate task of determining what was *enough help* for each student. A major challenge is how not to help too much; we firmly believe that the experience loses value rapidly when the hunches and fixes aren't generated by the student. In a mixed-age classroom, especially, there are bound to be varying levels of skill, so success can't look the same for everyone. Not everyone will succeed to the same degree. If that sounds heartless, we need only remind ourselves of the qualities we aim to develop in each student so that she can thrive when the going gets tough later in life: resilience, courage to risk failure and to try again, ability to dig in and work hard, reasoned assessment of the task at hand and the effort necessary to tackle it. Doing the work for her builds none of these qualities. Creating a compassionate environment in which students can fail, dust themselves off, and try again does. Too many adults and young adults are too fearful of failure to attempt the novel and difficult work through which humans truly grow. A child who learns early that mistakes can be amended and that success is sweeter when you've really worked for it will be willing to risk the leap and fly.

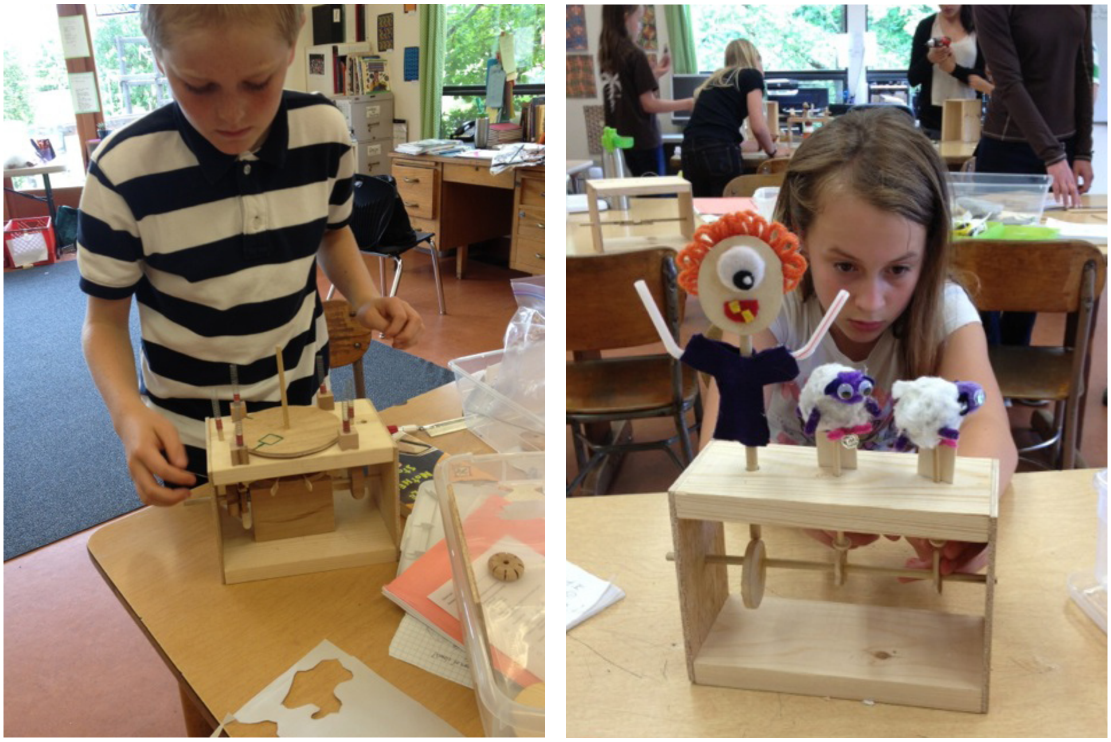
Intermediates at the scroll saw work station

A project of this scope reveals that there are many ways to fail. A student might have difficulties with the fine-motor manipulations required and need assistance with some portion of the fabrication. He might spend a long time unwilling to set aside an overly grand and complex vision that can't be achieved with the time and materials given. He might be unable to see how

It was important for each student to establish a thread of conversation with a single teacher. Students who bounced between adults for advice tended to get confused and wasted time as a new source of help worked to understand the underlying plans and strategies that had already been attempted.

to break the task into steps and need support in articulating how to work from A to B to C to D. In some students, we observed hindering habits and attitudes familiar from their work in other domains; in others the particular demands of the design tech challenge shed light on some novel need for special support. But these were exceptions. In most cases we were able to give hints and suggestions that allowed students to understand and correct design flaws for themselves. Holes were re-drilled, followers reshaped, axles sanded and even soaped to turn more smoothly. When Penelope's axle kept falling out of its shallow hole despite a cap she had added, her teacher operated the crank while Penelope watched carefully to see what was going wrong. She was able to realize on her own that a stopper on the outside of the box would solve the problem. Sophie had a clothespin person rubberbanded to a post who was supposed to lean forward and back, but would go too far in each direction. Again, close observation of the malfunction and talking through each motion while the teacher operated the crank led to a solution. Sophie decided that she would drill through the clothespin and install a bar for a pivot point, plus place a chair behind the person so she wouldn't fall too far back.

Everyone encountered frustrations and setbacks during this project. We worked assiduously to frame these moments as educative, and to make our aims transparent by praising perseverance and problem-solving and good design thinking rather than holding up an ideal of a beautiful and complicated final product—though beautiful and complicated automata were in abundance as we celebrated our hard work at the end of the unit with a gallery and demonstration for parents. As gladiators battled, Leonardo painted the Mona Lisa, and some sheep scampered past the blinded Cyclops with cunning Odysseus's men clinging to their bellies, we saw evidence of thoughtful planning, precise calculations, thorough knowledge of levers and cams, patient work, clever hands, and young minds afire with elegant and whimsical ideas. And this fall as we brainstormed for our class contribution to Arborfest, our annual school festival fundraiser, we heard, "Let's make something!" followed by a flurry of suggestions for mechanical toys. Let's make something, indeed.



Jasper and Sydney fine-tune their automata

WHEN THE SURFACE SHAKES
SENIORS DESIGN SEISMOGRAPHS

by Doreen Ho and the Senior team, grade 6-8

When the 6-8 Senior team began to plan a design tech project for our spring term, the convergence of curricular themes inspired our choice. In Humanities we were studying ancient China and the many innovations that sprouted from that fertile culture, while the Science Barn was housing investigations into wave motion and energy. Why not then consider and construct seismographs, which were first devised in CE 132 during the Han dynasty? We made no attempt to imitate the ornate beauty of Zhang Heng's *Houfeng Didong Yi* ("instrument for measuring the seasonal winds and movements of the Earth"), which period writings tell us was a two-meter bronze vessel adorned with eight dragon heads that would spit bronze balls into the mouths of bronze toads beneath to make a noise and supposedly indicate the direction of the earthquake. But it sparked our imaginations about the many different ways to register movement. What could our students build, given access to a variety of tools and materials, to practice design thinking and the iterative process of testing and revising to meet an open-ended creative challenge? What skills and habits might we instill along the way?

One morning in April, the Seniors came to class and found that the tables had been turned into six stations. At each station was a metal tray about 10" square, an ink pad, a ball bearing, a piece of paper, and an empty Sno-Kone cup. They learned that these were the basic materials that their teacher Greg had used to make a simple but brilliant device. One of the items was a red herring—not part of Greg's device. (It was the Sno-Kone; we just happened to have a stack of them in the closet.) The challenge was to see if they could figure out what Greg had invented.

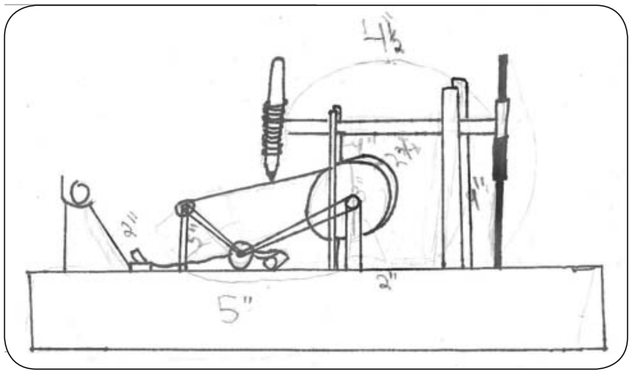
The students had about ten minutes to mess around with the items and come up with a list of devices that they might be able to build. Their Humanities teacher Linus roved the classroom, checking in with the groups, providing guidance or hints as needed. Several groups actually figured out that Greg had invented a seismograph. Some of them got close, in the sense that they thought it was a measuring device. After the brainstorming session, groups took turns explaining their theories. Linus praised everyone's efforts, then showed them how Greg's seismograph worked by simulating an earthquake with one of the tables. The punch line, of course, was that they were going to get to design their own seismographs.

The follow-up discussion asked, "What aspects of an earthquake does Greg's seismograph measure/capture? What aspects does it not register?" We talked about what can be measured in an earthquake, particularly strength, direction, and duration. The students noticed that Greg's device did well with side-to-side shaking, but not up and down, and that it could potentially measure strength, but probably not duration.

Next, students had a Humanities period to brainstorm seismograph design ideas. They wrote to the following questions: *What does a seismograph need? How would you make a seismograph that measures these different elements?* Students' instruments were not required to measure every aspect of an earthquake—it was fine to build a device that could register only the strength or the direction. In groups of two or three, they began to make sketches and plans.

Groupings were by same grade and Seminar cluster to work around fieldtrip and class constraints.

As they honed in on a design, they made detailed drawings from two different perspectives and included precise measurements. They considered a list of supplies and tools already available at school—cardboard, hot glue guns, drills, hammers and nails, styrofoam, wire, string, rubber bands, inkpads, skewers, cups, Sharpies, modeling clay, paper, cans, dowels, tape, ball bearings, X-Acto knives, Dixie cups, balsa sticks, plastic plates, chicken wire, plastic utensils, rope, washers, springs, pipe cleaners, tagboard,



Maya and Fiona's schematic

shoe boxes, and more—knowing that they could amplify it with materials from home if they wanted to.

Prototypes

The first week in May, we built prototypes. We opted to couple Humanities and Math periods to give students two 50-minute blocks of time during the morning to complete and test a working model. Most seismographs changed—some significantly—from initial inception to final product. Students learned a lot about materials and how they interact. Painting waxed paper plates with a water-based paint doesn't work well. In one case, the glue used to adhere plastic cups to a wooden base chemically melted the bottoms of the cups, which were supposed to hold water. Securely attaching two rounded surfaces (crossed dowels, for instance) to each other is difficult. Students had to make design decisions on the fly: *Do I continue with the same materials and work around the problem or do I switch materials? What other resources are available that I didn't think (or know) about?* They were able to confer with peers and teachers to guide their choices.

Doing all the building in one long session meant most importantly that students could solve problems immediately upon discovering them. A further benefit was that they were required to clean up only once; it was a big job that would have eaten a great deal of shorter work periods.

Students reflected on their prototypes by writing to the following questions: *What would you do differently and what would you do the same? How long do you think it will take you to make your seismograph?*

Each group made a final supply list that laid out what they would bring to school and what they would be relying on us to supply. We compiled all of the lists and made sure we had enough of each material to support every group's design.

Supporting Science

The following week we did wave activities in Math, using Slinkys to demonstrate pressure waves and shear waves, the two main types of waves generated by earthquakes. A quick push down the length of the stretched-out Slinky demonstrates a pressure wave, while a quick flick of the wrist will send a shear wave down the Slinky. The students could see that these are two different ways of putting energy into the spring. They experimented with Slinkys and wrote about what they observed, including the key facts that P-waves travel faster than S-waves and that wave speed and direction can be measured at different stations to triangulate the epicenter of an earthquake. Using these very long springs, students learned the vocabulary to accurately describe waves: *frequency, period, wavelength*. The activities were engaging, promoting further thought and discussion among students about how their seismographs would work based on their improved understanding of physics.

Seismograph Workshops

In mid-May, the Seniors had a two-day work session to build a final seismograph. The first day of the workshop was focused on preparing materials that required woodshop time and collecting all needed components. Having good parent volunteers was key. They helped problem-solve by giving suggestions and not doing work for the students unless it was necessary for safety. Each parent brought her own approach based on her unique skill set, experiences, and preferences. One parent helped students drill a hole at the end of a wooden arm; another volunteer solved the same functional challenge by helping students attach a washer to the end of the arm. Different types of braces were devised by different groups: prefabricated metal corner brackets in one group, fabricated wooden wedges attached to the inside of an angle in another, fabricated wooden triangles attached to the outside of a right angle in a third. Everyone finished his seismograph by the last day allotted for building.

Summative Demonstrations

The Seniors all demonstrated their working seismographs to an audience of younger students, and each group was able to explain exactly what their device could measure, what its limitations were, and how they might address those shortcomings in a future design. The seismographs largely fell into three categories:

Lily and Maria at work on a combination paintbrush-in-salt and spilled-water seismograph that could measure both direction and severity of a quake

Pendulum models: Sharpie suspended on a string, paintbrush in salt, nail in wet sand

Spilled-water models: Water or colored sand splashes out of cups filled to varying heights so that strength and direction can be measured. (This was messy for teams that didn't consider in advance how to contain the spilling water!)

Inked ball bearing in a bowl or tray: One team quickly built a working model, but then decided to situate it atop a pyramid structure. They ended up spending hours calculating angles and learning how to miter the edges of their plywood to achieve their vision. This contributed nothing to the function of their seismograph, but certainly served our overall aims in undertaking the design tech challenge.

Some of the more unusual models, as described by their inventors:

"The seismograph I worked on was meant to measure duration of an earthquake. A marble rolled in ink is situated precariously on the edge of a ramp with a slight decline. When an earthquake happens, the marble will fall from its perch and go down the long ramp. The earthquake will cause the marble to draw a squiggly, deformed line, but when the earthquake stops the marble will run in a much smoother line. So depending on how long the squiggly line is, you can determine how long the earthquake was."

"My seismograph measures horizontal movement. It is made up of a cone-shaped spring with a pencil [pointing upward] on the end. This is inside a structure that consists of four dowels that hold up a piece of foamcore. When the surface the spring is on shakes, so does the spring. The spring's movement causes the pencil to draw on the foamcore. I would have liked more time to make a dome for the pencil to draw on. This would be good because if there was a very high-level earthquake the pencil would still be able to record it."

"Our seismograph only measured strength of movement. In essence, our design is nine varying heights of PVC pipe [fixed to a board] and nine 7" dowels. The longer and stronger the quake, the more dowels will fall out of their pipes."

We asked students to reflect on the collaboration skills they had practiced: *How did the partnership work? Did you take a leadership role or follow a teammate's ideas? Did everyone contribute equally? Were you productive? What were some of your difficulties? How did you overcome them? What would you have done differently?*

"I learned that working with my friends is not always fun… we both have strong personalities. I felt I wasn't being listened to and my ideas were poo-pooed right away."

"The first design we were going to try making created quite a few problems. I was pretty skeptical about if the design would work, whereas my partner was absolutely sure it would work. I noticed I am really stubborn and realistic and do not like trying ideas with lots of holes in them."

All students also responded thoughtfully to the following assessment: ***What is it possible to measure in an earthquake? What are the essential elements of your seismograph, and what do they accomplish? What were some difficulties that you and your partner faced? How did you overcome them? If you were to build another seismograph, what would you do differently? What did you notice about yourself throughout the design process?***

Kennedy and Katie testing possible materials

"Next time, I would think about several different types of seismograph before immediately jumping into the first idea we came up with. I would really think through everything I did."

"When we first made a model of our seismograph, we used the coarse sand from the sandbox. The lines didn't show up as well and were thick, and we couldn't measure this well. Another problem was that when the sand was dry, it slid around with the earthquake, so we made it damp. To solve the first problem, we used brown sugar. But overnight the brown sugar became sticky and crumbly. We decided to use fine sand, but at first we couldn't find any. I collected some sand at Ocean Beach in San Francisco when I was there."

"I think I really improved in my problem-solving skills and also my planning skills."

"I noticed that I have an easy time collaborating with other people. I'm pretty flexible."

"I had a hard time planning ahead and just wanted to build it and change the plan as I went along. It was hard when my partner wanted to try something I didn't think would work or the other way around."

"I learned that you go through many ideas and most fail."

"I found my strength in bringing the group back together, back to collaboration. We were once far adrift but I helped us reconnect."

Reflections

From a planning perspective, building in time between each stage of the design challenge was important. First the idea of a seismograph was introduced. Students were told that they would be designing seismographs. A week or so later, they had class time to brainstorm, work on designs, and then choose a design. Another two weeks passed, during which they deepened understanding of the physics of earthquakes, and then they had time to build prototypes, test, and redesign. After another week we scheduled the final build. Those incubation periods were important. Even though students were not told to think about the project on a daily basis, there was an air of anticipation and excitement. They were preparing for it. The ideas were forming, consciously or unconsciously.

Time was also a key element in the nitty-gritty of the workshops. Students took advantage of having long periods to complete the actual building so that we didn't have to sacrifice a lot of working time to set-up and clean-up. Productivity was high and the kids didn't feel rushed to finish, so they could do quality work. Testing, evaluating, and redesigning was expected and scaffolded at every step.

Having students plan and produce physical evidence of their planning was key. Teachers and parent volunteers could check those drawings and make sure students were using their plan as a guide at the start of their building and not just starting to put pieces together. This was essential to their success.

Student access to appropriate materials and tools must be a primary consideration in planning design tech projects for the classroom. Which tools will require adult supervision, and how can that supervision be arranged? Which tools can be procured in sufficient numbers to prevent a logjam of children all waiting to use a particular saw or drill? Hand tools are portable and relatively safe, but for many jobs we found they were too time consuming, labor intensive, and inaccurate. Having some competent parents and teachers help in the woodshop let us walk the line between safety and allowing students autonomy to use more powerful machinery. We don't let kids use the table saw and restrict use of the band saw to simple and carefully supervised tasks. Electric drills, drill presses, and scroll saws are safe enough for kids to use alone, following proper instruction. Any tool, electric or not, can be very dangerous, and we were careful to provide direct instruction to emphasize safety.

Most Arbor students have had previous experience with these machines by the time they reach the Senior level.

The design tech process is inherently messy, both figuratively and literally, and mess is uncomfortable for some human beings, child or adult. The teacher must ensure that thorough planning is guiding the class in productive work, but part of the purpose of this challenge was to put the tending of the design cycle into the hands of the students, to let them discover for themselves the importance of careful thinking, anticipating possible malfunctions, responding to setbacks with grit and ingenuity. Had we attempted to engineer the mess out of the experience, it would have been less fruitful.

Successfully building something they had independently imagined was satisfying for the Seniors. They were able to practice the skills and habits of engineering thinking—working through the cycle of developing an idea, prototyping, refining, testing and refining further. The seismograph challenge ensured that *all* students built—certainly this has been an option in other projects before, but this time every student was asked to tinker, develop, and try. This chance to experience first hand the work of an inventor solving a problem lent extra resonance to their developing appreciation for the tremendous innovations and inventions in China's rich history. We hope it also allowed some students to glimpse capabilities within themselves that might be brought to bear on the great challenges of our own time and place.

MINDS ON FIRE

DESIGN THINKING IN THE PRIMARY JUNK BOX ROOM

by Deborah Mandelsberg and Felicity Nunley with Laura Frizzell

...the silvery down, they carry it
in their finchy beaks
to the edges of the fields,
to the trees,
as though their minds were on fire
with the flower of one perfect idea–
–Mary Oliver, "Goldfinches"

A productive morning in the Primary Nest Junk Box

"Can I plug in the hot glue gun?"
"Where are those big things Phineas brought?"
"How are we gonna use them for boats?"
"How do you spell 'Come to the store'?"
"Which stapler has the most staples in it?"
"Where did you get that feather?"
"Who wants all these colored balls?"
"What will you give me?"
"Do you want me to teach you how to do that?
"I'm gonna make some hot chocolate, would you like some?"
"Can I use that when you are finished?"
"How do you make that?"
"Let's use these...wait, can corks float?"
"Can you help me tape this thing together?"

These are just a few of the questions posed by K-1 students in a small, untidy room adjacent to the larger Primary Nest classroom. This "Junk Box" room—no larger than 12' x 12'—is a laboratory humming with creativity, where students are independently or collaboratively "on fire with the flower of one perfect idea." Low square tables and a tool bench with a vise miraculously fit in the space, offering optional work surfaces. Bins of everyday materials spill out, offering the promise of maps, boats, jewelry, and all manner of dramatic, interpretative scenarios. There are googly eyes, small plastic balls of every color, popsicle sticks and wood pieces, cardboard tubes and boxes of every size, string and yarn, feathers, plastic fruit crates, milk jug lids, corks, bottle caps, and lots of paper and fabric. Tools such as glue guns (with bushels of glue sticks), staplers, masking tape, and scissors wait beside the bins.

Students often choose to work on the floor when immersed in a project. What is noteworthy about the materials is that students seem to regulate themselves to use "just enough" and are skillful at sharing coveted novelties. They do count on having basic supplies sufficient to enable a satisfying outcome. Critical to their satisfaction, too, is ample time to explore and to see how things work, time to learn from one another. The parallel and collaborative work in the Junk Box might well be less harmonious if the time allotted to it felt more constrained.

This is a room where magic happens. Provided with everyday materials, children develop the skill of transformative thinking. They start to see possibility in the ordinary, to see that a lid with a flap can, if turned upside down, make a pretty convincing outboard motor on a cardboard box boat or, for that matter, a satisfactory armchair in a mouse-size apartment. The children are developing the habits of resourcefulness and of problem-solving. They are learning to adapt, to make do and re-imagine and re-form. All the while, they are asking, "What are the defining features of what I am making?" "What is important to make it work?" In short, "What matters?"

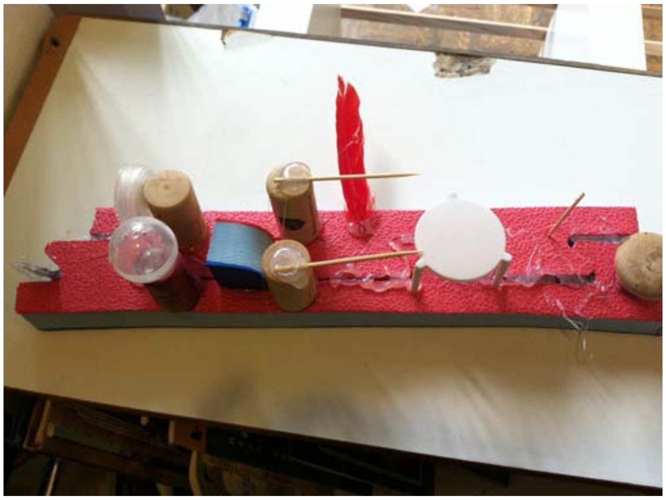
For a glorious 45 minutes first thing almost every morning, the Junk Box is open. Boats and robots take shape. Kids tinker to find the best way to make a hinge for a model barnyard gate, or collaborate to design a restaurant and its necessary (and hilariously complex) systems. On some days up to 15 students are engaged in projects and working harmoniously. What variables exist that allow for these sustained, cooperative, and highly creative endeavors? Does it work because each child drives his own inquiry? Is it because teachers strategically step aside, except to give an occasional redirection or 5-minute warning for a transition? Observations of the Junk Box activity allow us some intriguing glimpses of insight, if not declarative answers.

Max is a boy who finds his best self in the Junk Box, demonstrating extraordinary perseverance and self-direction. Today he takes stock of some new materials. "Look, we can make boats out of these," he says excitedly, pointing to some thick colored foam. Mo asks, "How are you gonna use them for boats?" Max replies, "I don't know, but we can make a ginormous boat!" Max gets to work checking the glue gun and gathering corks. He expertly glues four corks together with foam on top. "Do you want to test this in a bowl of water?" Deborah asks. "We're going to test it in the Rill," says Mo, who is working on his own project but taking great interest in the evolving boat. Max, proud and satisfied, looks carefully at his boat, imagining that trip down the school's spiraling sculpture of water and stone. "Wait! I need a steering wheel." He glues on a perfect piece for a wheel. Holding the boat up to inspect it for seaworthiness, he notices cracks along the bottom. "I want to glue the bottom," he determines, then waits for a turn to apply a heavy layer of glue-gun waterproofing.

The glue guns are central to Junk Box projects. Students don't like to wait for them to warm up to the perfect temperature for construction; they do, however, wait patiently for one another to finish, negotiating turns for fair access.

Meanwhile, Ronin, Aakriti, and Alina are engaged in creating a store. There is a running narrative from each child as she engages in dramatic play or finds just the right materials for the store. A defunct cell phone is liberated from one of the bins and the girls begin placing store orders. They also begin to develop a scenario about robbers in the store and proceed to call 911 on the phone. Other students are invited into their play. Alina, with perfect dramatic flair, says the police are taking too long. Purple crepe paper is strung from one end of the doorway to the other, in the hopes of barring the would-be robbers. This play unfolds amid the design tech work, all of the students coexisting comfortably in the small space.

There seems to be something particularly generative in sharing the experience of designing and tinkering. Even when students are working with total self-sufficiency on parallel projects, simply sharing a workspace can spark new ideas. In the adult world, we see the rise of "maker spaces" where innovators can access the specialized equipment that is too costly or impractical to keep at home; cooperative entrepreneurial ventures are being born from makers rubbing elbows with other creative people and seeing the possibilities in combining ideas. Our Junk Boxers share an understanding of what it feels like to satisfy the human urge to create, to explore and to accomplish, and they trust that their ideas will not be undermined. They are empowered by giving and receiving constructive feedback and by teaching each other new skills. We notice that rather than the competition one might expect when space and tools are so limited, the Junk Box is home to genuine interest in and excitement about one another's work.



Max's completed boat

"I am making a trophy for Henry," says a very focused Juliette. Elliot finds a ball chain and states with surety, "I could use this for something." Quinn wonders aloud what wood is doing in the metal bin, then holds up two triangles of paper and says with certainty that two triangles make a square. Elliot finds a checker piece and sings exultantly, "This piece is mine! Now I just have to figure out how to use it." He picks up an aluminum pan and says he can use it for a boat; nah, a shield. He is thinking on his feet, as many of them are.

There is, almost uniformly, a steady narrative that accompanies each student's tinkering. If they can say aloud what they are imagining as they lift an item to explore it, or narrate what they are presently engaged in, it seems to solidify their thinking. It is, we believe, a necessary element in these Junk Box endeavors, and perhaps one that could be mined for literacy strands. Thinking aloud as they refine their projects, students reveal their cognitive strategies, a gift for teachers ever in search of deeper understanding of each child's processes.

Grace is fashioning a long necklace out of rust-colored woven yarn. "Can someone help me cut this?" she asks. Aakriti enthusiastically offers, "I can!" It's hard to cut, but with four hands and two pair of scissors… success. "Where did you get that feather?" Grace asks Max. Max shows her where to find the feathers. He has used one on his boat as an oar—the scale is perfect. Grace continues designing her whimsical necklace, adding lots of masking tape to secure the filled plastic balls she hangs from it. Making a connection as she works, she says to no one in particular, "I opened an owl pellet and saw a rat skeleton." Aakriti asks, "What's an owl pellet?" "Owl vomit," Grace declares with authority.

Max asks a teacher if he can go to the Design studio to get a string. "I want to use it for Cat's Cradle. I brang my green one to Sun River but I left it there." Phineas offers a string he has just finished using: "Oh, I just did a disappearing knot. It's very easy." Phineas proceeds to share his trick. "You just tie a small knot and pull it and it disappears." Meanwhile, the teacher has brought in twine for Cat's Cradle. Max begins to weave the string around his fingers, enlisting a curious Aakriti to play the game. He asks her, "Do you want me to teach you how to do that?"

The Junk Box brims with sophisticated and deliberate navigation, negotiation, strategic thinking, and perseverance. Cooperation and support for one another's efforts is in abundance; the room becomes a very secure place in which to explore, and a place that influences children's curiosity. Watching the youngest children in the school react to obstacles, we see them building the skills and attitudes we deem essential: thinking on their feet; creativity; grit; cooperation and ability to brainstorm together; willingness to take risks, to steal good ideas, to inspire and be inspired, and to be helpful to one another. And when the original vision for a project must change to accommodate the vagaries of the materials or tools at hand, students tend to persevere rather than giving up. What drives that perseverance? And what does it mean to persevere in this context? Is it sticking to an earlier version of a plan, or changing mid-stream based on emerging evidence? Is it being on fire with one good idea that strengthens their perseverance, or that they are simultaneously reviewing, tinkering, and challenging both materials and their original ideas? The answer varies with the individual child. At Arbor, we aim to help every student develop both stamina to work toward that initial vision and the judgment and flexibility to change course if necessary without becoming discouraged. Each one of these Primaries will be given repeated opportunities to practice design thinking and all its attendant skills, and each will be encouraged in rounding out his predilections.

The idea of the Junk Box remains generative and nourishing up through the grades. Twenty or more 2-3 Juniors and 4-5 Intermediates can regularly be found in Open Design during recess, tinkering and building freely in the Design Studio.

How, then, do we keep this momentum going and enable an industrious group to go even farther? This year's Primary Nesters are a particularly design-oriented group of kiddos. Given the opportunities and materials, other groups usually find their way into happy and productive Junk Box interactions, but it is rare to have so much of the class involved so consistently. The usual constraints of a crowded classroom don't seem to apply in this particularly small space. We have watched, again and again, as the children naturally scale projects to fit the space, while they also incorporate their Theme work from the classroom—the boat building, for instance, has grown from studies of journeys and water this autumn.

One way to encourage even greater use of the Junk Box is to draw upon it during academic portions of the school day. Junk Box work spilled into our curriculum in a particularly fruitful way almost by accident one day in September. Juliette and a few others had begun to explore the possibilities for using Junk Box materials to please not just the eye and the imagination but also the ear: they were filling containers with small, rattly objects and, with the aid of vast quantities of masking tape, making shakers. Meanwhile, the annual school-wide fair was fast approaching and the music classroom was being transformed into an elaborate country store. Laura, our music teacher, was displaced. But what could have been an inconvenience turned into an inspired experiment: music class came to the Junk Box.

Testing the Junk Box shakers with Laura

Laura brought with her a fascinating collection of shaking and rattling instruments. She demonstrated the various sounds the maracas made—some were low and loud, others softer or higher in tone. Laura told the Primaries that, particularly in Latin and African music, the lower and higher register shakers are paired, adding a varied texture to the music. A Mexican percussionist with whom she once took a workshop referred to the low maracas as "male" and the high ones as "female," an idea that seemed to appeal to the Primaries as they thought about personalizing their creations. That got us to thinking: what makes something sound that way it sounds? We brought the Junk Box materials out into the main classroom and set about the challenge of making "male" and "female" shakers. With the choice of popcorn, flax seed, or salt for filler and with a large collection of containers and lids, we experimented: *What matters when making a shaker? Is its sound mostly determined by the size of the container? Or does it mostly matter what it's filled with, or how much filling you put in? Does a lot of filling make it louder?*

As they worked, the children were animated, building and testing, revising their designs and testing again. They listened carefully, adjusting their language to differentiate between soft and loud sounds and high and low tones. Many students initially planned to pack their shakers with as much popcorn as they could manage, on the theory that *more* of the loudest thing will be *really* loud. In fact, they discovered, an overstuffed shaker makes almost no noise at all. They developed new theories and offered advice. At the end of the period, we had an impromptu recital, shaking first our "female" shakers and then the "male." And led by Laura, we combined the sounds, learning some Latin-style rhythms.

It is important, we feel, that the Junk Box remain primarily a place for "non-commissioned" work. The children feel a very productive sense of autonomy when they can direct their own inquiry, and we try to tap this natural bent within our formal curriculum as well as during Choice time. This is not to say that teachers do not influence what happens within the Junk Box. Felicity and teaching apprentice Abby Block always have an ear tuned to the chatter within so that they can make strategic appearances when the robbers get too boisterous or an opportunity to sow the plump seed of a new idea presents itself. The skillful teacher can, rather than directing every aspect of learning, make enticing suggestions that children will snatch and carry forward themselves, enhancing the curriculum and making important ideas "sticky" through their incorporation into independent work and play. As we write, the foremost example is the Mayflower Museum being designed and curated in both Primary classrooms. The teachers did not decree that such a summative demonstration of unit studies would take place, but dropped hints enough to engender a flurry of imagining and building so that visiting parents can be transported to 1620 to practice period crafts and games and read realistic journal accounts of the historic voyage. The Junk Box has been well stocked with yarn as a Mayflower-inspired finger knitting craze has swept the classroom, and model boats continue to occupy many young builders each morning.

As far as we know, finger knitting was not actually practiced by the Pilgrims. But it serves as an easily taught stand-in for the sewing and similar useful crafts that would have occupied quiet hours for young 17th-century voyagers. The Primaries love to wind yarn between their fingers while listening to read-alouds, at Choice time, and even on the playground at recess.

Besides providing a venue for self-directed inquiry and expression, the Junk Box seems also to deserve some credit for the positive habits and attitudes children evince beyond its four walls. After a satisfying time in the Junk Box each morning, they transition to Circle. As Mary Oliver writes, "Then they drop from the sky. / A buttery gold, they swing on the thistles, they gather…" Now the Primaries seem to gather for the next work of the day with greater focus, with a readiness for conversation involving the whole group. They seem to be fueled by creativity and show evidence of having had time to practice leadership, to listen, to wait, and to plan. And we believe the confidence engendered by their unfettered tinkering supports creative problem-solving across realms. What might happen if there were time each day, in all classrooms, in which children's self-driven inventiveness was encouraged to flourish?

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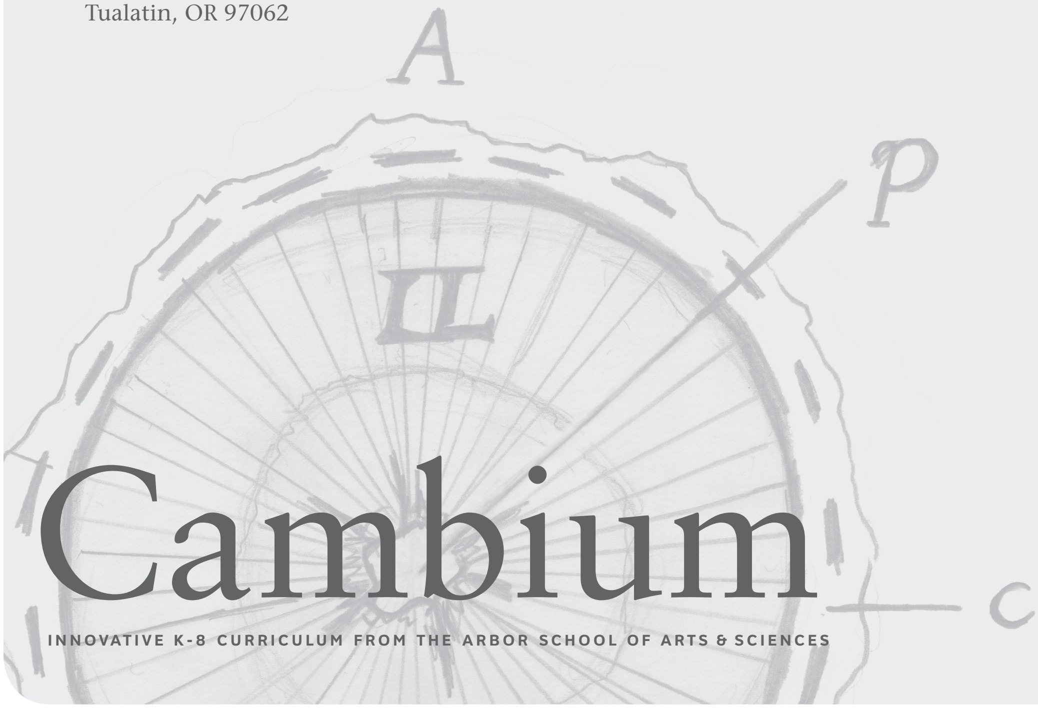

Cambium

INNOVATIVE K-8 CURRICULUM FROM THE ARBOR SCHOOL OF ARTS & SCIENCES

THE ARBOR CENTER FOR TEACHING AT
ARBOR SCHOOL OF ARTS & SCIENCES

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Cambium: (n) the cellular growth tissue of trees and other woody plants, from medieval Latin "change; exchange."

What content would you like to see offered in Cambium? Send us an email: cambium@arborschool.org

Masthead by Jake Grant, after an 1890 botanical illustration.

The Arbor School of Arts & Sciences *is a non-profit, independent elementary school serving grades K-8 on a 21-acre campus near Portland, Oregon. Low student-teacher ratios and mixed-age class groupings that keep children with the same teacher for two years support each child as an individual and foster a sense of belonging and community. An Arbor education means active engagement in learning, concrete experiences, and interdisciplinary work. For more information on the Arbor philosophy, please visit* www.arborschool.org.

The Arbor Center for Teaching *is a private, non-profit organization created to train teachers in the Arbor educational philosophy through a two-year apprenticeship while they earn MAT degrees and licenses, and to offer guidance to leaders of other independent schools. Its mission also includes the publication of material underpinning the Arbor School curriculum.*

Mo shows off his Junk Box boat

Cambium is free! Please forward it to your friends and relations and don't hesitate to let us know if there's anyone we should add to our mailing list. For more information and to purchase publications from the Arbor Center for Teaching, please visit our website: arborcenterforteaching.org. Cambium's development was made possible by a grant from the Bloomfield Family Foundation, which has also generously underwritten the publication of the Arbor Algebra series. We are ever grateful for their support.