Project Guide

Lindy 500 Kinetic Sculpture Race

Learning goals and skills:

Students learn to weld, work with steel, work with wood, repair bikes, use a laser cutter, sew, use CAD, use a Shop-Bot, etc.

They also practice real design – brainstorming, planning, sketching, prototyping, testing, failing, and iterating. Nearly all entrants run into obstacles that require rethinking and redoing at least parts of their projects.

The most important things they learn, in my opinion, are (1) patience, and (2) that with patience and determination one can accomplish great, improbable things, like a giant pedal-powered high-top sneaker.

Facilities and tools at a glance:

- Basic metal shop (mig welder, chopsaw, disc grinder)
- Basic wood shop
- Basic hand tools
- Basic bike tools
- See detailed materials and tools list at end of article.

Materials at a glance:

- Junk bikes, exercise machines, shopping carts, etc
- Square steel square tubing
- Scrap wood
- Store of spare bike parts

Project requirements - phase one - crazy bicycles

The Lindy 500 began as a sculpture class project - Using principally bike parts, wood, and steel, design and build something you can ride that doesn't resemble a normal bicycle. As with many projects, it's important for the instructors to try it out themselves before implementing it in a class. Make a few creative bicycles in your spare time and ride them around school. They make great advertisements for the project and help students realize what's possible.

For the first iteration of the project we restrict students to using no more than two wheels, or at least to use only one driven wheel. Inevitably some students will want to make a four-wheeled car sort of vehicle, which is a good deal more complex because bicycle drive systems (chains and sprockets) are designed to power a single wheel.

A second iteration of the project, or a more advanced version run with experienced students, might choose a particular design challenge- to design a bike for disabled users, seniors, or users that need to carry groceries and live in walk-up apartments, for instance.

As with most of our design/maker projects, we try and incorporate some form of public display at the end. This adds motivation for the students and is good publicity to boot. The first year we did this project we rode the machines across the soccer field with most of the school watching. The second year we opened the project up to the entire school as the Lindy 500 kinetic sculpture race. Either way, it gives students something to work towards.

Introducing the project

I usually start with a slideshow to get an idea of what other folks have done. You can get some fun images by googling "kinetic sculpture race". Also:

- http://www.ihpva.org/home/
- http://www.dclxvi.org/chunk/operations/index.html.
- Bikes & Trikes of Long Ago, 1989, Chandler Press
- Bike Cult, by David Perry
- Encycleopedia, published annually by Open Road Ltd

How bicycles work

Depending on the students' level of familiarity with bicycles, it can be useful to go over how bicycles actually work. One way to do this is fill a box with bike parts and have each student take one and figure out what it does, how it works, and explain it to the class. It's interesting to discuss other mechanical ways to achieve the same functionality – what's an alternative to a bike chain? (belts, gears). Besides using handlebars, how else could you steer? It's worth taking a close look at how bike wheel axles work- the axles themselves are stationary, with the bearings in the wheels. This is one reason that it's tricky to make bikes with more than one driven wheel – the parts needed have a driven axle that turns two wheels (like the ways cars work) aren't standard. Another useful thing to look at is the rake angle of front forks (the angle of the invisible line that runs through the front wheel axle and the head tube. This is pretty standard on bicycles (about 73 degrees). See if the students can figure out what happens if you modify the angle. Have them think about swiveling supermarket cart wheels (which have a trailing rake, and follow the cart) vs a forward rake. The bottom line is that pushing the front wheel too far out in front (i.e. insane chopper style) will make the bike hard to steer, as the front wheel can just flop over, while moving the front wheel too far backwards will give you a bike with a mind of its own.

Demonstrate the tools

Before design begins it's a good idea to demonstrate a few of the tools (mig welder, chopsaw, grinder, chain link tool) so students can see what's possible with steel tubing. We standardized on 1" square tubing because, although heavier, it's so much easier to work with than round tubing - no need for a tubing notcher to make rounded cuts - all tubing can be cut with a chopsaw. Welding on flat surfaces is also much easier than on curved ones.

This might be a good time to talk about weight loads and stresses on a bike frame and the utility (and ubiquity) of triangles in structural design, from bike frames to bridges.

The design process

It's useful to examine the way bicycles are used in other cultures, particularly in parts of Asia, where they are (or were) often a principal mode of transportation and way to move cargo. We watched a slide show from a friend who had spent time in Vietnam. One interesting aspect of bicycles as a design project is that there's so much room for improvement. The design of nearly all bicycles produced today hasn't changed much since high wheelers went out of style around the turn of the century. And yet, if you question the design of today's bicycles, numerous flaws are apparent: the rider's back is bent over, weight is on the wrists, and in an accident, the foremost part of the rider's body is the head. It almost seems that bicycles haven't changed because no one has thought to question their design. (Of course, there are lots of people questioning bicycle design, it's just that most of them haven't made it into large-scale production yet.) These ideas might prompt a discussion on how many other products could be redesigned, and how anybody can have a great idea.

Our design process loosely follows the iterative design thinking blueprint- brainstorm, improve, sketch/model, repeat, build. The first drawing exercise was to sketch, whatever size you liked, the bicycle you wanted to build. The sketches usually range from basic to fantastic. Each student explained his or her machine to the class. After each presentation we discussed the feasibility of the bicycle- would it work? Why or why not? If not, how could the design be changed? Could we build it with the tools and materials we had? Which ones? Most of the designs were modified through this group process.

The next step is sketching. First-time bike builders will often sketch great ideas without much thought as to how the bike will work mechanically. For most students I recommend (or insist) that they use an existing rear triangle / bottom bracket and pedals combination – why not take advantage of all that free, time-tested design to make your bike move? It's fine to move the bottom bracket to another location and extend the chain though. Once students have sketched ideas that are within the realm of possibility (a big realm!), we found it helpful to build scale models. Most beginner students aren't able to go straight from a drawing to production- there are too many things to think through. We created a set of 1:5 scale bicycle parts for cutting on a laser cutter out of wood. We use 5/16" underlayment from Home Depot. (Download the file here). We only included parts that there's not much sense in fabricating yourself - rear triangles with bottom brackets, wheels, forks, cranks and pedals, and gears. The holes in the parts are scaled to fit snap-together pin and post connectors used in upholstery (see materials list at end). For individual lengths of tubing, cut strips of the same wood used to cut the parts on a band or table saw.

The models should make sense structurally and mechanically before moving on to the next step. Is there room for the rider? Clearance for knees? Does the chain rub against anything? Are gears that are connected by chain absolutely parallel? Once the model is ready, it's time to find and cut the parts. Tubing lengths should in theory be 5x the pieces used in the 1:5 scale model. For first-timers it helps to lay everything out on a big table or on the floor so they can get the cut angles right. Joints (places where metal is welded to metal) should be tight (only small air gaps permitted) for strong welds.

By this point many students will be enthusiastic and impatient to finish their machines and begin terrorizing the neighborhood. It can be a bit of a letdown for them to realize that building a bicycle of any kind is a long process, usually marked by mistakes that take time to sort out. Welding is quick, grinding off a welding mistake, or a bad weld, isn't. This is a good time to emphasize patience. I've found that making tidiness in the shop part of the project grade is helpful too – it's all too easy to be so focused on one's project that suddenly it's time to rush to the next class, leaving a pile of tools, parts, and supplies strewn about, which slows everyone down.

Depending on the bike, it's usually a good idea to require working brakes. Chains usually work better when run through a rear derailleur (even if no gear changing is required) to keep them tensioned.

As with any extended project, regular group check-ins are helpful, both to spread the momentum around and to give students a chance to make suggestions to each other on their projects. Hopefully by this time the public demonstration has been scheduled so there's a date to work towards.

The bicycle design project stresses several key elements of design: the importance of planning (sketching, drawing, measuring, testing) before building, the value of getting input from others and working together, and that the work can be fun. Like many design projects, It also helped to put math and other academic subjects in a different light, encouraging students to see these disciplines as tools they can use to do what they want. Ideally students will discover confidence in themselves that wasn't there before- the feeling that they are designers, and that with enough effort and planning, they can create anything they put their hands to.

Phase two- school-wide kinetic sculpture race

The idea of the kinetic sculpture race is to create sort of a Burning Man atmosphere. We hold the race on the last day of school at lunchtime. Students, staff, and faculty are all welcome to enter. Participants get tremendously fired up for the event. Some begin work in the winter on their own, while others start work in participating art and science classes and after-school clubs. Participants range from 5th to 12th grade.

To drum up contestants I visit each grade meeting and show a few slides of previous races and invite students to come to the maker lab with or without ideas to see what's possible. I also evangelize among teachers. For ideas, I show slides from other kinetic sculpture races (google images) and past Lindy 500 entries on this website. One catalyst for ideas is to change the scale of an everyday object - this is how the giant hightop sneaker came about. I encourage students to brainstorm nutty ideas (a vehicle powered by a rider suspended in a harness six feet off the ground) and figure out how to make it work (they did). Our only requirements are that entries are (1) made by the contestants, and (2) don't tear up the soccer field that we hold the race on. I've so far used the first requirement to keep motorized entries out of the race, but homemade motors are allowed. To disabuse potential entrants of the idea that it's a race for speed, points are awarded thusly:

- Creativity – 20 points
- Completing the course – 20 points
- Sheer size and audacity – 15 points

- Engineering chops – 15 points
- Style and mojo – 15 points
- Costumes and hair – 15 points

Although in practice no point system is used. The race is named after Riverdale's Lindenbaum Arts Building. True glory comes from having your name permanently engraved on our huge homemade trophy, the Lindy 500 Victory Cup.

In a school with a lot of academic pressure like Riverdale, devoting time to designing and building a giant mobile hot dog, for instance, can help create a nice balance. Some students have told me that their time on this project was some of their most memorable in high school.

Materials, space and tools:
Space. You'll need storage space for scrap bikes and parts and the projects themselves. Both can be outdoors. We found it useful to maintain a small bike scrapyard that students could pick through to find parts. Your workshop will need to be ready for welding, which means some kind of ventilation and hopefully a concrete floor. Bins or cubbies for individual students or teams work really well for this project, as students may need small specialized parts for their projects. Having to go hunt in the scrapyard again for that exact sprocket because you lost it is a real time-waster.

Old bicycles and parts in any condition. Bike shops usually have a corner somewhere filled with dead frames and parts that they are willing to donate. Apartment building supervisors are a

good source too, especially near universities. Students and other tenants often abandon bicycles in these buildings' basements and bicycle lockers. I didn't have any luck with NYPD but your local police department might be worth a try. An email to parents can generate a lot of bike donations too.
Stripping the bikes and sorting the parts is a real time-saver. We used 5-gallon plastic buckets for brakes, derailleurs, chains, stems, etc.

Other wheeled mechanical items. Wheelchairs, shopping carts, exercise bikes, other exercise machines (steppers, ellipticals, treadmills, etc). You'd be surprised how much of this stuff is thrown away or there for the asking.

Cheap bike components from Amazon are an even bigger time saver**.** Search using the word "bulk". I found bulk derailleurs for $4 each. You'll want rear derailleurs, brake cable, shift cable, cable housing, inner tubes in common sizes (in the US, 16", 18", 20", 24", 26" 700C", with Schrader valves if possible), and maybe some tires and pedals. The rest can come from the junk bikes or be improvised. Basically you're setting up a low-cost bike shop. **Bike helmets** can be had for $5-$10 each by googling bulk bike helmets.

Cheap big caster wheels. Not every wheel needs to be a bike wheel. Harbor freight sells 10" inflatable casters in both swivel and non-swivel versions with load ratings of 300 lbs. They can be welded directly to tubing - no need for forks. $15 each and can be recycled endlessly.

https://www.harborfreight.com/material-handling/casters-swivel/10-in-pneumatic-heavy-duty-swivel-caster-60249.html

Bike tools. Amazon is a good place to get key bike tools (chain tool, cable cutters (different from wire cutters!), tire levers, a good pump, crank pullers). You can also get the Nashbar Essential Bike Tool kit, which costs about $50. http://www.nashbar.com/bikes/Product_10053_10052_524452_-1___204838.

Shop tools. With a few exceptions, I usually choose inexpensive tools from Harbor Freight for school projects. They tend to work well enough and cost a fraction of what better brands cost.

Steel tubing. The last time we ran this project we tried something new: standardizing on 1″ square tubing in two thicknesses, 16 gauge and 14 gauge. The advantage of square tubing is that since the sides are flat, you don't need to make round miter cuts to join it at angles. If you need to mate it with round tubing on a bike frame, you can cut the end with a hole saw on a drill press.

If working with round tubing (something I don't recommend), you'll need a **Tubing Notcher.** This connects to your drill press to make mitered (scooped out) cuts in tubing, so the tubes fit together nicely for welding. The Harbor Freight model costs about $50. You'll need a set of hole saws as well. http://www.harborfreight.com/pipe-tubing-notcher-42324.html

Drill press. Needed for the tubing notcher and useful for working with steel in general. Harbor Freight models are good enough. You'll want to get a good set of drill bits too.

Chopsaw. The $100 harbor freight model is good enough. http://www.harborfreight.com/14-in-3-12-hp-heavy-duty-cut-off-saw-61481.html. For cleaner, quicker, more accurate cuts and no dust or sparks, get a steel-blade chopsaw like this one: http://www.steelmax.com/product/s14-metal-cutting-saw-with-14-blade-and-stable-cast-iron-base/ for about $450 on Amazon. These are great saws.

Mig welder. In my experience it makes sense to get a good one – not Harbor Freight. Miller, Lincoln, and Hobart all make quality welders. Expect to spend some money on this, perhaps $1000 or more. Personally I like the Miller Multimatic 200. Get extra welding tips from the manufacturer. I've had good results from Harbor Freight Mig wire though. Harbor freight welding jig magnets are also super useful.

Hand grinder. You'll probably want two of these. Set one up with a grinding wheel, the other with a cutting wheel. They run about $15 at Harbor Freight. If you buy them there, get a few extras. http://www.harborfreight.com/4-12-in-43-amp-angle-grinder-69645.html.

Safety gear. Goggles, welding masks, gloves, and jackets. It's worth it to get at least two auto-darkening welding masks, they are much easier to use than the older flip-down kind. The Harbor Freight varieties are good enough.

Wood scraps - 2x2s, 2x4s, 1/4" plywood

Cheap paint - every Home Depot has an unclaimed paint shelf with cans of odd colors for $2-$9 each. Spray paint is fun too, but more expensive.

Fabric remnants from fabric stores like JoAnn Fabric.

A few gotchas:

- Left-size pedals are threaded backwards.
- Wheel nuts, particularly on older bikes, come in a wide array of diameters and thread sizes. Keep wheel nuts threaded onto wheel axles so they don't get lost or mixed up.
- When separating bike chain, use the chain link extractor tool to push the link pin almost all the way out, but don't go so far so that it pops off the chain. They are very hard to get back in. Get a few of these tools, if you lose your only one a lot of progress is stopped.
- Students are often so excited to ride their creations that they don't think about protruding sharp edges and other hazards. A safety check before launch is recommended, as are helmets.
- Chains have to be tensioned (usually with a rear derailleur) and running in straight lines with both gears parallel to one another. Otherwise they fall off.

- Allow time for testing and iterating. Students often assume everything will just work and plan to finish the day before the race.