Bernoulli’s Bike Blower

A Bicycle-Powered Science Demonstration

Designed By:
The Fantastic Cycle:
Joseph Cooney
Chelsea Hernandez
Joshua Hostler
Samantha Ortega
Humboldt State University

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Client: Zane Middle School, Ken Pinkerton

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1 Problem Formulation

1.1 Introduction

In this section the objective is defined and a black box model is included to illustrate how the state of the world will be affected by the completed project.

1.2 Objective Statement

The objective is to design and create a bicycle powered device that uses airflow to suspend a ball mid-air in order to demonstrate and teach children about forces and energy.

1.3 Black Box Model

Error! Reference source not found.-1 illustrates the Black Box Model that defines the state of he world before and after the project is complete.

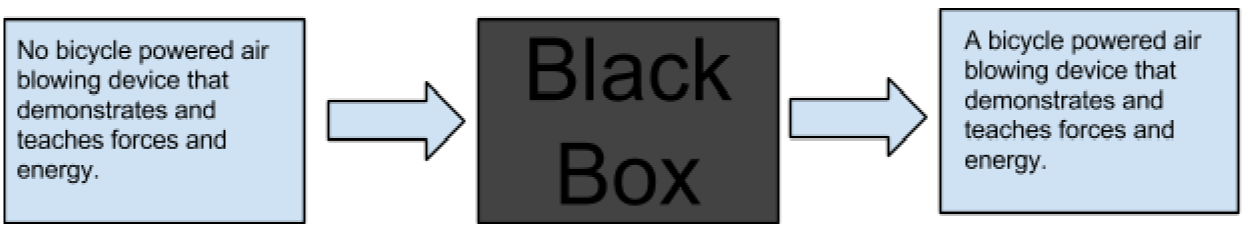

Figure 1-1 Black Box Model, which simplifies the problem to demonstrate what the bicycle powered air blowing device will yield

2 Problem Analysis and Literature Review

2.1 Problem Analysis

2.1.1 Introduction

The Problem Analysis defines the criteria, constraints, and specifications for the Zane Middle School Bike Blower. The Bike Blower must be an educational tool usable by the teachers and students of Zane Middle School.

2.1.2 Specifications and Considerations

The specifications and considerations are the parameters set by Zane Middle School that the Bike Blower must meet.

The Bike Blower must meet the following specifications:

- The Bike Blower will be used on site at Zane Middle School
- The Bike Blower must include the bicycle and industrial fan provided by the client.

The design of the Bike Blower takes into consideration:

- That the users of the Bike Blower will be the students.
- The curiosity of the students wanting to touch the internal body of the design and industrial fan blower, resulting in possible injuries

2.1.3 Criteria and Constraints

The Zane Middle School Bike Blower has the following criteria and constraints:

Table 2-1 Criteria and Constraints

Criteria	**Constraints**
Cost	Less than $400
Safety	Meets Public School Standards
Durability and maintenance	More than 4 years, less than one hour per year for maintenance
Aesthetics	Appeals to middle school students
Ergonomics	Sized and fit for use by middle school students
Educational Value	Meets Course Material
Fun	For kids and adults
Effectiveness	Demonstrate ability to work as needed
Ease of Use	Storage, area of use. One adult can move and setup
Sustainability	includes recycled components

2.1.4 Usage

The Bike Blower will be used to educationally demonstrate science concepts to middle school students. It will be demonstrated at the Math Festival in Eureka next year and possibly the Discovery Museum in Eureka as well. The Bike Blower will include adaptable components that allow students to experimentally study the course material.

2.1.5 Production Volume

The client requires that a single Bike Blower be created as a final product.

2.2 Literature Review

2.2.1 Introduction

General Physics, Existing Bicycle-Powered Generator Models, Bikes, Human Power, Pedal Power, Fans and Blowers, and Education Techniques were researched in order to create a base of knowledge necessary to create a human powered bike blower.

2.2.2 General Physics

In this section forces, electricity, and Bernoulli's principle are concepts from physics that are examined. These concepts are applicable to bikes, pedal power, and levitation of objects.

2.2.2.1 Forces

A force is defined as the action of one body to another, Figure 2-1 displays a bicycle that is not in motion and the various forces that act upon it (Hess R., 2011).. Figure 2-1 is a free body diagram, which is a diagram of an object being observed with minimum detail and distinct description of the forces acting on the bike. As seen in Figure 2-1 the force on the seat of the bicycle comes from the person's mass and gravity.

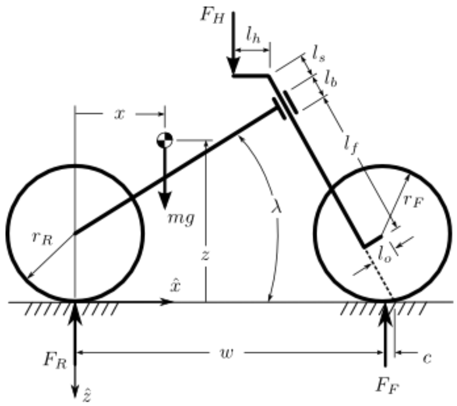

Figure 2-1 Free Body Diagram of Forces acting on a Bicycle (http://biosport.ucdavis.edu/researchprojects/bicycle/instrumented-bicycle/steer-torque-measurement)

2.2.2.2 Electricity

Figure 2‐2 is a wheel with equations for power, current, resistance, and voltage (Sengpielaudio, 2014). Power is a measurement of electricity with units of watts or horsepower. Current is a measurement of how electric charge flows through a circuit with units of amps. Resistance is a measure of force that resists electricity with units of ohms. Voltage is a measure of the electrical potential difference with units of volts.

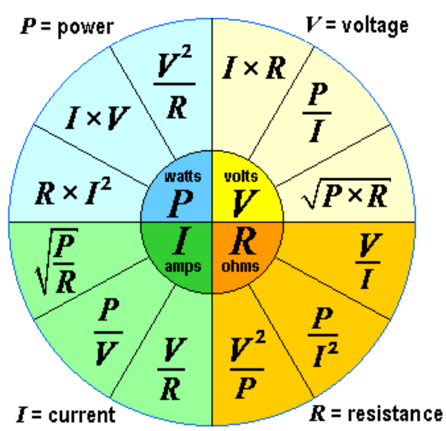

Figure 2-2 Electricity Equation Diagram (http://www.sengpielaudio.com/FormulaWheel-ElectricalEngineering.htm)

2.2.2.3 Bernoulli's Principle

Bernoulli's principle states that when a fluid's (gas or liquid) speed increases the fluid's pressure will decrease. In Figure 2‑3 Bernoulli's equation is given and variables are labeled.

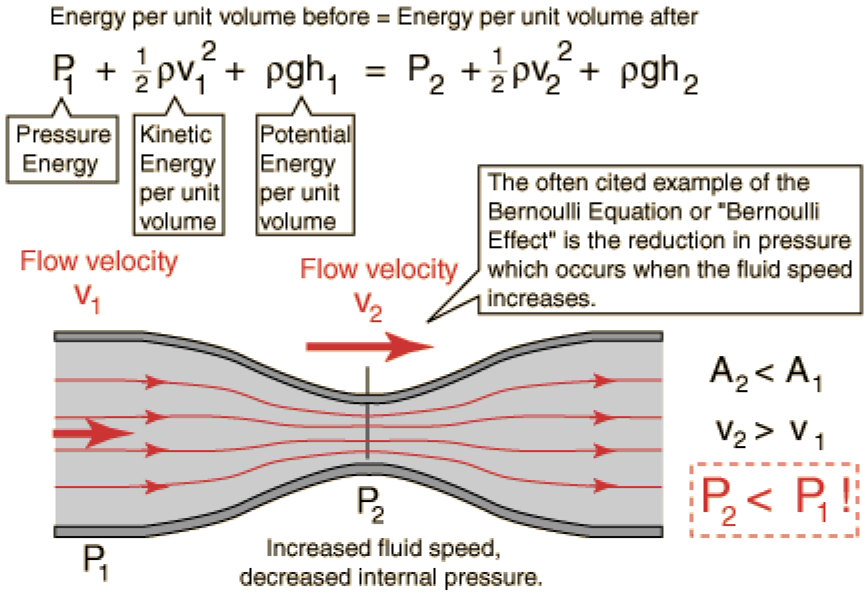

Figure 2-3 Diagram of Bernoulli's Principle (http://hyperphysics.phy-astr.gsu.edu/hbase/pber.html)

2.2.2.4 Applications of Bernoulli's Principle

Figure 2‑4 is an illustration of an airplane component that allows for flight based on Bernoulli's principle. The pressure difference between the top and bottom of the wing creates a lift due to the wing being pushed upwards (ThinkQuest, 2014). The Figure 2-4 displays how the shape of an airplane wing can have an effect on its lift.

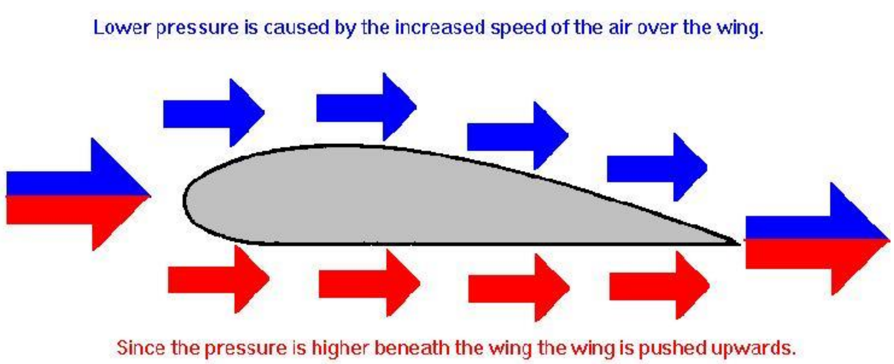

Figure 2-4 Application of Bernoulli's Principle (http://library.thinkquest.org/2819/bernoull.htm)

2.2.3 Existing Bicycle-Powered Generator Models

In this section examples of existing bicycle-powered models are examined.

2.2.3.1 Adaptable Bike Generator

An adaptable bike generator allows for users to bring their own bike. A bicycle trainer makes it possible for one to ride a bicycle without moving. People might use these stands when the weather is not in their favor, Engineering 215 Team Tour de Volts used a bike trainer stand seen in Figure 2‑5 (Team Lorax, 2010).

Figure 2-5 Team Tour De Volts Bike Stand (http://www.appropedia.org/WaterPod_Tour_de_Volts)

2.2.3.2 Stationary Mechanical Bike Blender

A stationary mechanical bike blender has the flywheel of an exercise bike attached to a drive shaft which is a component that allows for torque and rotation. The drive shaft has a disadvantage of being too heavy and costly (Orlando, 2000).

2.2.3.3 Stationary Electrical Bike Blender

A stationary electric bike blender has the flywheel of an exercise bike connected to an electric generator which is a device that converts mechanical energy into electrical energy. The disadvantages of an electrical generator are that they make the overall machine heavy (Orlando, 2000).

2.2.3.4 Mobile Bike Blender

A mobile bike blender includes a bike stand that allows for any bike to be attached. Any bike can be attached to this machine, which allows for easy usage. The rear wheel is elevated for the rider and the rider pedals in order to power the blender (Orlando, 2000).

2.2.4 Bikes

A bicycle is a simple structure made of a frame whose structure has two triangles inside of it. Bikes are examined in this section.

2.2.4.1 Bicycle Components

Figure 2‑6 is an illustration of a bike and its different components - simple machines. A simple machine is a basic component used for modifying forces and motion. (Merriam-Webster, 2014) The handlebars and saddle are components of the bike that are meant for the user to be able to ride comfortably and easily. The chainstay is a component seen in Figure 2-6, it is made up of a tube that connects the pedal area to the rear hub. Spokes are another component seen in Figure 2-6, they connect the hub to the rim of the bicycle wheel. The seat post is a component that allows for the height of the saddle to be altered.

Figure 2-6 Bicycle Diagram (Champoux, Richard, Drouet 2007)

2.2.4.2 Levers

Levers in bicycles appear as the crank arms on a crank set as seen in Figure 2‑7. Crank sets are composed of the cranks; the lever arms that the pedals are attached, and the front chain rings. The cranks allow the user to apply a force to generate torque in the front chain rings. Cranks have greater radii (longer lever arms create more torque) than the front chain rings, giving the user a mechanical advantage equal to the ratio of the torque applied to the crank and the torque applied to the chain by the chain rings.

Figure 2-7 Crank set (http://www.sram.com/sram/road/products/sram-red-22-crankset)

2.2.4.3 Gears

Gears are toothed wheels that are used transfer and adjust torque – a measure forces that cause rotation – and angular velocity – the rate at which an object rotates regardless of the radius of rotation. (Merriam-Webster, 2014) On a bicycle, there are two sets of gears; the front chain rings and the rear gear set, known as a cassette. Gears modify forces and motion through gear ratios.

2.2.4.4 Gear Ratios

Gear ratios affect how torque and angular velocity are modified. The gear ratio is also the mechanical advantage - the factor by which a simple machine modifies forces - of the system of gears. (Gerber, 1989) Gear ratios assume that the gears do not slip. The equations for gear ratios and mechanical advantage are in Table 2‑2.

Table 2-2 Equations for Mechanical Advantage and Gear Ratios (Design Aerospace LLC)

$$GR = \frac{T_b}{T_a} = \frac{N_b}{N_a} = \frac{r_b}{r_a} = \frac{\omega_a}{\omega_b}$$

GR	Gear Ratio
T	Torque
N	Number of teeth
r	Radius
ω	Angular Velocity

2.2.4.5 Wheel and Axle

Wheel and Axles, in their most basic sense, act like gears with a very large gear ratio. The rear cassette acts as the gear of the axle.

2.2.5 Efficiency

Mechanical efficiency is the ratio of input power and output power. Mechanical efficiency measures how effective a mechanical system is at transferring power and energy. Efficiency is always less than 100%. (Encyclopedia Britannica, 2014)

2.2.5.1 Friction

Friction is the resistance of motion due to contact. The primary cause of friction between metals is from adhesion. Adhesion is contact of the microscopically uneven metal surfaces. (Encyclopedia Britannica, 2014) Friction is the main cause of loss of efficiency.

2.2.5.2 Efficiency in Bike Gear Systems

Efficiency in well maintained drive-trains is as high as 98.5%. If the chain in the drive-train is not properly maintained then the chain will stretch. A stretched chain will not match the pitch of the gear, as shown in Figure 2-8, and will apply the majority of the force over fewer teeth. This will cause the teeth to wear down faster. As the teeth weaken and the chain stretches the efficiency will decrease. (Whitt, 1982)

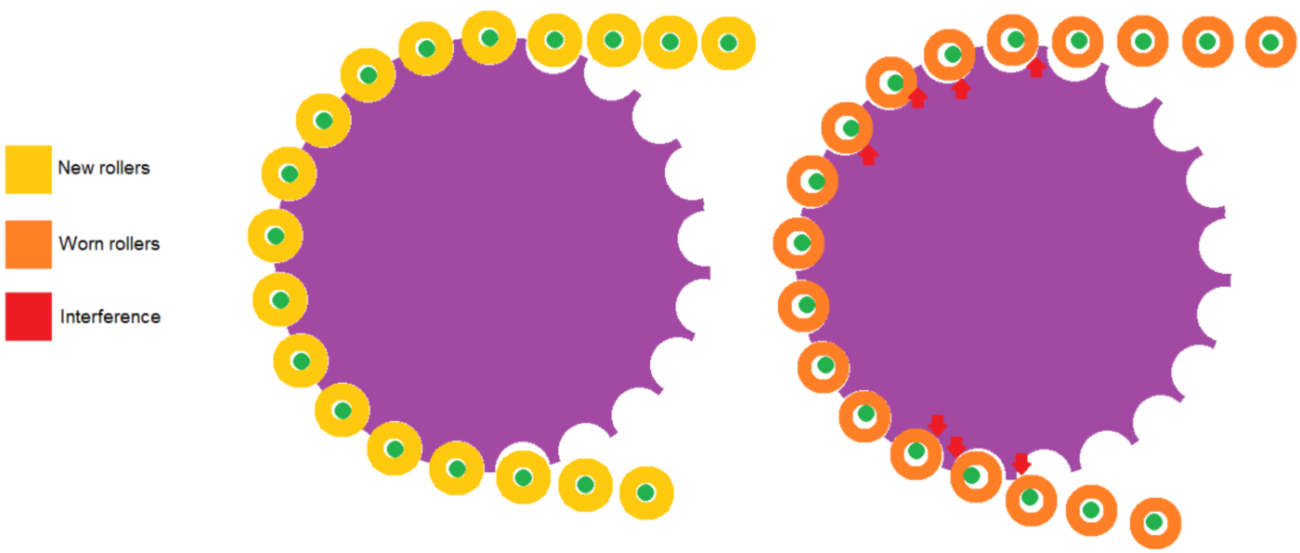

Figure 2-8 Stretched Chain (http://forums.roadbikereview.com/components-wrenching/chain-stretch-284509-4.html)

2.2.6 Human Power

Human power is an efficient method to generating power mechanically. Human power exerted in the form of pedaling, can generate a force to move a bike from point A to point B.

2.2.6.1 Abilities

Human power generation highly depends on the work exerted from a person to a system. Energy is taken in through fuel (food and drinks) for humans. Transferring that energy can be accomplished in a number of different ways, depending on the work put in. In Table 2-3 one can see how much power a human is capable of generating:

Table 2-3 Human Power Generation (http://pedalpowergenerator.com/buy-bicycle-generator-assembled-pm-motor-pedal-power.htm)

<table>
<tr><th>Power [Watts]</th><th>Time [hours]</th><th>Cost [$]</th></tr>
<tr><td>75</td><td>2</td><td rowspan="3">1.8</td></tr>
<tr><td colspan="2">Energy [Watt-hours]</td></tr>
<tr><td colspan="2">150</td></tr>
</table>

2.2.6.1.1 Age Barrier

A constraint on ability to generate power is age. Age is the measurement of human growth as a means of time and development. If a human is younger, they are still in the process of developing full potential. If a human is an adult, the amount of energy they can exert fluctuates depending on health conditions.

2.2.7 Pedal Power

Pedal Power as a definition is the ability to provide transportation, energy transfer, and efficiency via leg or arm cycling. Pedal Power is extremely efficient for the modern bike and the components, which it is able to generate power to.

Below is an example of what pedal power can generate:

Figure 2-9 Pedal powered submarine (http://www.luxury-gadgets.com/2010/08/17/sleek-pedal-powered-submarine-is-built-for-racing/)

Although pedal power is being explored in relatively modern inventions, there are developing countries that use this knowledge and power to create sustainable community uses.

Ex.) Figure 2-10 shows people of the Indian villages of Kinchlingi and Tumba, which use a pedal-driven biodiesel reactor to create self-sufficient, sustainable communities:

Figure 2-10 Women pedaling to generate biodiesel in Kinchlingi (http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=5bd0d82c-0b04-4d12-a163-e0e34e2f4af2%40sessionmgr112&vid=2&hid=103)

2.2.7.1 Ergonomics

Ergonomics is the investigation about humans and work. Optimizing the physical contact between humans and power generation.

Four important areas of bike ergonomics:

- The strain of the arms and shoulders
- The muscle support and position of the lower back
- The work of proper pedaling
- The crank-length

Figure 2-11 shows an image of how a person should be positioned on a bicycle:

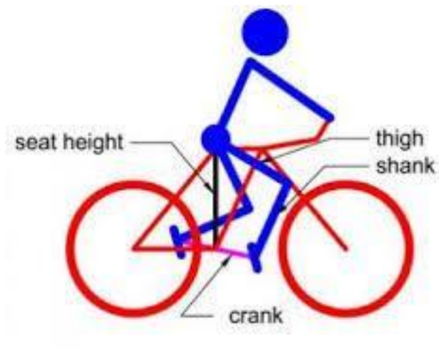

Figure 2-11 Bike Posture (http://phys.org/news/2012-03-optimum-method-bicycle-parameters-person.html)

2.2.7.2 Arm Power

Although pedal power is most commonly seen through the use of a foot pedal and crank system, there are ways to hand power a system if it facilitates the process of mechanical generation. Cycling is more efficient than any other method of travel and can generate power mechanically, as well as electric.

2.2.7.3 Leg Power

Leg force is the most common when using a bicycle for power generation. Pedal power has successfully demonstrated potential in water wells, grinders, and sustainable development. This type of power is so useful that a) 2 legs can generate about 8 times more power than 1 arm and b) one hundred calories can power a cyclist for three miles, but it would only power a car 280 feet.

2.2.8 Fans and Blowers

The Zane Middle School Bike Blower requires a component to provide airflow. Fans generate airflow against a resistance caused by ducts or other components in a system. This is done when the fan blades receive energy from a rotating shaft and transmit it to the air.

2.2.8.1 Types

Terminology from the American Society of Mechanical Engineers is used when discussing Fans, Blowers, and Compressors. A device may be physically identical but will be qualified as a fan or blower depending on the ratio of the discharge pressure over the suction pressure, defined as the Specific Ratio (Bureau of Energy Efficiency, 2006).

Table 2-4 Difference Between Fans, Blowers and Compressors (Bureau of Energy Efficiency, 2006)

Equipment	Specific Ratio	Pressure rise (mm Wg)
Fans	Up to 1.11	1136
Blowers	1.11 to 1.20	1136 – 2066
Compressors	more than 1.20	-

Fans and Blowers are divided into two general categories: centrifugal flow and axial flow.

2.2.8.1.1 Centrifugal

Figure 2-12 shows a centrifugal flow fan, in which airflow changes direction twice - once when entering and second when leaving. Centrifugal flow fans are described by the type of blade used to move air (forward curved, backward curved or inclined, radial). (Bureau of Energy Efficiency, 2006)

Figure 2-12 Centrifugal Fan (http://en.academic.ru/pictures/enwiki/67/Centrifugal Fan)

2.2.8.1.2 Axial
An example of an axial flow fan is shown in figure 2-13, in which air enters and leaves the fan with no change in direction. Axial fans are described by their physical configuration (propeller, tubeaxial, vaneaxial). (Bureau of Energy Efficiency, 2006)

Figure 2-13 Axial Fan (http://www.indiamart.com/gimpex-overseas/products.html)

2.2.8.2 Blowers

Blowers can generate higher pressures than fans. Major types are centrifugal blower and positive-displacement blower. Centrifugal blowers typically have an enclosed internal impeller. Single-stage blowers operate individually and have only one impeller. A multi-stage arrangement can be assembled by positioning two or more blowers in-line to further accelerate the airflow as it passes through each impeller. One of the key characteristics of centrifugal blowers is that airflow drops significantly as system pressure increases.

Positive-displacement blowers operate with rotors which seal against a housing to trap the air, providing a constant volume of air regardless of system pressure. Positive-displacement blowers turn much slower than centrifugal blowers and can clear blocked passageways by generating high pressure (Bureau of Energy Efficiency, 2006).

Table 2-5 Types of Fans and Characteristics. (Bureau of Energy Efficiency, 2006)

Centrifugal Flow Fans			**Axial Flow Fans**		
Type	Characteristic	Typical Applications	Type	Characteristics	Typical Applications
Radial	High pressure, medium flow, efficiency close to tube-axial fans, power increases continuously	Various Industrial applications, suitable for dust laden, moist air / gases	Propeller	Low pressure, high flow, low efficiency, peak efficiency close to point of free air delivery (zero static pressure)	Air circulation, ventilation, exhaust
Forward-curved blades	Medium pressure, high flow, dip in pressure curve, efficiency higher than radial fans, power rises continuously	Low pressure HVAC, packaged units, suitable for clean and dust laden air/ gases	Tube-axial	Medium pressure, high flow, higher efficiency than propeller type, dip in pressure-flow curve before peak pressure point	HVAC, drying ovens, exhaust systems
Backward-curved blades	High pressure, high flow, high efficiency, power reduces as flow increases beyond point of highest efficiency	HVAC, various industrial applications, forced draft fans, etc.	Vane-axial	High pressure medium flow, dip in pressure-flow curve, use of guide vanes improves efficiency	High pressure application including HVAC systems, exhaust
Airfoil type	Same as backward curved type, highest efficiency	Same as backward curved, but for clean air applications.			

2.2.8.3 Efficiency of Fans and Blowers

The Air Movement and Control Association (AMCA) International , and the International Standards Organization (ISO) have worked to develop means to classify fan efficiency. The AMCA standard focuses on defining a fan efficiency metric, called a fan efficiency grade (FEG) based on the aerodynamic quality of the fan separate from its motor and drive. (Cermak, 2013) Among centrifugal fan designs, aerofoil designs provide the highest efficiency, but their use is limited to clean, dust-free air. Axial-flow fans produce lower pressure than centrifugal fans, and can exhibit a dip in pressure before reaching the peak pressure point (Bureau of Energy Efficiency, 2006).

2.2.8.3.1 Best Efficiency Point

A fan's performance curve can be used to find its best efficiency point (BEP), where it operates at maximum efficiency relative to energy required while reducing maintenance. When a fan is run near its BEP, performance is improved and wear is reduced (US Department of Energy, 2003).

2.2.8.3.2 Efficiency by Type

Overall fan efficiency is affected by the fan enclosure and the design of the air discharge, resistance severely influences efficiency and functioning of a fan. Determining which fan or blower is best for an application depends on many factors including desired flow rate, pressure, type of material handled, and space limitations. Typical ranges of fan efficiencies are given in Table 2-6. (Bureau of Energy Efficiency, 2006)

Table 2-6 Fan Efficiencies (Bureau of Energy Efficiency, 2006)

Type of Fan	Peak Efficiency Range
Centrifugal Fans	
Airfoil, backward curved / inclined	79 - 83
Modified Radial	72 – 79
Radial	69 – 75
Pressure blower	58 - 68
Forward curved	60 - 65
Axial Fans	
Van axial	78 – 85
Tube axial	67 – 72
Propeller	45 - 50

2.2.8.4 Airflow Performance

The performance of a fan depends on the number of fan blades it has, their shape, and the system in which the fan operates. Performance can be described in terms of efficiency, volume of air produced, pressure, static force on the blades, and torque on the hub. Table 2-7 shows that to compare the performance it is important to use identical operating characteristics in each case. (BASF, 2003)

Table 2-7 Typical Operating Conditions (BASF, 2003)

	Minimum	**Maximum**

Fan Speed	1100 rpm	1800 rpm
Air Flow Rate	85 m3/min (3000 cfm)	113 m3/min. (4000 cfm)
Static Pressure	0.062 kPa (0.25 inch water)	0.124 kPa (0.50 inch water)

2.2.9 Education Techniques

The way that teachers interact with their students is extremely important for a person's understanding of concepts and skills. Explaining and clarifying an answer can be helpful when students give short responses to a question. Table 2-8 describes different kinds of educational techniques:

Table 2-8 Educational Techniques and Methods
(https://www.wku.edu/senate/documents/improving_student_learning_dunlosky_2013.pdf)

Description	Techniques
Generating an explanation for why an explicitly stated fact or concept is true	1. Elaborative interrogation
Explaining how new information is related to known information, or explaining steps taken during problem solving	2. Self-explanation
Summaries (of various lengths) of to-be-learned texts	3. Summarization Writing
Marking potentially important portions of to-be-learned materials while reading	4. Highlighting/ underlining
Using keywords and mental imagery to associate verbal materials	5. Keyword mnemonic
Attempting to form mental images of text materials while reading or listening	6. Imagery for text
Text material again after an initial reading	7. Rereading restudying
Self-testing or taking practice tests over to-be-learned material	8. Practice testing
Implementing a schedule of practice that spreads out study activities over time	9. Distributed practice
Implementing a schedule or practice that mixes different kinds of problems, or a schedule of study that mixes different kinds of material, within a single study session	10. Interleaved practice

3 Alternate Solutions

3.1 Introduction

Section 3 presents alternative solutions for assembly of major components of the Zane Middle School Bike Blower. A movable airflow is desired to demonstrate Bernoulli's principle when airflow is not vertical, which may be accomplished through articulation of the blower or a movable discharge nozzle. All options utilize a recycled exercise bicycle and an industrial blower provided by the client, while prioritizing safety and fun.

3.2 Brainstorming

Several brainstorming sessions, found in Appendix C, were used throughout the development of alternative solutions. An unstructured brainstorming session was used to ensure all ideas were presented. Structured sessions later developed more detailed designs from the initial ideas. Ken Pinkerton, a teacher from Zane Middle School, contributed ideas and helped define the end use of the solution.

3.3 Alternative Solutions

Alternative solutions are presented for the Zane Middle School Bike Blower that have been developed through these brainstorming sessions. The solutions, supported and developed through literature reviews and design team meetings, focus on criteria and constraints. The following sub-sections 3.3.1 through 3.3.9 describe alternate designs to produce a bike-powered air blower as desired by the client.

The basic design of each component is decided primarily as a consideration of safety while using the two major components (bike & blower) provided by Zane Middle School. The client envisions a large-scale demonstration of Bernoulli's principle. The following alternative solutions are given to address the criteria using different designs.

3.3.1 Tilt-a-Belt

In the design Tilt-a-Belt, a belt drive is connected to the exercise machine to meet the criterion of sustainability. Figure 3-1 depicts the flywheel of the exercise machine being connected to the aluminum blower, allowing for a belt drive system. Belt drive systems are used as a source of motion to transmit power efficiently. The safety criterion is met by the usage of a mechanical barrier known as a baffle. The cost criterion is strongly met because belt drives are inexpensive. The education criterion is well met with the component of having a tilt table so that children can gain a better understanding of Bernoulli's principle.

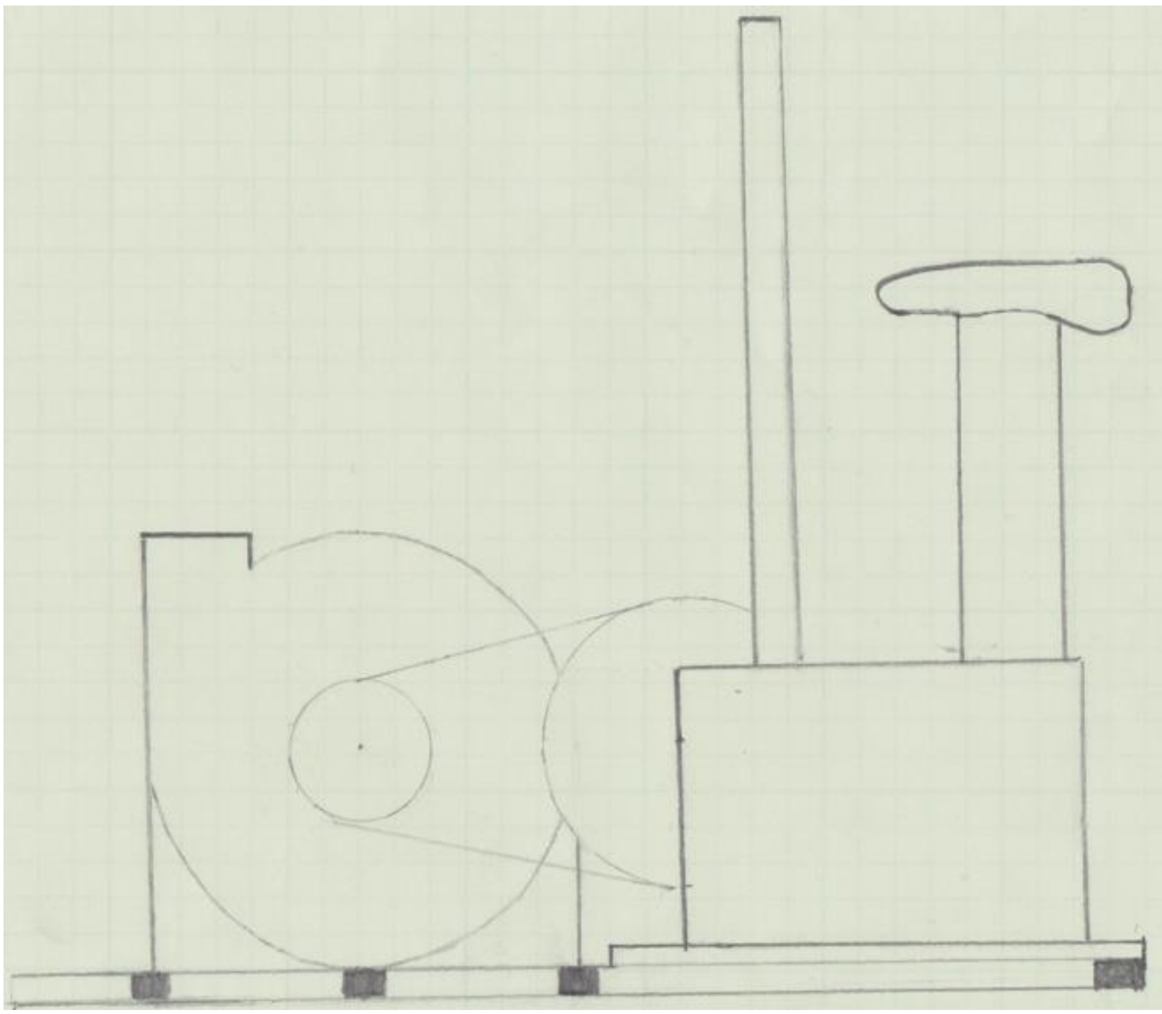

Figure 3-1 Tilt-a-Belt (Illustration by Joshua Hostler)

3.3.2 Tilt-a-Belt Extra Accident Free

In the design Tilt-a-Belt Extra Accident Free, a belt drive is connected to the exercise machine to meet the criterion of durability and ease of use. The belt drive allows for a durable machine that easily comes apart and easily reassembles. The safety criterion is met with the components of a baffle and screen to prevent children from getting hurt. Belt drives are inexpensive and can save a few dollars, meeting the criterion of cost. The tilting fan base as seen in Figure 3-2, allows children to tilt the air blower; strongly meeting the criterion of education.

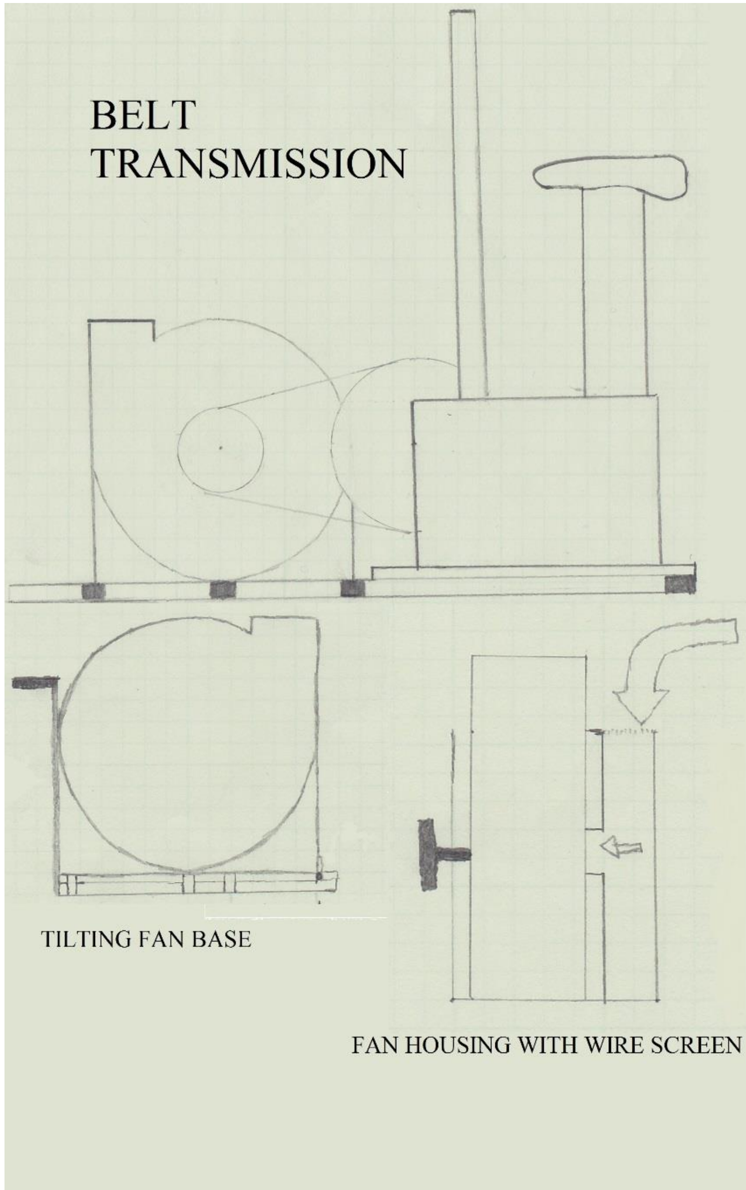

Figure 3-2 Tilt-a-Belt Extra Accident Free (Illustration by Joshua Hostler)

3.3.3 Rock Steady Tilt-a-Whirl

In this alternative shown in Figure 3-3, the exercise bike is connected to the blower pulley with a drive belt similar to an automotive fan belt. The safety criterion is met by enclosing the drive belt and pulleys in a box which incorporates mechanical barriers (baffles) and screens to prevent entry. The blower functions, and fun and educational value are incorporated with the moveable nozzle. The Rock Steady Tilt-a-Whirl meets the criteria of sustainability constrained to using the recycled bike and blower, and low cost.

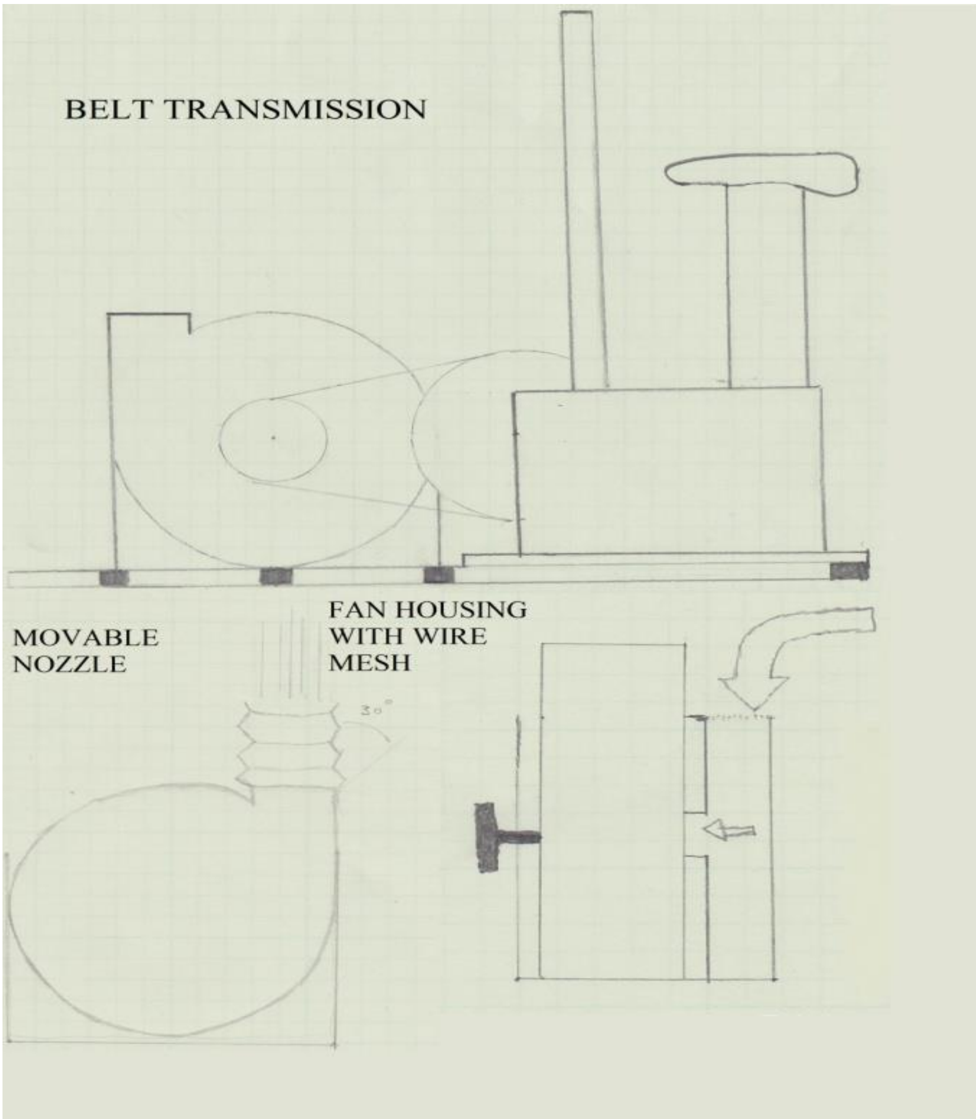

Figure 3-3 Rock Steady Tilt-a-Whirl (Illustration by Joshua Hostler)

3.3.4 Rough it Up

In the design Rough It Up, a baffle connects to the exercise bicycle to meet the criterion of safety and durability, as seen in Figure 3-4. Baffles are normally used to prevent vibration and are designed to direct the flow of fluids for maximum efficiency. The benefit of having a friction drive is that it has an infinite number of potential gear ratios while using very few transmission components.

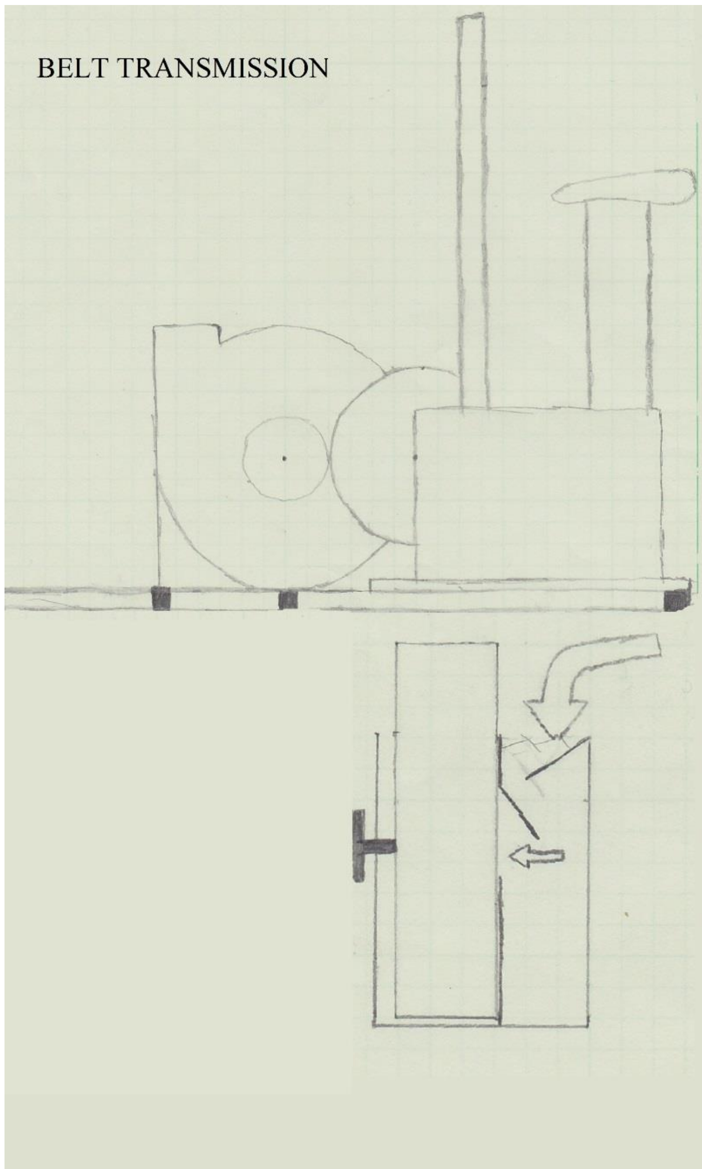

Figure 3-4 Rough it Up (Illustration by Joshua Hostler)

3.3.5 Rough it Up Extra Accident Free

In the design Rough It Up Extra Accident Free, a baffle and a screen are connected to the exercise bicycle to meet the criterion of safety and ease of use. Figure 3-5 depicts the fan housing with wire screen which helps prevent accidents from occurring and meets the criterion for safety. No children should be able to stick their fingers in the machine.

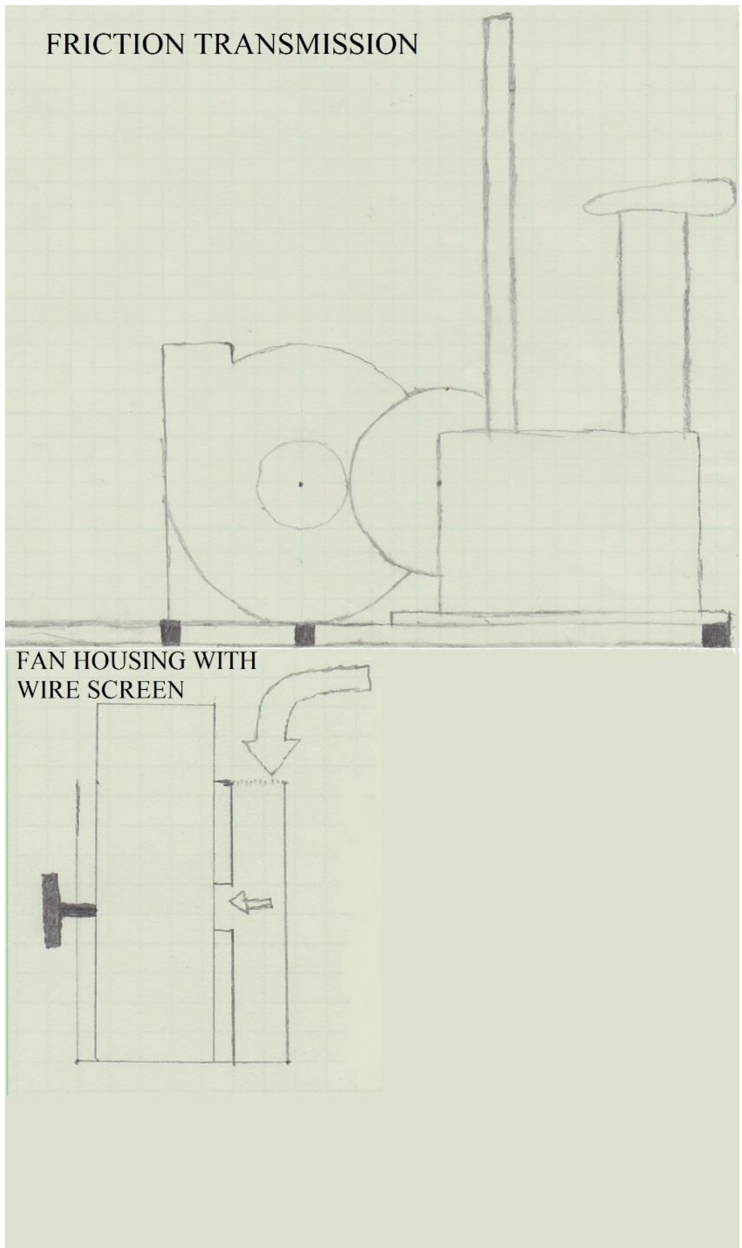

Figure 3-5 Rough it Up Extra Accident Free (Illustration by Joshua Hostler)

3.3.6 Friction Fun

A friction drive system is a mechanical transmission that uses a primary wheel drive (connected to a drive) perpendicular to the face of a secondary wheel or disk to create movement about the drive shaft of a system (What is a friction drive?). With increased velocity, there is an increase in power generation. The friction drive allows for the change and redirection of the airflow generated. However, there are limitations to how much power can be put through the friction drive because of the acceleration at which it passes on to the gear pulley. The baffles around the fan intake also prevents children from misplacing extremities from the fans air intake. This is done by creating more turns to reach the intake than is possible for an arm to perform as demonstrated in Figure 3-6. The movable nozzle of this design controls how much airflow is being exerted out of the fan and it also allows the flume to change angles in airflow.

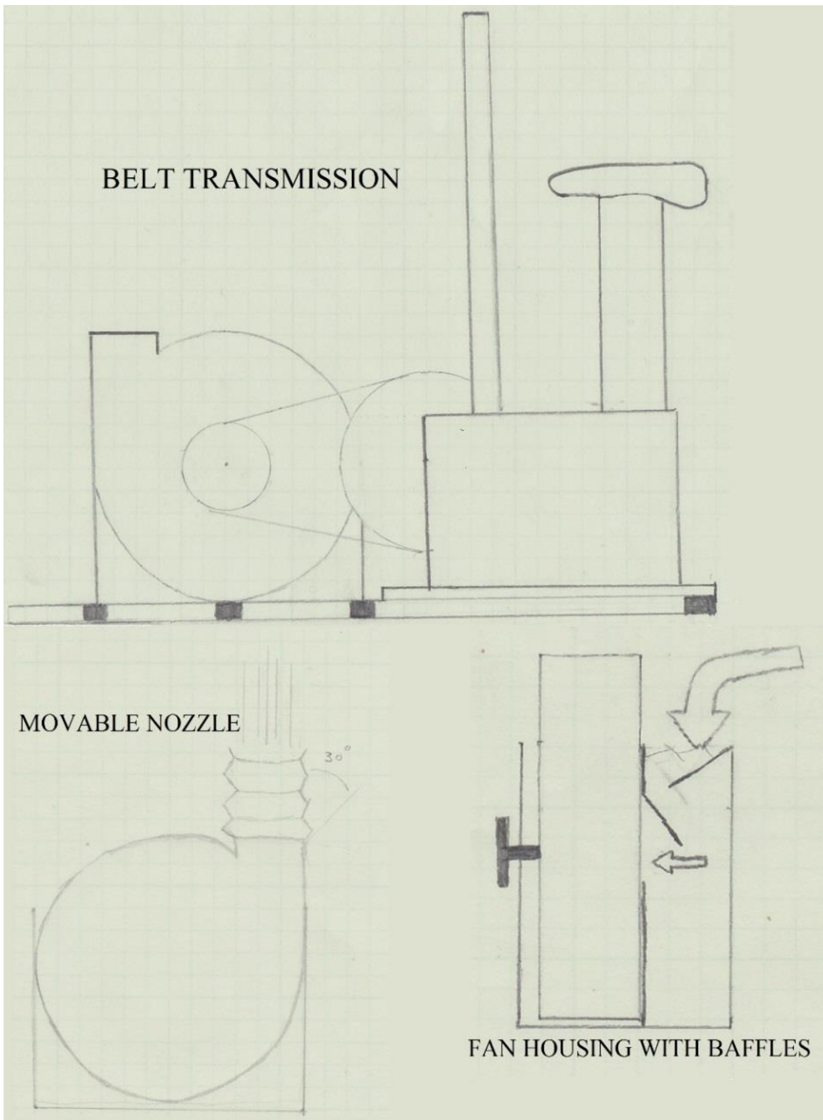

Figure 3-6 Friction Fun (Illustration by Joshua Hostler)

3.3.7 Ber-µ-Li's Bicycle

A friction drive has an infinite number of potential gear ratios while using few transmission components, as opposed to a standard transmission with sprockets or gears (What is friction drive?). In Figure 3-7 the fan housing in this model employs a metal screen to prevent large objects from entering the fan chamber and baffles to prevent children from reaching the fan's air intake. The movable nozzle allows for airflow at different angles controllable by the operator. The screens secure that the fan will not be interrupted by objects that may be thrown into the system. If there were to be any malfunctions the fan would have to be opened and relieved of test subjects (origami, plastic parts, etc…) to function once more.

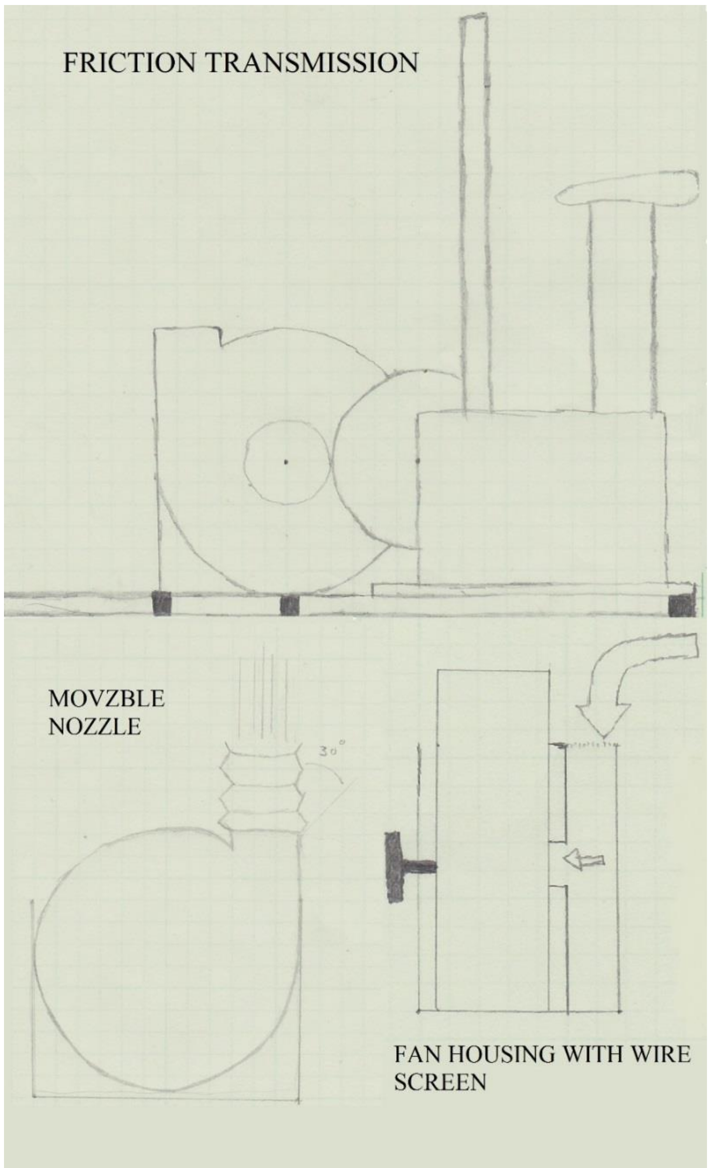

Figure 3-7 Ber-mu-Li's Bicycle (Illustration by Joshua Hostler)

3.3.8 Pop-Eye's Option

The hand cranked blower in Pop-Eye's option uses input from the operator's arms to power the blower and generate airflow. Figure 3-8 shows how the crank of the exercise bike is relocated and outfitted with handgrips to allow comfortable operation by hand. The blower is not contained in a safety box, instead relying on screens covering the intake and exhaust to satisfy safety criteria of having a barrier to prevent unwanted objects entering the blower. Meeting ergonomic criterion requires location of the hand crank and drive system from the crank to the blower pulley which may need additional safety measures. Functionality criterion is limited to all components being rigidly mounted and airflow is vertical only.

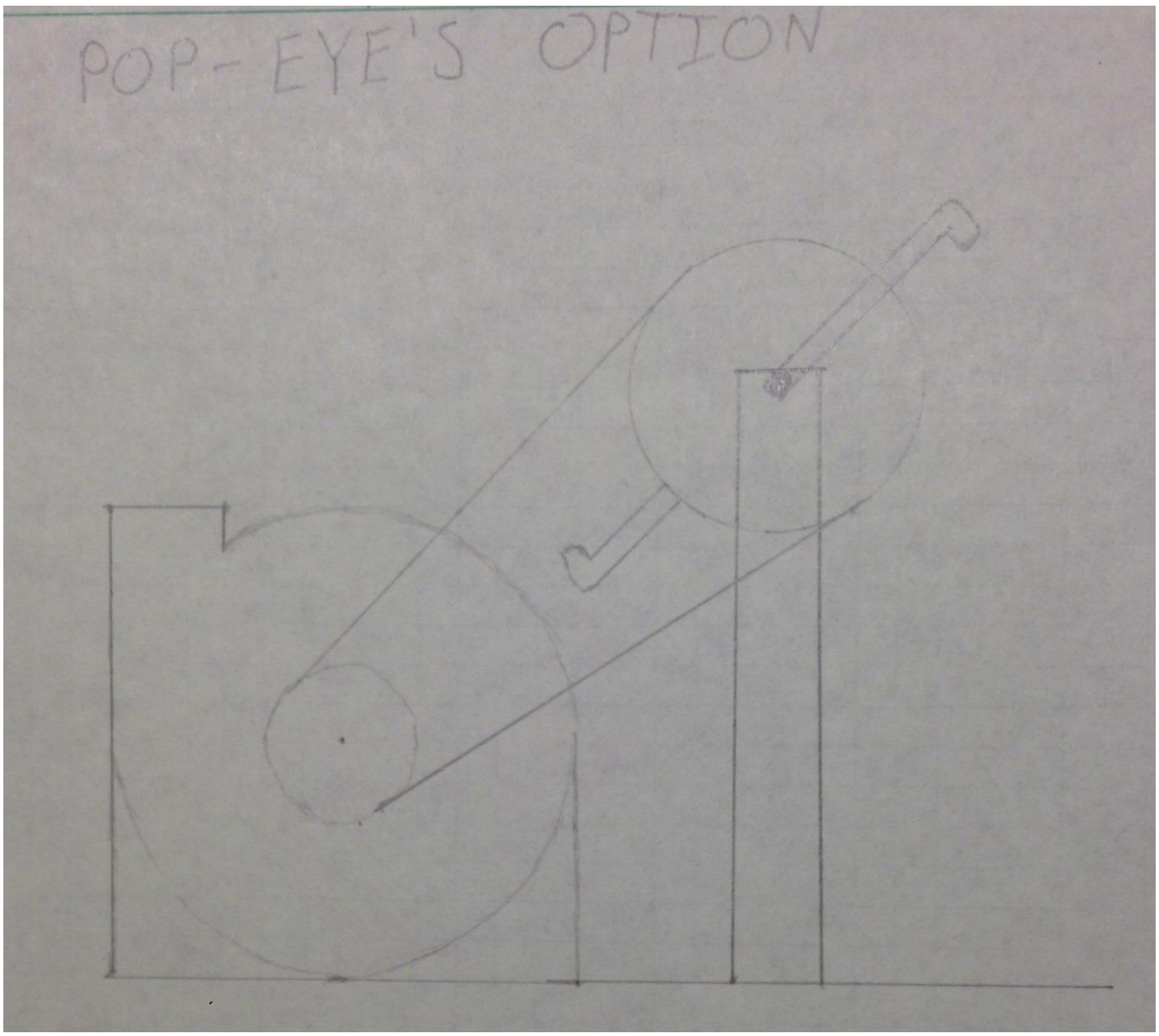

Figure 3-8 Pop-Eye's Option (Illustration by Joshua Hostler)

3.3.9 The MacGyver

In the electric fan alternative called The MacGyver, a generator is powered by the exercise bike as shown in figure 3-9. The generator supplies electricity to an electric motor attached to the blower. The bike flywheel drives the generator through either a friction or belt drive. The electricity generated is used to power an electric motor which turns the fan. The blower is not enclosed in a safety box, satisfying safety criterion relies on screens covering the intake and exhaust to provide a barrier against unwanted objects entering the blower. This design eliminates the need for a mechanical drive system between the bike and blower, allowing for movement of the blower to address the criteria of fun, functionality and educational value. The MacGyver option requires additional components and maintenance and weighs more than a mechanical drive. These characteristics do not score well to satisfy the criteria of reliability, portability and cost.

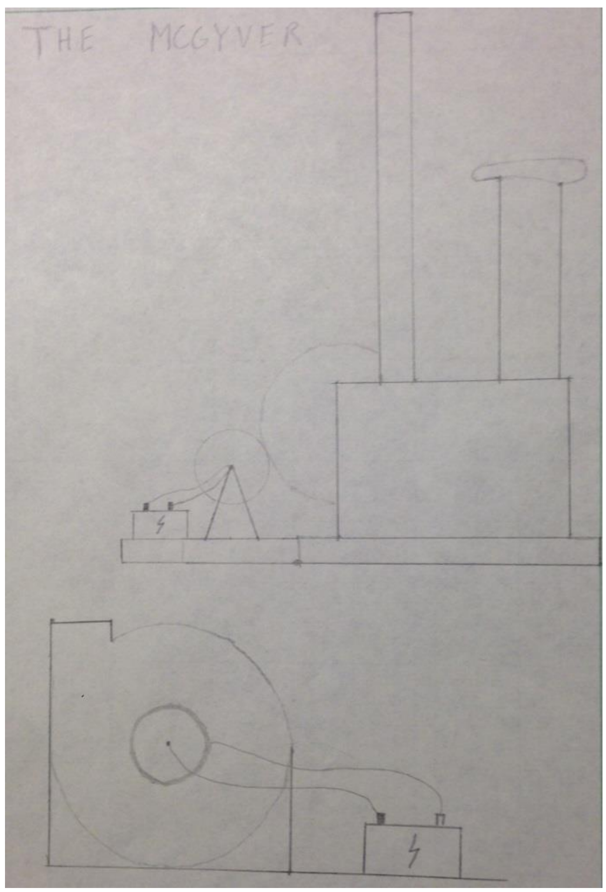

Figure 3-9 The MacGyver (Illustration by Joshua Hostler)

4 Decision Making Process

4.1 Introduction

The decision making process defines the criteria, evaluates alternative solutions, and picks the best alternative solution design for the bike blower. The Delphi Matrix numerically determines which alternative solution is the best choice according to the weighted criteria. The final decision describes and identifies how each criterion is satisfied.

4.2 Criteria

The following criteria from section 2 were used to evaluate the alternate designs:

Cost – Cost of the project must be less than $400 total for all materials and other expenses.

Safety – Safety requirements must meet public school standards.

Durability & Maintenance – The product must have a lifespan of more than 4 years. Maintenance requirements should be less than one hour per year.

Aesthetics – Aesthetics should be pleasing to kids.

Ergonomics – The bike blower should be capable of being comfortably operated by a range of operators of different sizes.

Educational Value – Education value should meet course material requirements as established by the client.

Construction Time – The construction time must be less than 45 days. This timeframe includes procurement of all necessary materials and testing functionality of completed blower.

Fun – Fun is defined as enjoyable for kids and adults.

Effectiveness – Effectiveness is defined as the ability to suspend a ball in airflow provided by a pedal-powered blower.

Ease of Use – The size of all components must be such that they can be disassembled and moved by two adults. The disassembled product must be stored within 25 square feet. Assembled bike and blower must fit in area of use.

Sustainability – The product must include recycled components.

4.3 Solutions

Nine alternate solution designs have been developed to achieve the client's goal of an up-cycled pedal powered blower to demonstrate Bernoulli's Principle. Section 3 shows full descriptions of the following alternatives:

- Tilt-a-Belt
- Tilt-a Belt Extra Accident Free
- Rock Steady Tilt-a-Whirl

- Rough it Up
- Rough It Up Extra Accident Free
- Friction Fun
- Ber-µ-li's Bicycle
- Pop-Eye's Option
- The MacGyver

4.4 Decision Process

The Fantastic Cycle conducted the decision making process through two group brainstorming sessions, individual brainstorming, client criteria, and the use of a Delphi Matrix. The Delphi Matrix utilizes criteria weights and a scoring of each alternative design in each criterion. Table 4-1 shows the criteria weighted on a scale 1-10, from lowest to highest importance.

Table 4-1Criteria and Weights

Criteria	Weight
Safety	10
Fun	9
Effectiveness	9
Cost	6
Aesthetics	6
Durability and Maintenance	5
Educational Value	5
Ease of Use	5
Sustainability	5
Ergonomics	4
Construction Time	3

The alternative designs were scored on a scale of 1-50 on a Delphi Matrix. Each team member analyzed the criteria and alternative designs and submitted their weights and scores to a spreadsheet where the scores were averaged. The team then confirmed the results as an accurate representation of the team's standards.

Table 4-2 Delphi Matrix

Criteria			Solutions								
List		Weight	Tilt a Belt	Tilt a Belt	Rock	Rough It	Rough It	Friction	Ber-mu-	Pop-	The
Cost	Less than $400	6	30 / 180	25 / 150	33 / 198	40 / 240	30 / 180	39 / 234	38 / 228	17 / 102	8 / 48
Safety	Meets Public School Standards	10	22 / 220	37 / 370	35 / 350	37 / 370	40 / 400	35 / 350	43 / 430	18 / 180	15 / 150
Durability and Maintenance	Less than 4 years, less than one hour	5	25 / 125	35 / 175	41 / 205	43 / 215	36 / 180	37 / 185	40 / 200	28 / 140	21 / 105
Aesthetics	For kids	6	23 / 138	28 / 168	28 / 168	22 / 132	18 / 108	30 / 180	30 / 180	30 / 180	25 / 150
Ergonomics	For kids	4	22 / 88	28 / 112	32 / 128	28 / 112	32 / 128	35 / 140	37 / 148	20 / 80	19 / 76
EducationalValue	Meets Course Material	5	35 / 175	23 / 115	32 / 160	18 / 90	25 / 125	43 / 215	46 / 230	27 / 135	25 / 125
Construction Time	Less than 45 days	3	34 / 102	35 / 105	37 / 111	42 / 126	37 / 111	35 / 105	32 / 96	23 / 69	23 / 69
Fun	For kids and adults	9	30 / 270	28 / 252	35 / 315	15 / 135	18 / 162	37 / 333	40 / 360	23 / 207	20 / 180
Effectiveness	Demonstrates ability to work as needed	9	36 / 324	37 / 333	41 / 369	27 / 243	28 / 252	39 / 351	41 / 369	18 / 162	20 / 180
Ease of Use	Storage, area of use. One adult can move	5	18 / 90	25 / 125	23 / 115	37 / 185	33 / 165	40 / 200	40 / 200	22 / 110	23 / 115
Sustainability	Includes recycled components	5	38 / 190	36 / 180	36 / 180	30 / 150	27 / 135	42 / 210	42 / 210	18 / 90	17 / 85
Total			1902	2085	2299	1998	1946	2503	2651	1455	1283

4.5 Final Decision

The Fantastic Cycle determined that Bernoulli's Bicycle is the optimal choice to meet the client's criteria. The Delphi Matrix scores Ber-µ-li's Bicycle at 2651, the highest score received. The team then compared Ber-µ-li's Bicycle with Friction Fµn and concluded that Ber-µ-li's Bicycle was the best fit design. Ber-µ-li's Bicycle is the safest design, while still maintaining low cost and an efficient build style. Safety is the number one criterion as this machine will be operated by children, therefore the final decision was made in respect to the high safety rating of Ber-µ-li's Bicycle.

5 Specification of Solution

5.1 Introduction

The final solution, Bernoulli's Bike Blower, is described in full detail throughout this section. Bernoulli's Bike Blower is a combination of designs mentioned in sections 3 and 4. The costs of hours and materials, instructions for usage, results, and a discussion are all included in this section. The description of Bernoulli's Bike Blower explains the machine as a whole, as well as elaborates on several components of the machine. Costs are described in means of the amount of time and money spent on this project. Instructions for Bernoulli's Bike Blower include an assembly and operational guide to utilizing the machine. The results for this particular section indicate what the machine is capable of. The issues faced during the construction of the machine and needs for improvement are discussed as well.

5.2 Description of Solution

Bernoulli's Bike Blower is an educational hands-on experience for kids to learn about Bernoulli's principle, which states that pressure from external forces is greater than the internal pressure of the system. By enhancing the pedaling of the bike, the device uses a six gear drive system that begins operation by generating power to the flywheel. A chain connects to a two gear drive mounted on the platform where everything rests, which rotates an intermediate shaft assembly to another gear on the pulley attached to the fan blower. This system causes the fan to spin, thus creating airflow to the designated object.

The final design of Bernoulli's Bike Blower has a wooden box that encloses the fan blower for safety regulations, as well as a wooden box around the gear system. Both boxes include visuals of what's inside to give viewers an idea of how the internal system operates. Both boxes are also painted with black chalkboard paint for the students at Zane to enjoy. Once in use, the airflow generated by pedaling levitates objects provided by the user. The system works and meets the criteria depicted by our client, as well as the criteria laid out by the Fantastic Cycle.

5.2.1 Bike

A recycled exercise bike is used in Bernoulli's Bike Blower to fulfill the client's desire to re-use discarded equipment by removing the items from the waste stream and repurposing them for educational purposes. The exercise bicycle is a mechanical design and has a conventional bicycle crank and pedal assembly. The crank and pedal assembly has a large crank gear that connects to a smaller gear on the original flywheel of the exercise bike. This provides an increase in rpm at the flywheel, which is later multiplied through the additional drivetrain. The original exercise bicycle's bodywork encases the initial drivetrain and provides protection from the moving chain and gears. Seat height of the bicycle is adjustable to accommodate operators of varying sizes. The flywheel spins free of the crank and pedals, similar to a bicycle wheel, so that the operator's legs aren't fixed to the rotation of the blower.

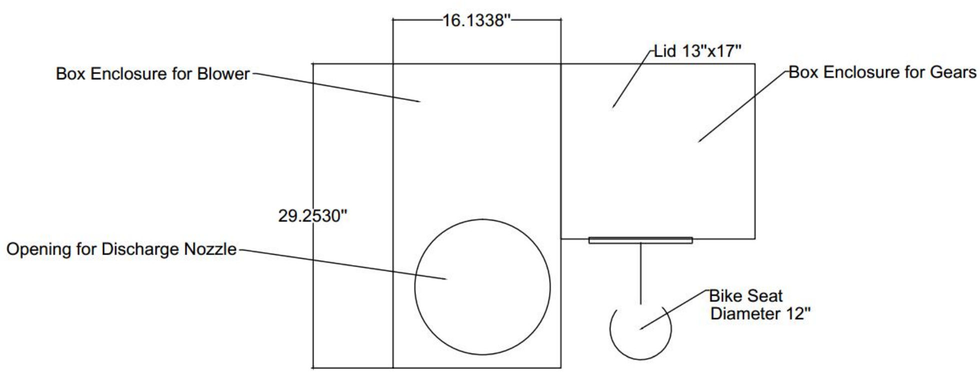

Figure 5-1 AutoCAD of Aerial View of Bernoulli's Bike Blower by Samantha Ortega

5.2.2 Gearing

Multiple gears provide a mechanical advantage which increases torque for the user and rpm at the blower in order to generate sufficient air flow from the blower, which is otherwise unobtainable by other methods of power transmission. The increased force required for the user to power the machine provides a counter-intuitive benefit to the "Ease of Use" criterion. Without the added resistance the user must pedal at a much faster rate which becomes difficult to maintain while still yielding poor results. The decreased pedaling rate also makes the machine safer to operate, satisfying another critical criterion.

The current gear transmission uses 6 gears, two in each step-up. Each step-up provides an increase in rpm at the blower, equivalent to the input multiplied by the ratio of the number of teeth on each gear involved. The first step up employs a 52 tooth gear powering an 18 tooth gear. The second step up creates a tooth ratio of 44/18. The third step-up creates a tooth ratio of 50/14. The final ratio created by the combination of the three step-ups provides 25 rotations on the blower for each single rotation of the pedals on the bike.

5.2.3 Drive to Intermediate Shaft Assembly

The large flywheel of the exercise bicycle is used to drive a smaller gear on the intermediate shaft assembly to achieve maximum increase in rotational speed. A gear drive system is incorporated to provide reliable transfer of power without slippage. Use of common bicycle gear drive components ensures availability of replacement parts while minimizing cost.

5.2.4 Chain Drive from Intermediate Shaft Assembly to Fan

A small gear is attached to the pulley of the blower, so that the intermediate transmission powers the blower while providing the final step-up in the overall transmission.

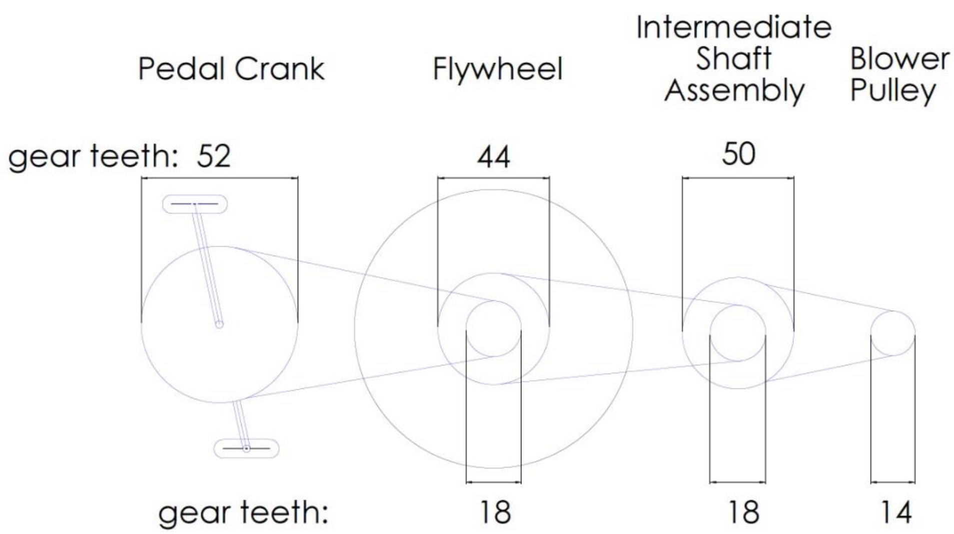

Figure 5-2AutoCAD of chain drive by Joseph Cooney

5.2.5 Fan/Blower

A recycled industrial blower supplied by the client is used to produce airflow for Bernoulli's Bike Blower. The original drive pulley of the blower is modified to accept a smaller chain gear for a more positive connection while also increasing the multiplication factor of the drive system.

The blower is held stationary in front of the bicycle and positioned to discharge vertically with minimum ducting to reduce airflow resistance.

5.2.6 Box

The box prevents children from getting injured as well as the machine from being vandalized. The box encloses the intermediate shaft assembly, flywheel, and blower. Plywood and metal screens were the materials used to construct the box. The plywood is painted with chalkboard paint, allowing students to decorate it as they wish. The box is designed for ease of use and transportation. A feature that allows for easy access for maintenance on the intermediate shaft assembly is a top that can open. The box also features latches for a better grip when transporting.

5.2.7 Discharge Nozzle

Attached to the industrial blower is a discharge nozzle for airflow to directly impact the object to be levitated. Bernoulli's principle states that as the speed of air increases, the pressure within decreases. Thus the discharge tube and discharge flange operate together to satisfy the generation of vertical airflow to the designated object. This meets our criteria of Educational Value, Effectiveness, and Fun. The students of Zane Middle School will not only have fun watching levitating objects by their own input of power, and they'll also get to experience how a complex mechanical system operates.

5.2.8 Levitating Objects

Objects with a large surface area and a small mass were found to be the easiest and most efficient for levitation. Balloons reach great heights at little pedal power, because balloons are so light they can be levitated really high in the air. A beach ball is slightly heavier than the balloon which makes the pedaling a bit more difficult. Kites were an option that have yet to be tested. Kites do not weigh much and their surface area is not spherical which would make for an interesting observation.

5.3 Costs

Section 5.3 contains a detailed description of the costs for Bernoulli's Bike Blower. The costs are divided into the cost of hours spent, cost of materials, and cost of maintenance.

5.3.1 Design Cost (Hours)

Every individual team member's hours of the Fantastic Cycle were gathered and collected to create the pie chart in Figure 5-3. These hours were spent on brainstorming, researching, writing documents, editing documents, sketching designs, and building Bernoulli's Bike Blower. The design cost came out to a grand total of 188 hours.

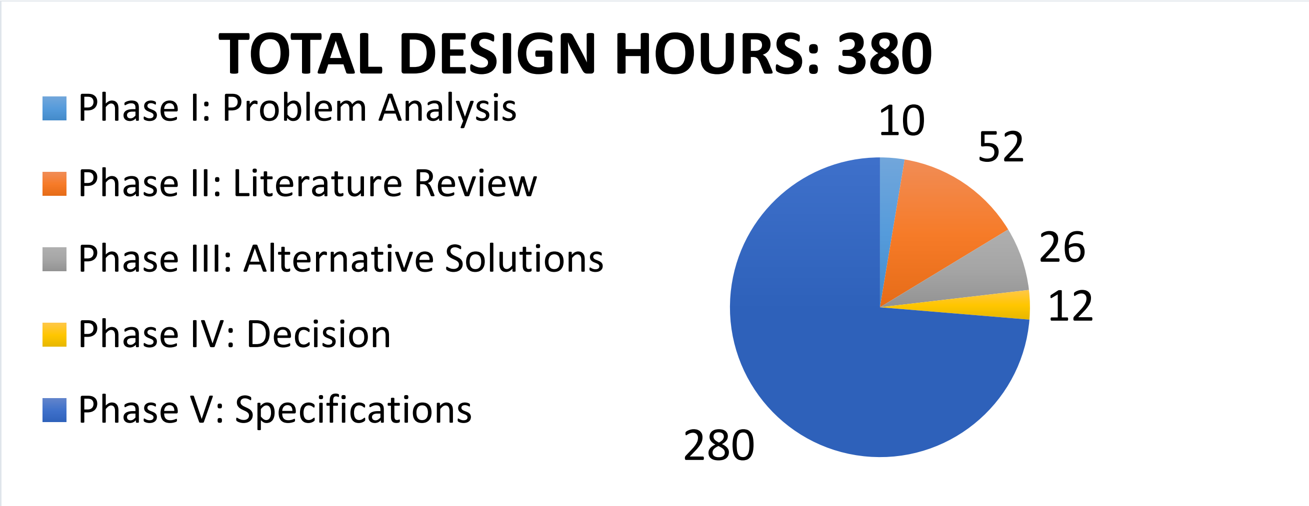

Figure 5-3 Design Cost in Hours

5.3.2 Implementation Cost

The amount of money the Fantastic Cycle spent on Bernoulli's Bike Blower was $172.27. Without donations the retail cost it took to build Bernoulli's Bike Blower is $764.27. Table 5-1 lists out the materials and their prices used for Bernoulli's Bike Blower.

Table 5-1 List of Materials and Costs to recreate Bernoulli's Bike

Item	Quantity	Fantastic Cycle's Cost	Retail Cost
Exercise Bike	1	0.00	150.00
Aluminum Industrial Blower	1	0.00	350.00
Bike Body Bolts	6	8.00	8.00
Bike Support Feet	2	5.60	5.60
Handlebar Grip	2	0.00	20.00
Rubber Tape	1	9.99	9.99
Plywood	1	21.99	21.99
2x2 Box Framework	4	11.56	11.56
Screens for Windows	2	8.28	8.28
Chest Handles	1	3.99	3.99
Latches	2	15.58	15.58
Casters	4	0.00	25.00
Caster Bolts	16	7.20	7.20
Discharge Tube	1	15.29	15.29
Collar for Discharge Tube	1	5.84	5.84
Soft Foam Tape	1	7.19	7.19
Safety Screen	1	2.39	2.39
Discharge Flange	1	8.99	8.99
Hose Clamps	2	5.38	5.38
Paint	3	35.00	35.00
Intermediate Shaft Assembly	1	0.00	10.00
Aluminum Hub	1	0.00	10.00
Gears	3	0.00	15.00
Chain	4	0.00	12.00
Total		**172.27**	**764.27**

5.3.3 Maintenance Cost

The maintenance required for Bernoulli's Bike Blower is described in Table 5-2.

Table 5-2 Annual Maintenance Cost

Item	Description	Cost ($)
Box	Box repairs	0-10
Discharge Nozzle	Replacing old discharge nozzle	20
Screws or bolts	Replacing minor parts	0-1

5.4 Instructions for use of Bernoulli's Bike Blower

Bernoulli's Bike Blower is designed to be disassembled for storage when not in use. Assembly and use is accomplished by following the steps outlined below:

5.4.1 Attaching bicycle to blower box

The two main components, recycled exercise bike and box-enclosed blower, must be securely connected before use. The front feet on the metal frame of the bike fit into corresponding receptacles on the box to position the bike flywheel in line with the intermediate shaft pulley. After the bike is in position, the intermediate shaft drive chain is routed around the large flywheel gear and intermediate shaft gear. As shown in Figure 5-4, closing the drive cover box locks the bike frame into position in the blower box.

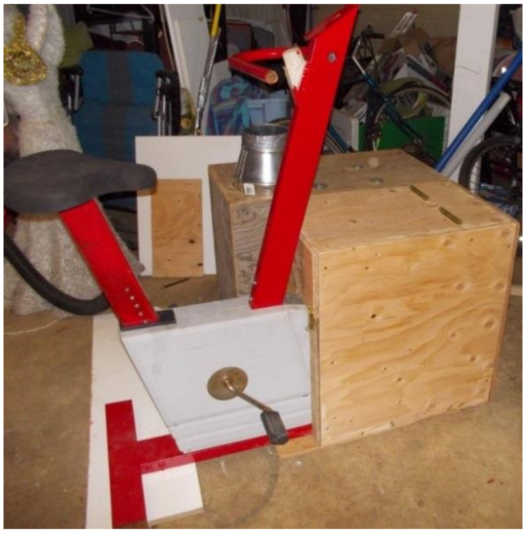

Figure 5-4 Bicycle Attached to Blower Box

5.4.2 Connecting bicycle chain drive to intermediate shaft

The exercise bike's flywheel has an added chain gear and bicycle chain that has to be connected to the matching pulley on the intermediate shaft. Figure 5-5 shows the bike frame feet in the blower box receptacles and the flywheel next to the intermediate shaft pulley. Route the chain around both flywheel and intermediate shaft gears, allowing the bike to sit flat on the ground in location applies tension to the chain.

Figure 5-5 Bicycle Chain Drive connected to Intermediate Shaft

5.4.3 Securing drive component shield

The drive components of Bernoulli's Bike Blower must be shielded for safety before operation. Figure 5-6 shows the box shielding the drive components that prevents accidental contact with the moving parts. This additional shielding is hinged for bike placement, after which the shield is closed and latched. Closing and latching the drive cover secures the bicycle frame feet into the box.

Figure 5-6 Drive Component Shield, secured

5.4.4 Attaching discharge nozzle to blower box

The discharge tube must be attached to the blower discharge port on top of the box prior to use as shown in Figure 5-7. The discharge nozzle is attached to the discharge port with a hose clamp, securing the two pieces together.

Figure 5-7 Attaching Discharge Nozzle to Blower Box

5.4.5 Operating bicycle

Powering Bernoulli's Bike Blower is similar to pedaling a bicycle, as shown in Figure 5-8. Generation of airflow is accomplished by rotating the pedals of the exercise bike to power the blower. The bike and blower box must be on a firm, flat surface and securely attached to each other. When the bike frame feet are in position in the blower box receptacles, the bicycle will be stable and will not require balance by the operator. The seat of Bernoulli's Bike Blower is adjustable for comfortable operation by riders of different heights and leg lengths. After adjusting seat height, the operator sits on the seat and pedals while holding securely to the handlebars. Greater airflow is achieved with faster pedal rotation. When a ball is placed above the discharge nozzle, it will be levitated relative to the amount of airflow. Articulating the discharge nozzle will cause the ball to float "off-center", seemingly defying gravity.

Figure 5-8 Operation

5.5 Results

Although there were multiple solutions, Bernoulli's Bike Blower using a gear transmission was the best option that met our criteria. We were able to satisfy our client's specifications and create a solution that the students at Zane Middle School could enjoy and learn from.

5.6 Discussion

Numerous tests revealed that many of the original design ideas were ineffective. The final design specifications, which are considerably more detailed than the original design, provide solutions to the many problems faced during the development process.

The original design employed a direct friction drive from the flywheel of the exercise bicycle to the pulley of the fan blower. At first there was not enough friction between the two wheels so a layer of rubber was added to the fan pulley to provide a better contact surface. This helped but the fan was still not providing enough airflow. It was also found to be difficult to maintain contact between the flywheel and the pulley. In an attempt to remove the pulley from the fan, so that it could be machined for better contact, part of the pulley broke, shown in Figure 5-4.

Figure 5-9 Broken Pulley

At this point, a chain and gear transmission were tested to check its ability to maintain positive contact while simultaneously increasing fan speed. The new transmission, although more detailed and complex, proved to solve several issues present in the direct friction transmission. The chain and gear transmission completely eliminate slipping. In addition, the gears allow an increase in the airflow from the fan to a sufficient level needed to levitate an object.

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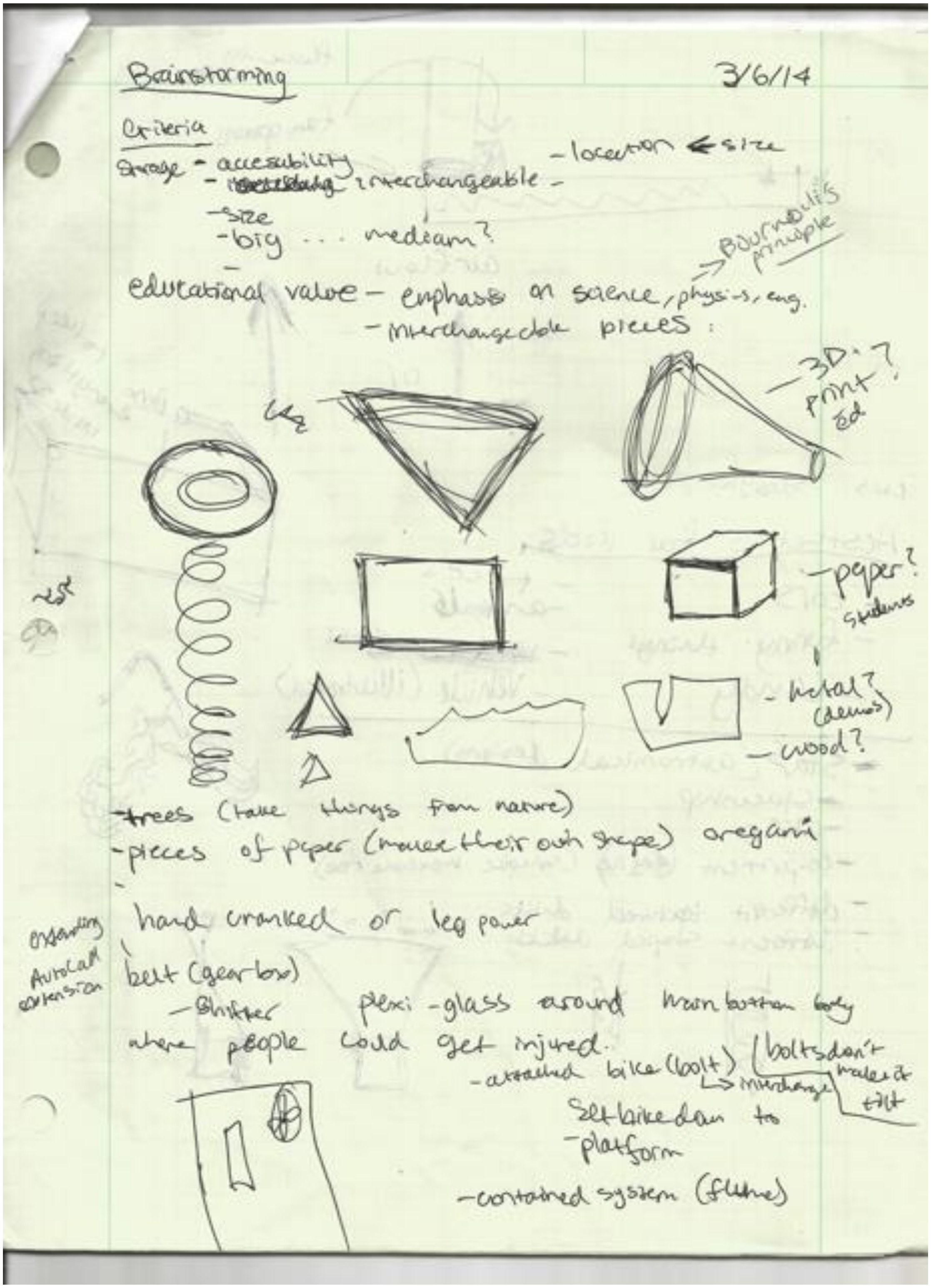
Appendix B – Brainstorming Notes



Brainstorming 3/6/14

Criteria

Storage - accessibility - location ← size
- interchangeable -
- size
- big ... medium?

→ Bournoulli's principle

educational value - emphasis on science, physics, eng.
- interchangeable pieces :

- 3D? printed
- paper? students
- metal? (demos)
- wood?

- trees (take things from nature)
- pieces of paper (make their own shape) origami

hand cranked or leg power

expanding Autocad extension

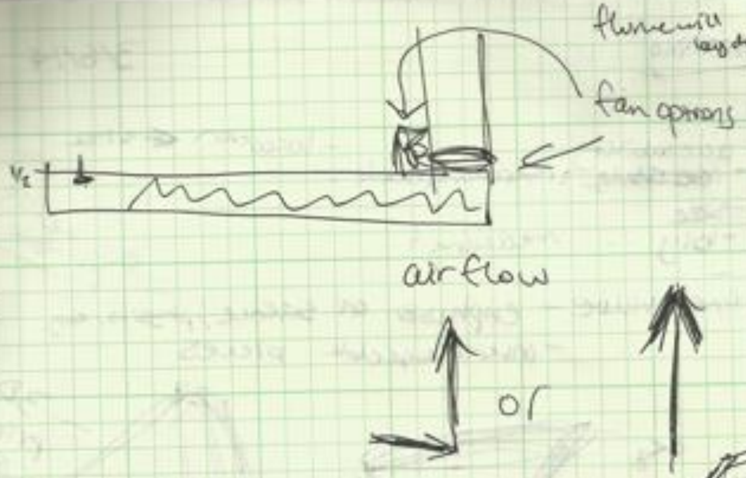
belt (gear box)
- shifter

plexi-glass around main bottom body where people could get injured.

- attached bike (bolt) → interchange

(bolts don't make it tilt)

set bike down to
- platform
- contained system (flume)

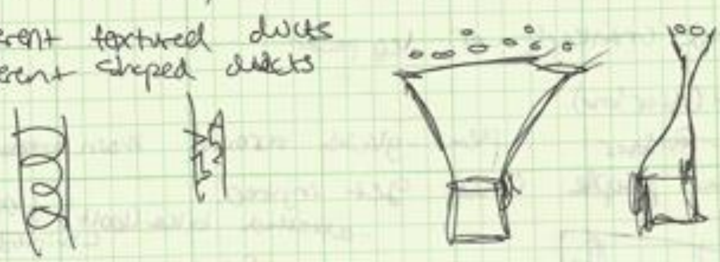


kids ->design

Aesthetics for kids,

- cars
- funny things
- candy
- trees
- animals
- [illegible]
- vehicle (illustrated)

- stars (astromical designs)
  - spaceship
  - aliens
- compartment (dry ice) (smoke machine too)
- different textured ducts
- different shaped ducts



- Alt solutions -

		Pic
? joe	belt drive w/ 1st box, tiltable blower - uses turns like a vending machine	Yes
sam	belt drive w/ 2nd box style, tilt table (uses box w/ turns & screens)	Yes
~~Sam~~ sam	~~belt drive, box style 2, Moveable nozzle~~ friction drive - no tilt table - flywheel to blower - box style 1	
joe	generator powered fan - no box, no tilt	
chelsea?	hand crank - no box no tilt	
chelsea	moveable blower / tilt table	Yes
joe	friction drive moveable discharge nozzle	
OPTION if needed	gears shiftable gears - -	

Appendix C – Acknowledgements

Behind most every project and team stands an invisible support system. The Fantastic Cycle is no exception. Without this system of amazing people and businesses the Fantastic Cycle would not have been able to create Bernoulli's Bicycle Blower.

First, a thank you to Mr. Ken Pinkerton from Zane Middle School for donating the industrial blower and exercise bike.

Second, a thank you to Marty Reed, the equipment technician at HSU, who aided the Fantastic Cycle with advice and assistance with Bernoulli's Bicycle Blower. The time Marty took to help the Fantastic Cycle was a priceless contribution.

Third, a thank you to Revolution Bike Shop in Arcata for their donation of handlebar grips, a spare bicycle, bike chain master links, and spare gears.

Again, thank you everyone who supported the Fantastic Cycle throughout the course of the project.