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Contents

Table of Figures

1 Problem Formulation

1.1 Introduction

In Section 1 of the design process, the formulation of the objective statement will be presented. A black box model of the design process is shown in Figure1-1.

The client is Zane Middle School. Zane is a 6th-8th grade Magnet school with STEAM (Science, Technology, Engineering, Art, and Math) being the focus for the future. Zane formed a partnership with Humboldt State University (HSU) around STEAM principles. The HSU course Intro to Design includes a group project which tasks engineering students with building a structure or apparatus relating to STEAM. For the Spring 2015 semester at HSU, Team GID (Get it Done) has been tasked to build a probability machine for Ken Pinkerton, a teacher at Zane Middle School. The probability machine fits into Zane Middle School's STEAM curriculum, because the probability machine will be designed to provide middle-school students with a hands-on demonstration of the mathematical concept of probability.

1.2 Objective

The objective of this project is to design a probability machine that demonstrates probability using hands-on physical methods for Zane Middle School engineering students. The probability machine must educate middle-school students on the mathematical concept of probability, must be safe for children to operate, and must cost no more than $400.00 to build.

Figure 12 By the end of this project, Zane Middle School will have a probability machine that shows students how probability works.

2 Literature Review

2.1 What is Probability??

2.1.1 Definition

Probability is a ~~strong~~ likelihood or chance of something. People use the concept of probability to estimate the chances of an occurrence. Many of these methods of estimation involve the use

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of past experiences to predict what will happen in the future. Probability can be described as the mathematical theory of uncertainty~~.~~ (Isaac, 1995~~)~~).

2.1.2 Significance

What makes the theory of probability stand out in mathematics is the inconsistency of final results. Probability can be measured by using mathematical formulas, but that does not mean the final results will reflect that number. The probability of a flipped coin landing on heads is 50%~~0.5~~, but there is still a possibility that a trial of four coin flips will result in three heads and one tails. Even if the coins were flipped with the same amount of force and at the same angle, the results would still remain unpredictable due to the “uncertainty principle,” which dictates that it is impossible to predict the exact position and direction of very small particles~~.~~ (Isaac, 1995~~)~~).

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Despite these limitations, probability can still be a useful tool to help make unpredictable phenomena more predictable. Even if results do not perfectly reflect the calculated probability, they are still consistent enough to merit the use of the concept. As long as there are many trials or possible outcomes, the results should remain consistent with the calculated probability~~.~~ (Isaac, 1995~~)~~).

2.2 Mathematical Description

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2.2.1 Mathematical Definition

The mathematical definition of probability can be represented by the formula

$$\text{Probability of Favorable Results} = \frac{\text{Number of Favorable Results}}{\text{Total Number of Trials}}$$

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By this mathematical definition, probability must be a number between zero and one, where a probability of zero is an impossible result, and a probability of one is a sure thing~~.~~ (McGervey, 1986~~)~~).

2.2.2 Pascal’s Triangle

Named after the French mathematician Blaise Pascal, the Pascal’s Triangle has a wide variety of uses in mathematics. The Pascal’s Triangle is oftentimes used for the expansion of binomial series’. Pascal’s Triangle also has a place in the calculations of probabilities. By using the mathematical definition, it’s easy to determine that a flipped coin landing on heads has a probability of 50%~~0.5~~. However, in order to calculate the probability of a coin landing on heads three times in a row, Pascal’s Triangle can be used.

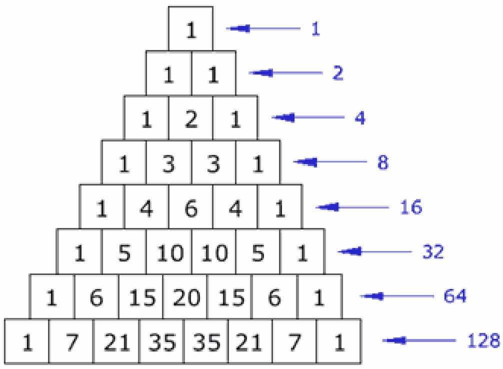

Figure 3421-11-1 Pascal's Triangle can be used to determine the probability of something happening more (Math is Fun, 2014) <http://www.mathisfun.com/images/pascals-triangle-4.gif>

~~Figure 1-11-1 Pascal's Triangle can be used to determine the probability of something happening more than once (Math is Fun, 2014).~~

P= k/S or P= $k/2^n$

In Figure 2-2, if the result is heads, shift down to the left, and, if the result is tails, shift down to the right. To determine the probability of three coin flips all landing on heads, go to row three and shift to the far left. The probability of such an outcome is 0.125.

Probability Triangle									
Row #									
0					1.000				
1				0.500		0.500			
2			0.250		0.500		0.250		
3		0.125		0.375		0.375		0.125	
4	0.0625		0.250		0.375		0.250		0.0625

Figure 5621-21-2 The Binomial Probability Triangle shows the probability of each possible outcome of many coin flips (Killian, 1976).

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0.5 0.5 ~~coin flips is~~

~~2.6.1~~2.3.1 Gambling

In gambling, probability can be used to determine whether or not a bet is in one's favor. For example, by using the formula in the Mathematical Description section, one can determine that the probability of rolling a seven on two six-sided dice is 1/6, while the probability of rolling a six is only 5/36 (McGervey, 1986).

Another example of probability in gambling is the probability of drawing an ace in a game of poker. Assume that two players are playing with a deck of 52 cards, and each player has 5 cards. One player wishes to exchange two of his/her cards for potentially getting two aces. Assume that there are four aces in the deck and that neither player currently has an ace. This formula can be used to help calculate the probability of two events occurring back-to-back:

$$P = A * B$$

Where P is the total probability, A is the probability of event one happening and B is the probability of event two happening (McGervey, 1986). Since both players have five cards, there are 42 cards in the deck now, so the probability of drawing one ace (probability A) is 4/42, or 2/21. Next, we will determine probability B. Keep in mind that there are 41 cards in the deck now that the first ace was drawn, so probability B is 3/41. The total probability is the product of A and B, which is 2/21*4/41 = 8/61, or about 13%~~0.009~~. Therefore, although this exchange may have positive results, this player should not get his/her hopes up for two aces!

~~2.6.2~~2.3.2 Statistics

We already somewhat delved into statistics in the Pascal Triangle section, but we can delve even further by plotting a bell-shaped curve. Something worth noting about the binomial triangle in Figure 2-2 is that, for each row, the probability is at its greatest in the center. This result reflects the probability of a flipped coin landing on heads, which is 50%~~0.5~~. Therefore, a bell-shaped curve of number of heads vs number of possible results will peak at the mid-point of the x-axis.

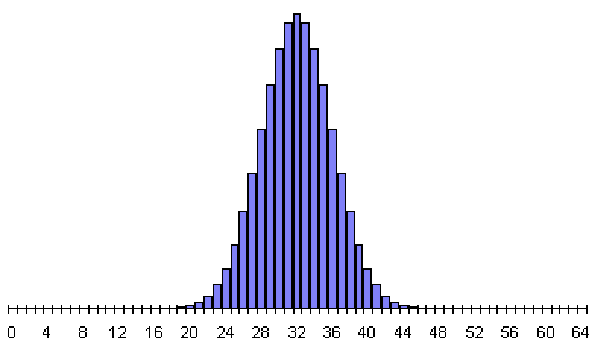

Figure 78~~21-3~~~~1-3~~ The bell-shaped curve peaks at the midpoint, because the probability of a coin landing on 50%~~0.5~~ (Walker) <https://www.fourmilab.ch/rpkp/experiments/figures/bd64.png>

2.72.4 Children Learning Styles

2.7.12.4.1 Grade 6-8 Teaching Methods

~~Have kids work in small or big groups and ensure all the kids are included in all work; do not allow the kids to be grouped with friends often, have the kids sit with other peers in the classroom. It is good to make every student feel important in his or her efforts to contribute and to never embarrass a student in front of their peers. Make questions for the kids challenging enough to have them think for extended periods of time, also have the children work for the answer rather than giving the answer out. Teach the kids how to make decisions from planning and to break down the tasks they are assigned because not all of the kids will understand complex language. (Needs in text citations)~~

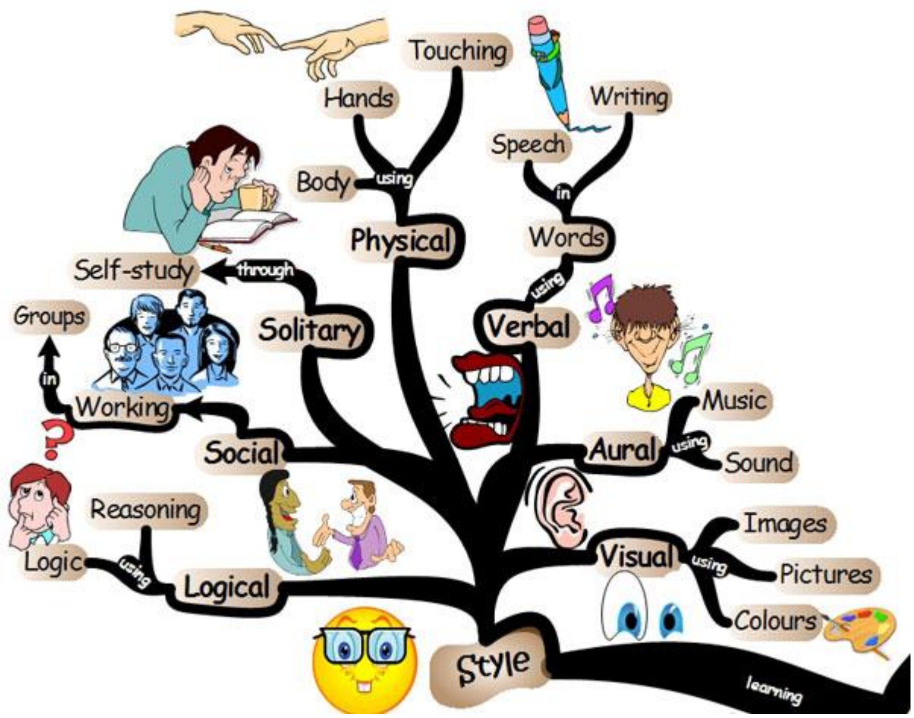

Figure 91021-41-41-31-3: Learning Methods <(http://www.ccsf.edu/content/ccsf/en/about-city-college/slo/professional_development/learning_styles/_jcr_content/contentparsys/imagebanner/image.img.jpg/1360704177544.jpg>)

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2.7.22.4.2 Core Curriculum

The kids will have to be able to cite the text and be able to prove their stance. The kids will have to be able to write a summary of the text only due to their prior knowledge of it. The kids will have to be able to follow distinct steps to a process. The kids will have to be able to understand and read independently at a satisfactory level.(citation)

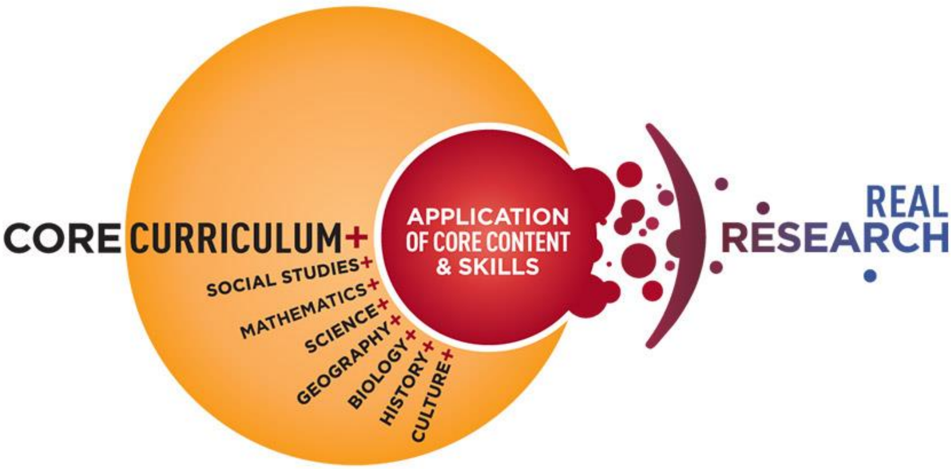

Figure 111221-51-51-41-4: Core Curriculum <(http://thinkglobalschool.org/wp-content/themes/tgs-theme/images/core_curriculum.jpg))http://thinkglobalschool.org/wp-content/themes/tgs-theme/images/core_curriculum.jpghttp://thinkglobalschool.org/wp-content/themes/tgs-theme/images/core_curriculum.jpg>)

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2.7.32.4.3 Pedagogy

Pedagogy is the method and practice of teaching. Engaged pedagogy supports student activities when the instructor takes on the role of being the facilitator rather than being the dominant figure in the classroom. This method has a high student learning statistic. Provide statistic (citation)

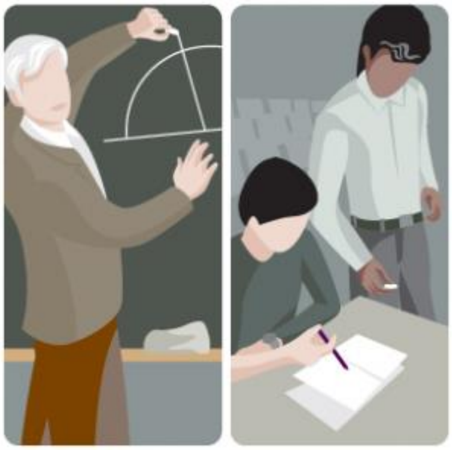

Figure 131421-61-61-51-5: Pedagogy

<http://learndat.tech.msu.edu/sites/default/files/styles/in_content/public/Characters01.jpg?itok=jlmMyUU4>http://learndat.tech.msu.edu/sites/default/files/styles/in_content/public/Characters01.jpg?itok=jlmMyUU4>

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2.82.5 School Curriculum

Zane imposes the program of STEAM: Science, Technology, Engineering, Art and Math. STEAM is used for prepping students for skills needed in the 21st century's workforce. The main goal is to teach the needs of today's society while satisfying the student's interests.(citation)

2.92.6 Examples

2.9.12.6.1 Galton board

A GGalton, board also known as a quincunx or a bean machine, is a vertical board with pins or wedges placed in offset rows. The top of the Galton board has a funnel that directs balls that are dropped into the machine onto the first pin or wedge. The balls then bounce off of each pin or wedge; with each bounce the ball will either fall to the left or right of the pin, with equal probability. (Hilsenrath and Field 1983) Once a ball falls all the way through the pins it falls into it's a column. The purpose of a quincunx is to demonstrate deviation, the more layers of pins used and the more balls used the closer the end result will be to a standard deviation curve. (Chernov and Dolgopyat 2009) The curve can be skewed by moving pins or slanting the entire bean machine.(Hilsenrath and Field 1983)

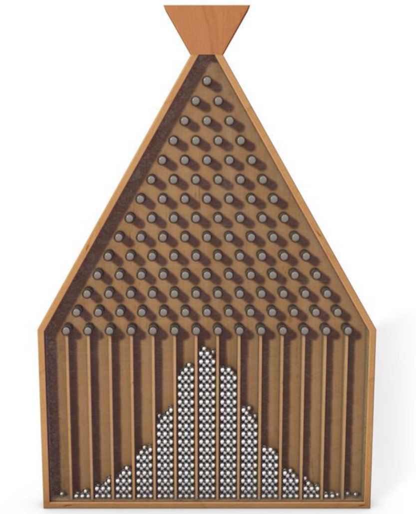

Figure 151621-71-71-61-6 One example of a quincunx machine <(http://www.etereaestudios.com/docs_html/inspirations_htm/maths_index.htm>)

2.9.22.6.2 Roulette wheel

roulette Rroulette wheel is a casino game that involves a large wheel with the numbers 00,0, and 1-36. Half of the numbers are black and the other half are red with the exception of 0 and 00 they are green. The numbers are ordered on the wheel such that large numbers alternate with smaller numbers and even numbers alternate with odd numbers. During game play the player places a bet predicting where a ball will land on the wheel then a ball is rolled along a groove and the wheel is spun in the opposite direction as the ball slows it falls out of the groove and lands intoon the wheel. Players can bet on: a single number, two numbers, three number, four numbers, six numbers, twelve numbers or eighteen numbers. A single number bet pays 35 to 1 but the chances of winning, assuming even probability of landing on any given tile, are 1 to 38388. ("Roulette", http://www.math.uah.edu/stat/games/Roulette.html)). An off balance wheel have skewed probability for landing on a given number . (Ethier 1982)).

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Figure 171821-81-81-71-7 An example of a roulette wheel <(http://fineartamerica.com/featured/the-roulette-wheel-tom-conway.html>)

2.9.32.6.3 Lottery machines

2.9.3.12.6.3.1 Air powered lottery machines

Air powered lottery machines blow air into a clear enclosure filled with light plastic balls, usually numbered one through fifty. There is one hole in the top of the machine that the air or balls can escape through. The air rushing through the enclosure causes the balls to bounce around and randomly hit the hole in the top and get blown out. In order for the machine to be completely random all of the balls must be weighted equally, lighter balls are more likely to be selected. (Karim nice).)).

2.9.3.22.6.3.2 Gravity powered lottery machines

In Gravity powered lottery machines numbered balls are dropped in to an enclosure that has two paddles spinning in opposite directions that mix the balls. Once the balls are sufficiently mixed they are let out through a door that is controlled by an optical sensor, at the bottom one at a time. (Karim nice).)).

2.9.42.6.4 Pachinko Machine

A Pachinko machine is an arcade game from japan that is frequently used as a gambling device. A Pachinko machine consists of a vertical board with pins placed in a design and pockets that reward the player with extra game pieces if a ball makes it in them. The player uses a spring and plunger to shoot the balls in to the game board at varying velocities. If the ball makes it in to a winning pocket 10-15 more balls are rewarded. If the ball does not make it in to a winning pocket it is collected by the Pachinko machine. (Dan Reed)).

Figure 192021-91-91-81-8 one example of a pachinko machine <(http://pachinkoparlour.blogspot.com/2012/03/more-pachinko-machine-pictures.html>)

2.102.7 Teacher Criteria

Ken Pinkerton has requested a model that would demonstrate probability. The goals of this project are to create a machine that can clearly demonstrate probability mathematically and visually while being interactive with the students. The machine should be durable, moveable, and easily storable in a small space.

2.112.8 Building Materials

2.11.12.8.1 Acrylic

Acrylic is a plastic that is similar to glass but created from polymers of acrylic acid or acrylates. Acrylic is a light weight material, one square foot that is 1/8" thick weighs in at less than ¾ of a pound. In comparison to glass acrylic is soft, which allows it to break into large pieces with softer edges. Because of the softness characteristic acrylic has, cleaning and handling should be done carefully. Acrylic is also strong but if continuous force is applied then only a maximum force of 1500 psi should be exerted. The softness allows the acrylic to be easily cut and glued to other surfaces making the loss of strength from gluing negligible. If caught on fire, acrylic will decompose into water and carbon dioxide. If there is not enough air to react then carbon monoxide may form. (Citation)

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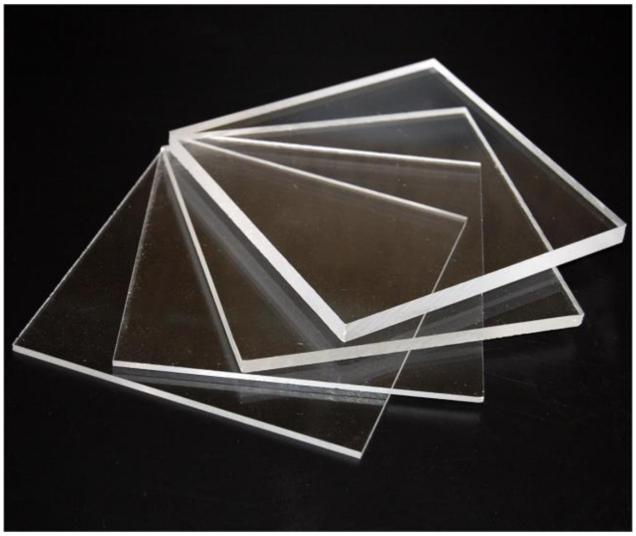

Figure 212221-101-101-91-9 Sheets of acrylic
<(http://www.tapplastics.com/product/plastics/cut_to_size_plastic/acrylic_sheets_clear/508>)

2.11.22.8.2 Glass

Glass is a hard, brittle surface, created from sand, soda, lime, and other chemicals. The weight of glass can vary depending on the type of glass but typically a 1/8" thick square foot sheet of glass weighs 3.5 pounds. Glass is stiff and brittle causing sharp rigid edges when broken. Glass has a hard surface making it easy to clean. The smooth texture of the glass makes gluing difficult and requires a special type of glue. Glass also requires special tools to cut. Glass Melts at extreme temperatures.

Figure 232421-111-111-101-10 Sheets of glass
<(http://www.starfireglassandmirror.com/glass.php)http://www.starfireglassandmirror.com/glass.php>)

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3 Problem Analysis

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3.12.9 Introduction

The problem analysis contains constraints, specifications and criteria that have been selected with the client in order to insure that the final design can be easily and effectively implemented by the client.

3.22.10 Specifications

Specifications are constraints that must be met in order for the project to be successful. The specifications for the probability machine are that it is:

- Interactive with the students
- Storable in a crowded class room
- Completed before the math fair (April 26, 2015)

3.32.11 Criteria

Criteria presented in a table with constraints ordered by weight.

Criteria	Weight	Constraints
Educational Value	10	Demonstrates probability to 6-8th graders.
Ease of Interaction	8	Students must take some part in using the machine.
Durability	8	Remains operational and scratch resistant.
Aesthetics	6	Attracts and keeps the attention of 6-8th graders.
Portability	4	Easily moved by one adult.
Ease of Implementation	4	Less than 10 minute set up time.

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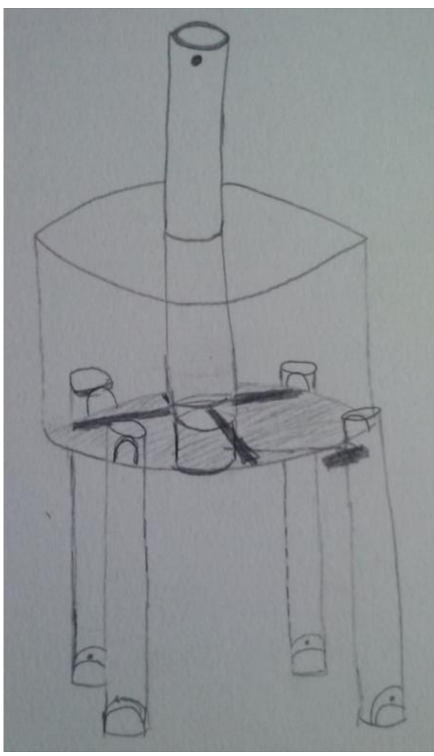
Safety	4	Meets district standards.
Cost	3	Does not exceed $400.

~~4~~3 Alternative Solutions

~~4.1~~3.1 Introduction

The Alternative solutions section includes descriptions of six different solutions that meet the client's criteria and .

~~4.2~~3.2 Centrifugal Machine



The C~~c~~entrifugal M~~m~~achine consists of four major parts. ~~First of which is~~The first part contains two clear 2' long tubes. ~~with o~~One tube is fitt~~ing~~ed inside of the other and ~~the first~~both are just wide enough for a ping pong ball to fit ~~in~~through. The outer tube has a nob attached to allow ~~easy grip to slide~~sliding up and down around the inner tube. The inner tube has a four equal way divider at the bottom. Each divide has its own small opening. Next is a 1'6" wide, 9" tall cylindrical clear tube with a black base. There are four holes equally spread out around the side-base of the cylinder. The first set of tubes sit inside the larger tube on the base. The smaller cylinders are vertical to the larger cylinder with the flat sides of the 1' 6" cylinder facing up and down. There are four spinning arms ~~that rotate around the base of the smaller tubes that sit~~ at~~in~~at the base in the middle of the larger cylinder~~ and also at the base~~. The spinning arms are attached to a small cylinder that fits around the two tubes that are in the center of the large cylinder to allow the arms to rotate freely. This cylinder also protrudes out the bottom of the larger cylinder where a spring loaded pull cord is attached to spin the cylinder and arms when the machine is in use. The machine has four tubes that are 3' long and wide enough for a ping pong balls to fit ~~in~~ through. ~~with openings at one end of each tube~~Each tube has an opening at one end. These tubes are attached to the side-base of the largest cylinder facing down to catch the ping pong balls as they come out of the four openings on the cylinder base. These tubes act as legs for the machine and hold the larger cylinder off the ground. The openings at the bottom have movable latches to remove the ping pong balls.

The operation of the Centrifugal Machine involves a number of steps. ~~To begin using the machine~~First, ~~Ping~~ping-~~Pong~~ pong balls are added to the set of tubes that sit on the larger cylinder with the four-way divider shut. ~~Next t~~The~~thet~~The pull cord ~~is activated by pulling it which sends~~ causes the arms to ~~rotating~~ rotate around the center tubes. The four-way divider is opened by lifting the outer tube by its knob, allowing the balls to fall into the largest cylinder. In the largest cylinder, the balls are forced to the outside by centrifugal force created from the rotating arms. ~~which are~~The balls are then sent through the openings at the base of the larger cylinder. ~~and then are collected~~ The balls land in the legs of the device~~. The balls~~ and ~~can be~~are collected by sliding up the latch at the bottom of the tubes.

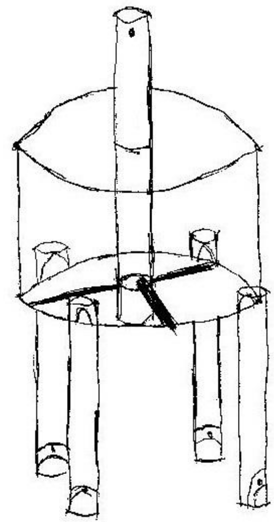


Figure 2526 The Centrifugal Machine uses spinning arms and four chambers to demonstrate probability.

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A number of components make up the Air Mix Lottery Machine. ~~Air mix lottery machines demonstrate probability by using an upward stream of air and numbered ping pong balls to show the likelihood of a certain number being selected. An~~The ~~air~~ Air ~~mix~~ Mix ~~lottery~~ Lottery ~~machine~~ Machine ~~can be~~is composed of a container, ping pong balls inside the container, tubes, vents at the top of the container, and an air jet power source. Figure 3-3 illustrates how an air mix lottery machine ~~can be~~is designed.

The selection process of The Air Lottery Machine will be discussed. As shown in Figure 3-3, ~~air-mix lottery machines~~ The ~~a~~Air ~~-~~M~~m~~ix L~~l~~ottery M~~m~~achine~~s~~ is~~are~~ powered by an air jet~~s~~ at the bottom of the container. The~~se~~ air jet~~s~~ mixes~~mix~~mixes the balls ~~up to even the odds of each ball being selected by the lottery machine.~~, and the ~~Vents~~ vents at the top of the machine ~~are then~~ manually open~~ed~~ to allow air to escape the machine~~,~~. ~~which~~ The air jet and the vents create~~s~~ an upward force of air that carries randomly-selected ping pong balls through the tube. Gravity then carries the selected ping pong balls to a storage tube. ~~This~~ The storage tube is for record-keeping and for showing which balls were selected (Nice, 2001).

~~Since this air mix lottery machine is designed to teach probability to middle-school students, a number of changes are present.~~The Air Mix Lottery Machine meets the client's criteria in a number of ways. In regards to aesthetics, the air mix lottery machine ~~is not composed of numbered balls. Instead, the air mix lottery machine~~ is composed of colored balls, because colors are ~~more~~ attractive to middle-school students ~~than numbers are (source?)~~. The air mix lottery machine is also durable, because middle-school students are generally ~~more~~ less ~~careless~~ careful than adults. Furthermore, the ~~air~~ Air ~~mix~~ Mix ~~lottery~~ Lottery ~~machine~~ Machine is easily operated by middle-school students, because all that the users need to do is press a button~~,~~. ~~and is safe to use.~~

The biggest challenge in building an air mix lottery machine is finding a safe and reliable source of air power. The client cannot provide such a source, and some sources, such as blow-dryers, can get dangerously hot. In order for the Air Mix Lottery Machine to be safe, a blow-dryer without the heating element is a better option for the air power source.

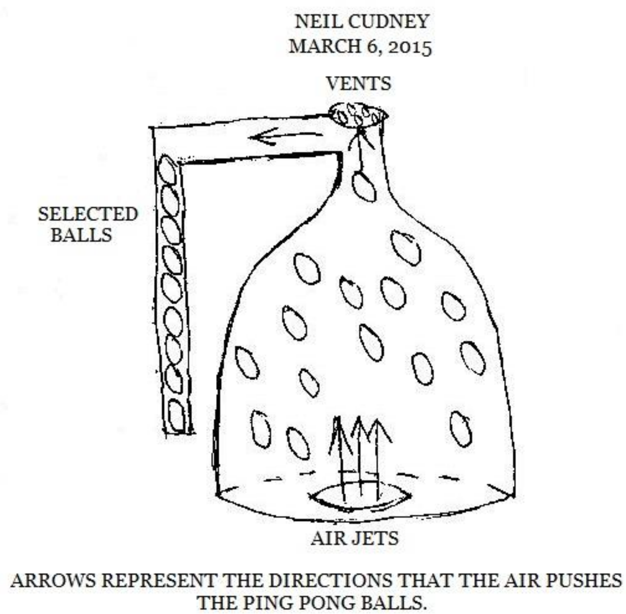

Figure 2728~~33~~3~~3~~3~~3~~3 ~~3~~: An air-mix lottery machine uses air pressure to randomly select a ping pong ball (Nice, 2001).

~~4.5~~ Distributer ~~machine~~Machine

The ~~distributer~~ Distributer ~~machine~~ Machine randomly distributes ~~a ball that is placed in the top~~balls to one of the four chutes on the side. The chutes on the sides are clear so that the color and order of the balls can be observed by the students. The body of the machine is a cylinder to allow the ramp ~~(A)~~ to rotate. The ramp ~~(A)~~ is held in place by a drive shaft ~~(C)~~ and rotated by the using a recoil starter ~~(D)~~. A recoil starter is used in order to prevent ~~the~~ students from rotating at a predictable speed. While the ramp is rotating, a ball is placed in the tube ~~(E)~~. Once a ball is placed in the tube, ~~(E)~~ it falls down to the rotating ramp ~~(A)~~. The ramp then rotates until it is one of the collection chutes~~ (B)~~. ~~Then t~~The~~the~~~~the ballt~~The~~the~~ balls fall~~s~~ in the collection chute to machine demonstrates a one ~~and~~ in four probability of ~~the~~ a ball falling into any given chute.

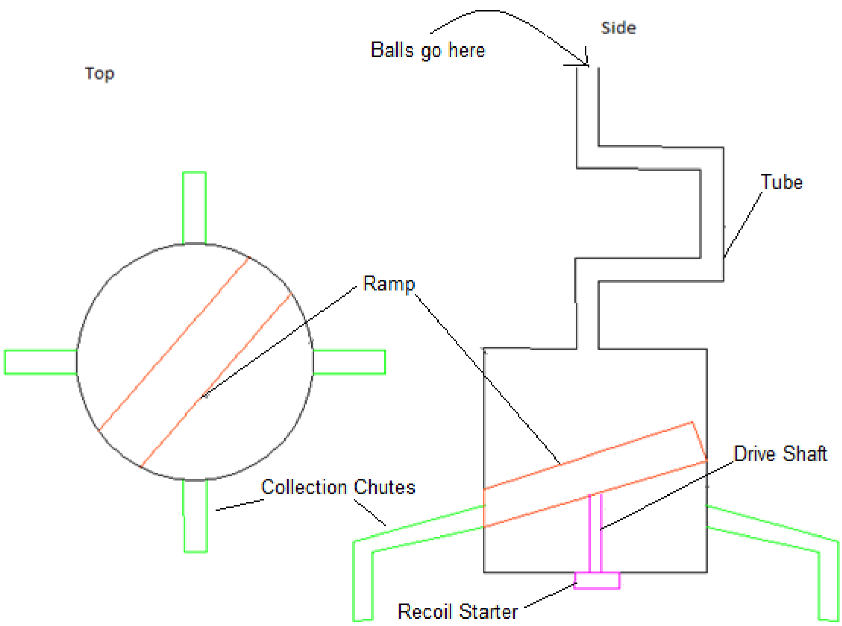

Figure 2930 The distributer machine randomly sorts balls into one of the four collection chutes.

Lottery ~~launcher~~ Launcher

The lottery launcher is similar to the air mix lottery machine but tosses the balls out rather than collecting them in a tube for viewing. The lottery launcher uses a fish tank for the body of the machine (C). The balls (E) bounce around the inside of the enclosure because the inside is slightly higher pressure than the outside. ~~and a~~A large volume of air is moved across the enclosure by the fan (A) attached to the fan is ducting (B) that ensures the air moves across the enclosure and out the tube (D). The lottery launcher randomly ejects, every so often, one colored and/or numbered ball (E) through the tube (D).

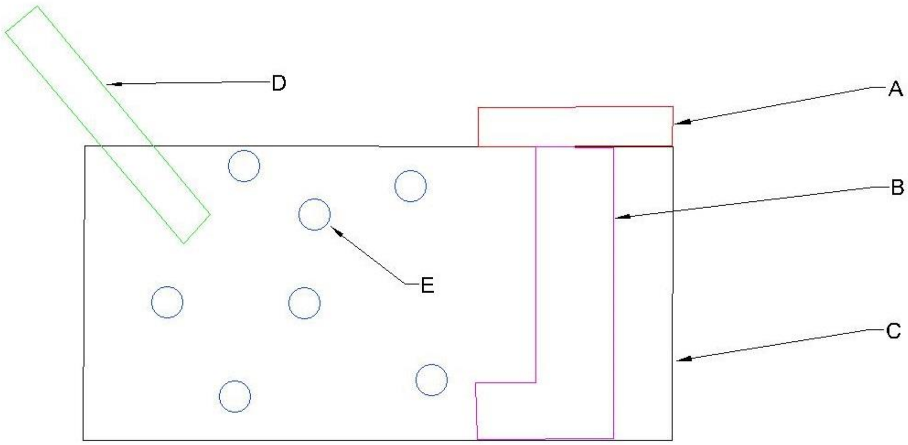

Figure 31Figure 323-3-53-53-53-5: The lottery launcher tosses balls that are randomly selected by an air mix process.

4.73.6 Quincunx

A quincunx probability machine demonstrates probability using bb's and pegs within a 2-dimensional plane to show the likelihood of a bb falling in a certain chamber (Pierce, 2014). The pegs are attached to a rectangular surface, such as a board, in the shape of a triangle. Boards are placed parallel to the triangle's sides to ensure that all bb's remain in the triangular portion of the quincunx. To keep the bb's strictly in a 2-dimensional plane, a see-through surface, such as glass, vertically covers the surface of the quincunx. A specific number of chambers, equal to the number of peg rows plus one, are arranged in an equal manner at the bottom of the quincunx. The majority of the bb's fall into the center chambers and form a bell-shaped curve at the bottom of the quincunx. Figure 1-2 shows the arrangement of a quincunx with twelve rows of pegs and thirteen chambers.

The bb's enter at the funnel-shaped top of the quincunx and bounce either left or right on one peg in each row. The probability of a bb bouncing in the same direction in all twelve rows is small, which is why the end chambers have the least amount of bb's.
Since this Quincunx is designed for middle-school students, the durability and safety of the machine are important. Therefore, the Quincunx contains see-through plastic instead of glass. The Quincunx has a picture of the Zane middle school falcon to draw the attention of the students.

The downside of the quincunx is the lack of student interactivity. The only interaction required for the quincunx is pouring bb's into the top funnel. Unloading and reloading the bb's at the bottom chambers can also prove to be inconvenient for continued usage.

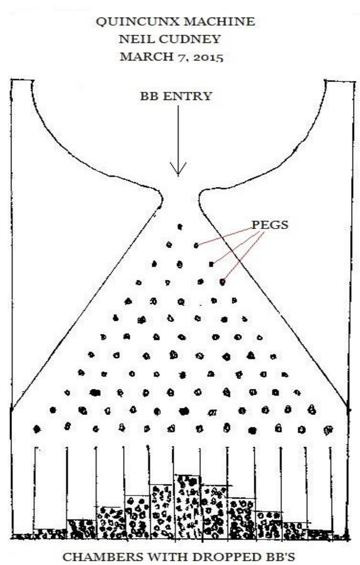

Figure 333433-63-63-63-6: The quincunx machine shows that dropped bb's are more likely to land in center chambers than in side chambers (Pierce, 2014).

4.83.7 Skee Drop

The Skee Drop probability machine is an idea we came up with in our brainstorming session. The Skee Drop is a modified version of the arcade game as you can see in the figure. The bottom part of the machine has holes for the balls to drop into and resembles Pascal's Triangle as well as the bell curve. The machine works by first dropping the balls into the top container that pivots in a full rotational motion (as shown in the figure). Once the ball falls out of the first container it then falls into the larger container that is filled with pegs to alter the drop path of the ball several times to prevent the same drop path of any two balls or more happening often. Once the balls drop through the larger container filled with pegs, it they will fall onto the skee ball platform. In the figure, it shows an example of what the platform looks like. Unlike in the figure, the platform will be laid/set at a slight angle. Therefore,so that when the balls hit the platform, they will roll down into one of the skee ball holes, creating a trend in the middle which is similar to the bell curve. This alternative solution demonstrates probability to the students because of the formation of the bell curve once the balls reach a destined hole. The students will be able to drop the balls into the container and control which direction the balls will shoot out from the pivot head into the container. The construction materials will be clear acrylic.

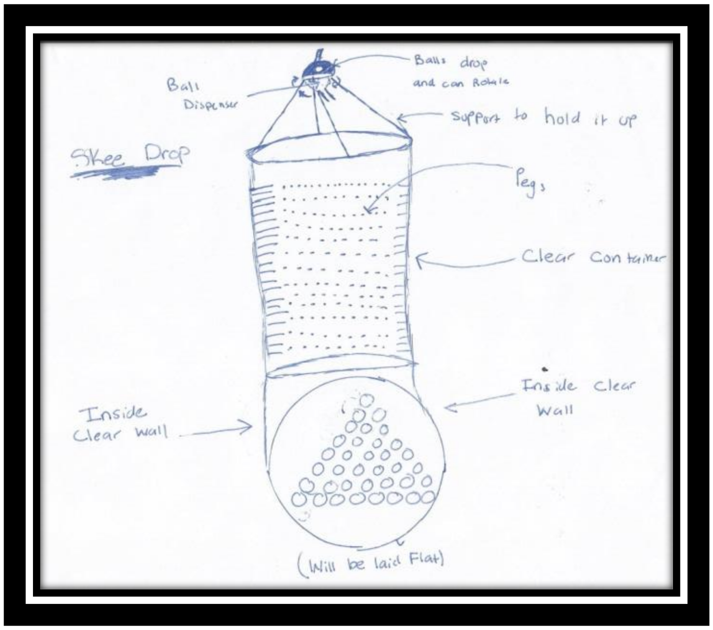

Figure 3536~~33-7~~3-7~~3-7~~3-7 The Skee Drop machine shows how balls will be dropped from the pivotal head onto the slanted ramp, hitting the pegs, and rolling into the Skee ball holes creating The Bell Curve on the other side.

~~5~~4 ~~Descision~~Decision Process

The alternative solution that GID has decided to use for the project is determined by the Delphi matrix.~~ which~~ The Delphi Matrix is used to select the solution from our client criteria. We took into account the criteria as well as other things that could possibly be utilized in our alternative solutions. The alternative solution selected reflects the client's criteria the best.~~In our decision process we calculated out the numbers and the quincunx machine came out to be the clear winner. The quincunx machine is the model we will be using in our project. The quincunx met all criteria requirements the best out of all other alternative solutions.~~

4.1 Criteria Definitions

The criteria definitions help to determine the decision of which solution will best meet our client's needs. The definitions give more detail and direction to what the intent of the criteria is. More information about the criteria can be found in section 3.2.11 of the document.

Safety- Must meet district safety codes. The machine is able to be used improperly and still be safe.

Educational Value- The ability to visually teach students how probability works to 6th-8th graders.

Ease of Interaction- The machine should be simple so children can interact with it. No specialty tools should be needed when using the machine.

Durability- Withstands ~~ware~~wear and tear from children for an extended period of time as well as functionality. Should be resistant to scratches in order to preserve the visual integrity.

Aesthetic- The ability to attract and keep the attention of 6th-8th graders. Supports school spirit by including school colors.

Portability- The ability to be easily moved by a single adult and easily fits through doorways.

Ease of Implantation- This can be described as the ability to fit through a doorway and to be moved by one or two people.

~~**Safety-** Must meet district safety codes. Cannot harm the students in anyway, even if used improperly.~~

Cost- Defined as being able to keep the price of the machine affordable.

~~5.1~~4.2 Solutions

This section posts the different possible alternative solutions from section 3. More specific information about the machine can be found in section 3 of the document.

Centrifugal Machine

Air Mix Lottery Machine

Distributer Machine

Lottery Launcher

Quincunx

Skee Drop

~~5.2~~4.3 Decision process

In order to select which alternative solution would be implemented, ~~A~~all of the alternative solutions from section 3 w~~h~~ere entered into a Delphi matrix. Each of the alternatives were~~as~~ rated on a scale of 1 to 10, 10 being the most important and 1 the least important, for each of the criteria. This score ~~is~~was then multiplied by the weight of the criteria. Criteria and weights can be found in detail in section 2.3. All of the scores from each criteria were added up for each of the alternative solutions and the solution with the most total points was selected. ~~possible~~

Table 1: Delphi matrix outlining the merits of each of the alternative solutions.

Criteria	Weight	Centrufugal Machine	Air mix Lottery Machine	Distributer Machine	Lottery Launcher	Quincunx	Ski-drop
Educational Value	10	8 / 80	5 / 50	8 / 80	5 / 50	9 / 90	4 / 40
Safety	10	8 / 80	10 / 100	8 / 80	7 / 70	10 / 100	7 / 70
Ease of Implementation	8	9 / 72	6 / 48	9 / 72	7 / 56	6 / 48	9 / 72
Durability	8	5 / 40	8 / 64	5 / 40	8 / 64	9 / 72	5 / 40
Aesthetics	6	9 / 54	9 / 54	7 / 42	10 / 60	9 / 54	9 / 54
Portability	4	5 / 20	9 / 36	6 / 24	8 / 32	10 / 40	3 / 12
Cost	3	3 / 9	8 / 24	3 / 9	8 / 24	6 / 18	3 / 9
Totals		355	376	347	356	422	297

4.4 Final solution

The final solution that was chosen by the Delphi matrix was the quincunx as seen in table 1 with the highest overall score. It had the highest score in the Delphi matrix because it is simple, durable and, most importantly, it can be used to teach multiple different probability lessons using various equations and principles of probability. And with safety being a top priority, the quincunx has the smallest risk of injuring children.

5 Design Specification

5.1 Introduction

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The specifications for a product are essential for its final design. The most common listed specifications include: the description of a solution, design costs, implementation costs, maintenance costs, instructions for implementation, how the model is used, and how the model will be maintained. These specifications can describe the final design. Testing the final design of the quincunx probability machine probability machine demonstrates how pascals triangle creates a bell curve.

5.2 Design description

The quincunx machine is a rectangular box that is five feet tall, three feet wide and one and a half inches in depth as seen in figure 37. There is a hopper at the top of the machine which feeds the balls into the center. The bottom foot of the machine is a drop chute that collects the balls by running them down a ramp to the side of the machine. The quincunx machine is made primarily from 1/8 inch aluminum sheet and ½ inch diameter aluminum round stock. The back board, chute and legs are all constructed from 1/8 aluminum sheet while the pins that are used to redirect the balls are made of ½ inch diameter aluminum round stock. The viewing area of the machine will have a face plate constructed from ¼ inch Plexiglas that wraps around the side of the machine.

Figure 37 AutoCad drawing of the quincunx machine. By Eli Wallach

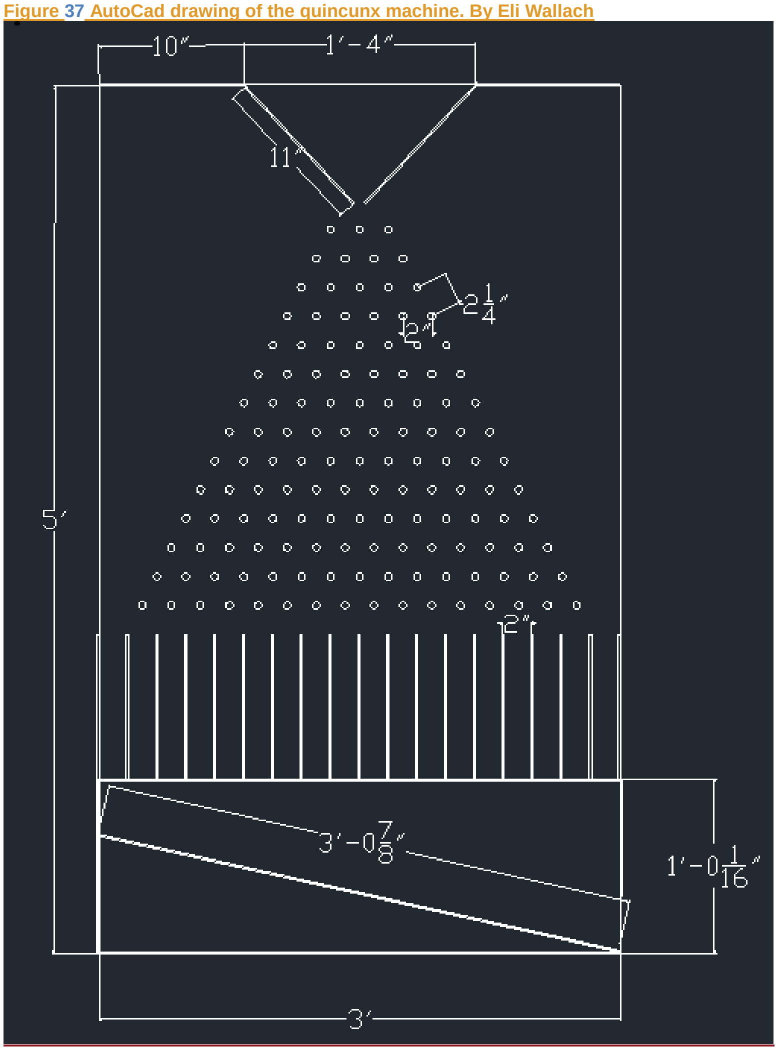

Figure 38: Picture of quincunx after painting

5.3 Costs

5.3.1 Design Cost

The design costs specify the amount of hours GID spent on each section of the probability machine. A total of 59.7 hours were spent on planning and building the probability machine. Figure 5.13.21 illustrates the distribution of hours spent throughout each section.

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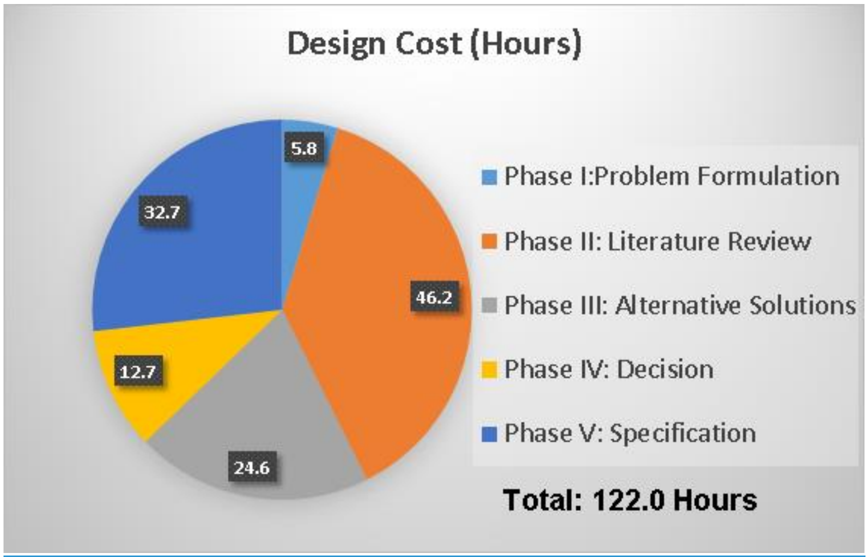

Figure 395-5-1: The design cost in hours.

5.3.2 5-1Implementation Cost

Figure 5.2 shows the costs of the materials that were needed to build the quincunx machine. The total amount of money spent on these materials is $150.99. Some of these materials were donated but the most expensive material was the acrylic sheet. The aluminum rods were purchased as a 12' round instead if individual 3/2" rounds to save money.

Implementation Cost		
Item	Quantity	Price
Aluminum Sheet 15' X 5'X 1/8"	1	Donated
Bouncy Balls	150	Donated
Acrylic Sheet 4' X 3' X 1/4"	1	$81.00
Aluminum Round 1/2" X 12'	2	$30.00
Acrylic Glue	1	$9.99
Paint	3	$30.00
	Total:	$150.99

Figure 4055-25-25-25-2: Cost of materials for the quincunx machine.

5.3.3 Maintenance Cost

Maintenance of Since the quincunx machine should be minimal since it is made mostly made from using durable aluminum which is a light weight and durable metal,., the cost of maintenance should be very small. The maintenance required only costs about 20 minutes of man power per month. Maintenance also requires a damp cloth and Philips screw driver.

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5.4 Instructions for Implementation

5.4.1 Location

5 The Quincunx machine williswill be located at Zane Elementary School, specifically in Mr. Pinkerton's class room. The device will be standplacedstand on the ground standing upright. When not in use, with two twenty-two inch feet running perpendicular to the machine will be leaned upright against a wall.for balance.

5.4.2 Instructions

If desired the balls can be left in the machine with the shape of the curve. If not, or one want to use the machine is to be used again locate the handle there is a drawer that on the frontcan be pulled out of the machine at the bottom of the bell curve. This drawer is located at the bottom of the acrylic where the balls are resting which is labeled 3 on figure 46. Make sure when the drawer is pulled out that somethingthe side latch is ready to catch the balls as they roll out of the collection chute which is labeled 4 on figure 46. After the balls are collected,closed properly. Collect the balls again and repeat the process can be repeated.or leave the balls in the bottom of the machine.

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Figure 41: 1: Loading hopper, 2: Aluminum pins, 3: Balls fall into chambers to form bell curve, 4: Collection chute.

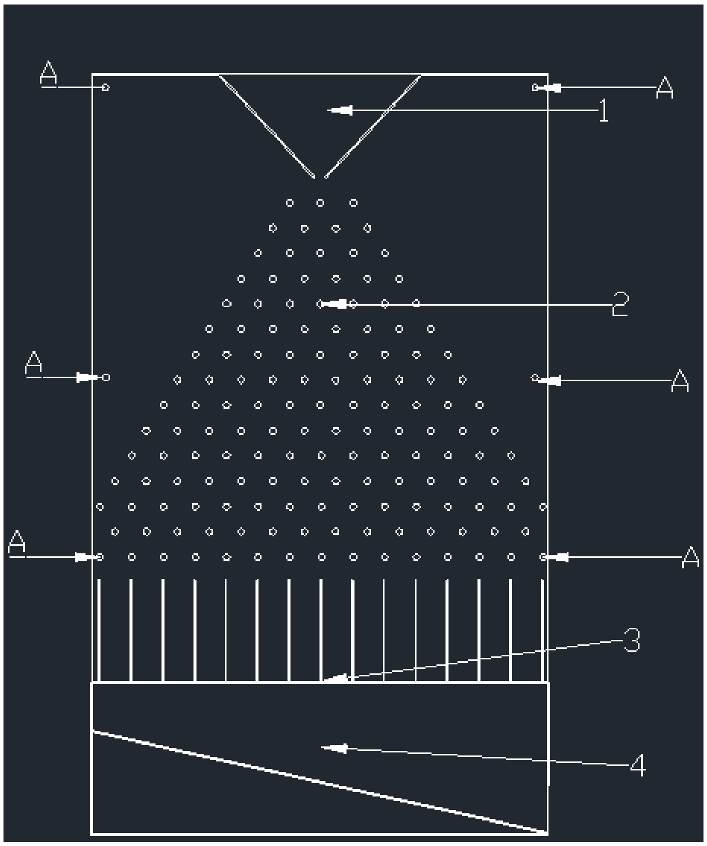

Figure 42: A: location of bolts to remove acrylic

Cleaning the machine requires a Philips screw.driver. There are six bolts that must be removed in order to take the acrylic panel off of the aluminum. Which are labeled A in the above figure, figure 47. The ~~There are six~~ bolts are located on the outer edges of the acrylic, as seen in figure. When taking the bolts off make sure enough pressure is kept on the acrylic so it does not fall. Once the bolts are off, carefully remove the acrylic and gently place it upright lying against a wall or another flat surface. Take a damp cloth and wipe down the inside of the machine to remove any dirt, dust or any other unwanted substance. Once the machine is clean the acrylic can be placed back onto the frame and carefully bolted back into position. Any residue that accumulates on the outside of the machine should be wiped down with a damp cloth whenever desirable.

5.5 ResultsResultsReesults

The quincunx probability machine creates the bell curve using bouncy balls that students place in the hopper. To simulate this, balls were tested and used from a downsized prototype of the probability machine. Given examination, the bouncy balls have a fifty percent chance of bouncing in either direction (left or right) after hitting a pin. The continuous fifty percent chance of the balls falling from one side of a pin to the other side pin keeps the probability curve from getting skewed and keeps the predictions held to its assumed outcome. Having more balls also keeps the curve from being skewed which is why we chose to use 250 bouncy balls.

76 References

(Unknown) "Roulette" *12 games of chance* <http://www.math.uah.edu/stat/games/Roulette.html> (February 21, 2015)

California State Board of Education. (2014). "Content Standards" Current Standards <http://www.cde.gov/be/st/ss> (May 3, 2015)

Cardinal Glass Industries. (2011). Architectural Glass Guide, Troy, Michigan.

Dan Reed "How the Game Works" *Dan's Pachinko Data Page* <*http://faculty.ccp.edu/faculty/dreed/Campingart/pachinko/*> *(February 22, 2015)*

Davenport, S. (2007). Designing With Laminated Glass, St. Louis, Missouri.

Isaac, Richard. Ewing, J.H., Gehring, F.W., Halmos, P.R. (1995). The Pleasures of Probability. Springer-Verlag. New York. Cars, Goats, and Sample Spaces. 2.

Joseph Hilsenrath, and Bruce F. Field(1983) "The Mathematics Teacher", Vol. 76, No. 8, 571-573

Karim Nice "How Lotteries Work" *How stuff works*<*http://entertainment.howstuffworks.com/lottery3.htm*> *(February 22, 2015)*

Kaysons. (Unknown). Physical Properties of Acrylic Sheets, (Unknown)

Killian, Rodney C., and Kepner, Henry S. (1976). "Pascal's Triangle and the Binomial Probability Distribution." *Pasc Trig Bino Prob.* 69(7). 561-563.

McGervey, John D. (1986). Probabilities in Everyday Life. Nelson-Hall. Chicago. Principles and Propositions. 1-6.

McGervey, John D. (1986). Probabilities in Everyday Life. Nelson-Hall. Chicago. Statistics. 16.

N. Chernov, and D. Dolgopyat "Journal of the American Mathematical Society", Vol22, No.3, 821-858

S.N. Ethier,(1982) “Journal of the American Statistical Association”, Vol. 77, No. 379, 660-665

(UK) . (Uk). “What is acrylic.” Google, <http://www.google.com> (Feb. 22, 2015).

(UK) . (Uk). “What is glass”.” Google, <http://www.google.com> (Feb. 22, 2015).

(Unkown) .(2008). “Glass vs. Acrylic Comparison.” Evonik Industries, <http://www.acrylite.net> (Feb. 22, 2015)

/www.biblecharts.org/teachersandteaching/Methods%20for%20Teaching%20Middle%20Schoolers%20_6-8.pdf

(Unknown) .(2014). “Library” Teaching Methods, <http://serc.carleton.edu/20966> (February 24, 2015)

(Eureka City Schools) .(2015) “Zane Home” Eureka City Schools, <http://www.eurekacityschools.org> (February 24, 2015)

(Unknown) .(Unknown). “Methods for Teaching Middle Schoolers - Bible Charts” Google, <http://google.com>