EDSGN 100

Design Project #1

FINAL REPORT

Electric Toothbrush Redesign

Introduction to Engineering Design
EDSGN 100 Sec 024

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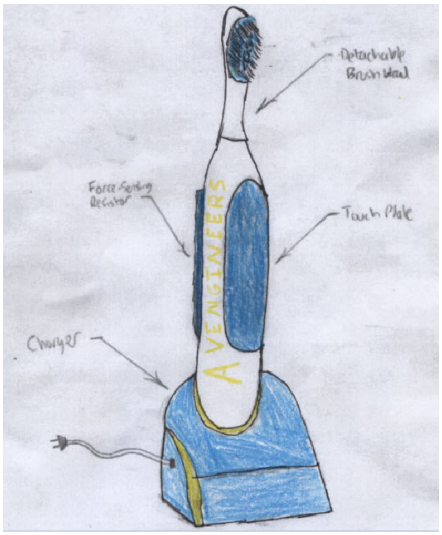

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Executive Summary

The ultimate goal of this project was to redesign an electric toothbrush. In this case, the toothbrush we were tasked with redesigning was the Oral B Kids' Ironman Spinbrush. During the redesign process, which is laid out below from the problem statement to the final design, we changed our target customers from young children to adolescents (ages 18-23) and designed a toothbrush that tailors to their needs and situations. Our final design was a toothbrush that is both economical and innovative. The end result is a toothbrush that meets both the financial and functional needs of the average college student.

Electric Toothbrush Redesign

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1.0 Introduction

The problem addressed was the redesigning of an electric toothbrush (in this case the Oral B Kids' Spinpbrush). Section 1 explains how we tore down the cheap disposable electric toothbrush, noting any lacking of good design. Section 2 details the gathering of information from potential customers. They told us what they wanted, and it was then up to us to figure out how they would receive what they wanted. Section 3 describes our pre-concept generation external search. We first gathered information on how other people solved the problem. This benchmarking set us heading the right direction. We then generated ideas and narrowed them down based on the importance of the customers' needs, which is explained in detail in section 4 . Once we saw which ideas would be most practical and efficient, we made a detailed analysis on what technology would be implemented, and how much it would cost, which can be found in section 5. In section 6, we have a finalized product, and a solution to the initial problem of having a toothbrush that consumers did not want. Section 7 consists of a conclusion of the project.

1.1 Problem Statement

Reverse engineer and redesign an electric toothbrush, following the design process and utilizing the strategies discussed in class.

1.2 Mission Statement

Our mission is to design a toothbrush that is reusable, effective, and appealing to teens.

2.0 Customer Needs Assessment

Without a target audience, the design process can be aimless and unproductive. After all, the ultimate goal of design engineering is to create a product or process that meets or exceeds the customers' needs and expectations. It is for this reason that the collection of customer needs is a vital piece of the design process. Although our initial target audience was young children since they were the target audience of our initial toothbrush, we soon realized that we could gather far more customer needs if we changed our market to adolescents since we are in a town with tens of thousands of students between the ages of eighteen and twenty two. Thus, all of the people whom we interviewed or placed in our focus group (five of Jake's roommates) for customer needs were in college, attending Penn State University. In

order to gain customer needs, we asked our roommates, classmates, and other peers what they look for in a toothbrush. We asked them what factors went into the decision to buy toothbrushes that they have bought in the past, and how their current place in life (as college students) might affect that decision in the future.

Questions asked during interviews and in the focus group:

1. What kind of things do you expect in a toothbrush?
2. What kind of things/features do you wish were in your toothbrush?
3. What factors go into your decision to buy a toothbrush?
4. Do you think your taste in toothbrushes has/will change?

2.1 Results of Customer Needs Collection

After asking customers what they look for in electric toothbrushes, we organized their responses in a list, with no ranking, listed in no particular order. We then tallied the number of times each need was mentioned by customers, and placed the six most commonly-mentioned needs at the top of our hierarchy of customer needs. This allowed us to focus on certain aspects of our toothbrush, giving us the kind of direction that is necessary for a design project.

Table 1. Initial Customer Needs List Obtained from Interviews/Focus Group

Personal (some sort of customization)
Good battery life
Easy to turn on and off
Cool-looking
Cheap
Water-resistant
Easy to clean
Effectively brushes teeth
Feels good to hold, substantial
Large head, many bristles
Doesn’t make a lot of noise
Doesn’t turn off after certain amount of time
Rechargeable
Long enough neck to reach molars in back of mouth
Won’t break after being dropped
Has protective case
Spinning of head doesn’t feel substantially slower once i

contact with teeth Neck doesn't bend when pressure is applied Toothpaste inside brush Attachable floss head Reusable (Replaceable head) Multiple spinning pieces on brush head

Table 2. Hierarchal Customer Needs List Obtained from Interviews/Focus Group

1. Cheap 2. Brush head spinning doesn't slow down 3. Quiet 4. Easy to turn on and off 5. Reusable (replaceable head) 6. Feels good to hold, substantial

These were the six most-mentioned customer needs for electric toothbrushes of college students. It makes sense that price of the toothbrush was repeatedly one of the first things that people mentioned, since many college students are on a tight budget and are not willing to spend a lot of money on a toothbrush. For this reason, we decided to make an electric toothbrush with a replaceable head because this is the most economical choice. Rather than buying a brand new toothbrush every month or so, customers will only need to buy a new brush head every month.

3.0 Pre-Concept-Generation External Search

This part of the project involves looking at the competition in order to gain insight into the many ways of solving the problem at hand (designing an electric toothbrush). It is by doing this that we understand the more general context of the toothbrush market, so that we may have tangible targets and expectations that should be met.

3.1 Product Teardown/Dissection

Product teardown is the process by which a person or team gains an understanding of a product by taking it apart.This means that while tearing a product down, measurement, observation, and analysis are paramount at every step. In our teardown, we measured various physical characteristics of the different components of the toothbrush and analyzed the ways in which these components worked together in order to make the toothbrush work. By doing this, we gained an understanding of how the

toothbrush works. This, in turn, was the first step that allowed for innovation.

3.2 Results of Teardown

By carefully breaking down our toothbrush, we gained many measurements of its capabilities and innate qualities (See Appendix A for details of all of the measurements taken during the teardown process). In terms of the overall system, our toothbrush was very simple. The major components were the motor, the battery, and the brush head. Only one battery was needed to supply electrical energy to the simple circuit, which in turn powered the oscillating brush head. The on/off button is on the front of the toothbrush. The brush is turned on by pushing the button up and off by pushing the button down.

3.3 Benchmarking

In this part of the process, we used the quantifiable measurements that relate to our most important customer needs. We examined our competition's toothbrushes in order to understand the kind of standards which we must uphold when designing our toothbrush. The quantifiable, objective measurements we felt were most related to our customer needs were: noise level (addresses quiet customer need), the percent increase in current under load against current under no load (addresses consistent brush speed customer need), and the price of each toothbrush (addresses cheap customer need). Our team's initial toothbrush data is in bold print in the table below.

3.3.1 Benchmarking

	Average noise level (dB)	% increase in current under load vs. current under no load	Price ($)
Team 1	70.4	45	12.97
Team 2	69.4	1662	6.79
Team 3	73.6	30	5.00
Team 4	**69.2**	**5.1**	**5.00**
Team 5	60.0	82	9.00
Team 6	71.4	56	6.99
Team 7	70.0	32	5.99
Team 8	30.1	168	8.49

3.3.2 Target Specifications

This quantitative benchmarking combined with the House of Quality (see Appendix A), which benchmarked both quantifiable and qualifiable aspects of the toothbrushes of our competition against our own toothbrush, allowed us to set target specifications. In the House of Quality we used, we only benchmarked against the four competitors that we felt used sufficient qualitative description in their reports. This allowed us to rank the toothbrushes, creating a working hierarchy, so that we understand where in the hierarchy our given toothbrush stood. Based off of this, we set these target specifications:

	Ideal	Marginally Acceptable
Location of on/off switch	touch sensor on front	button near thumb
Ergonomic hand grip	30 OO Shore rubber	25-35 OO Shore rubber
Noise level	60 dB or less	69.2 dB
Price to manufacture	$7.00	$8.00
% increase in current under load against current under no load	Variable current depending on user's actions	70%
Reusability	Replaceable brush head	N/A

Perhaps the most noticeable aspect of the target specifications is that our marginally acceptable target noise level for the toothbrush is the same as the noise level of the current toothbrush. We decided that it was not completely necessary for us to create a quieter toothbrush (which would likely involve a new motor) at the detriment to affordability. Furthermore, our toothbrush was originally slightly quieter than most of the competition's toothbrushes.

4.0 Internal Search and Concept Selection

4.1 Concept Generation

In order to generate concepts, the main strategy we used was Rolestorming, in which one looks at a problem from the perspectives of multiple types of people. Our three main roles were:

1. College student that buys absolute cheapest products- this student would use a simple selection process, only looking at the one-time price of each toothbrush.
2. College student that thinks about overall cost- this student would consider both the current purchase in front of them, along with their future toothbrush purchases. They think in both the short-term and long-term with concern to cost.
3. College student using parents' money- this student will look for a quality electric

toothbrush that will clean their teeth well, and will likely have a higher price threshold than other college students.

From these roles, we generated five concepts that addressed our most important customer needs. From the first role, we generated a very cheap, reusable Avengers electric toothbrush, which would be similar to our given Ironman toothbrush, but would allow people to choose a toothbrush head dedicated to their favorite of their Avengers (Ironman, Captain America, etc.). While this design is not exciting and technologically advanced, it would be very cheap, which might be the only thing that goes into some college students' decisions. From the second role, we generated an electric toothbrush that comes with a recharging dock. Although this would be a more expensive one-time purchase, the student would only need to replace the brush head about once a month after the initial purchase. From the third role, we were able to get more creative. With a higher budget, we generated multiple concepts. First, we came up with an idea for a toothbrush with touch sensor activation. This would be a big improvement from our initial toothbrush, whose on/off button was not in an ideal place for the hand. Next, we came up with a concept for a toothbrush in which the user would be able to control how fast the bristles of the brush head move based on how hard they squeezed the toothbrush. This is referred to as our "Spring" idea in our selection matrix because we were initially thinking that a spring would be used in order to measure the pressure imparted by the user (the spring was later replaced by a force-sensing resistor, as discussed in Section 5.1.2). Lastly, we came up with an idea to have an ultraviolet light (sometimes referred to as a "black light"). Ultraviolet lights are known to illuminate materials, which could be useful when a person is brushing their teeth. The light would be able to virtually show a person where they still need to brush because if there are patches of teeth that still have plaque, the ultraviolet light would reveal it.

4.2 Initial Evaluation

After the customers needs had been specified, we weighted the needs based on importance. We then rated each idea against these needs, thus giving each concept a score. The weights yielded the products that we intuitively expected to have the best results.

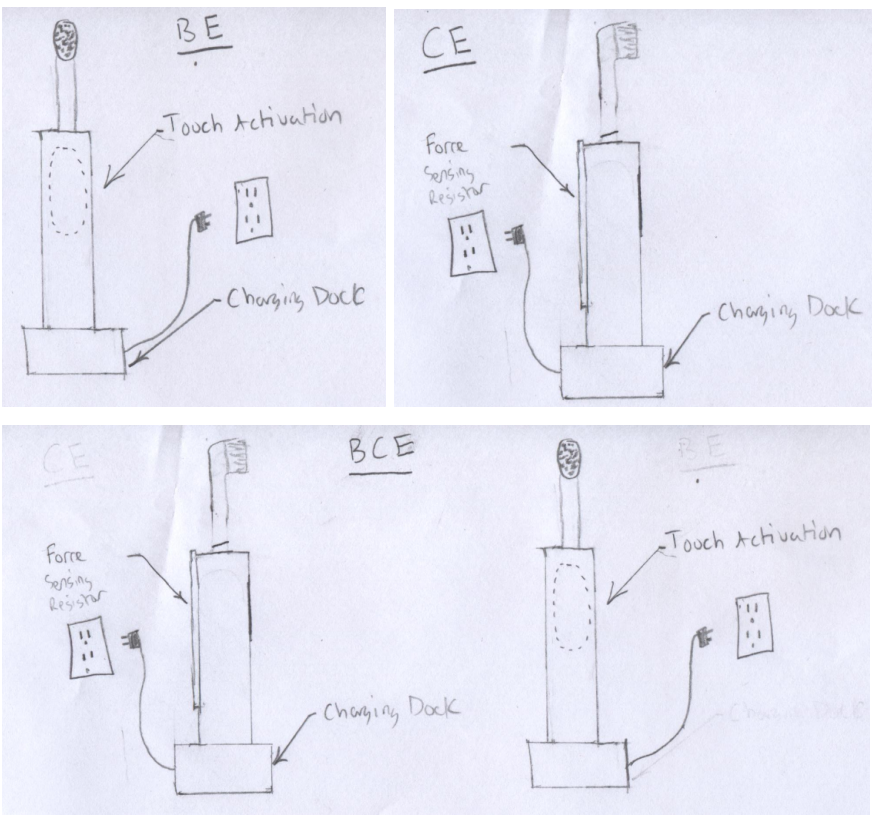
4.2.1 Concept Selection Matrix

		A		B		C		D		E	
		Avengers		Sensor		Spring		Blacklight		Charging Dock	
	%	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Steady Spin	20	2	0.4	3	0.6	5	1	3	0.6	3	0.6
Easy Access Switch	15	2	0.3	5	0.75	3	0.45	3	0.45	3	0.45
Ergonomic Grip	10	3	0.3	3	0.3	3	0.3	3	0.3	3	0.3
Quiet	20	2	0.4	3	0.6	2	0.4	3	0.6	3	0.6
Cheap	20	4	0.8	3	0.6	3	0.6	3	0.6	1	0.2
Reusable	15	3	0.45	0	0	0	0	0	0	5	0.75
Total	Total		2.65		2.85		2.75		2.55		2.9
Continue?	Continue	no		combine		combine		no		combine	

4.2.2 Combined Concepts

Rather than keeping our highest rated idea, we decided to combine our concepts into concepts BE, CE, and BCE.

4.2.3 Sketches of Three New Concepts



4.3 Second Evaluation

We took our three new concepts and weighed them against each other using the same scale.

4.3.1 Second Concept Selection Matrix

		BCE		BE		CE	
		Sensor, Spring, Charge		Sensor, Charge		Spring, Charge	
	%	Score	Weighted	Score	Weighted	Score	Weighted
Steady Spin	20	4	0.8	3	0.6	3	0.6
Easy Access Switch	15	4	0.6	3	0.45	4	0.6
Ergonomic Grip	10	3	0.3	3	0.3	3	0.3
Quiet	20	3	0.6	2	0.4	2	0.4
Cheap	20	2	0.4	2	0.4	2	0.4
Reusable	15	5	0.75	5	0.75	5	0.75
Total	Total		3.45		2.9		3.05
Continue?	Continue	Yes		No		No	

4.4 Final Selection

We decided to go with the highest scoring option, BCE. This is the best design, as it has two desirable features that are not commonly found in toothbrushes.

5.0 Post-Concept-Selection External Search

With our product concept selected, the next step involved finding out what kind of technology would go into our toothbrush, and if the technology was achievable. The external research process provided us with a realistic limit as to what our product is capable of.

5.1 Literature Review

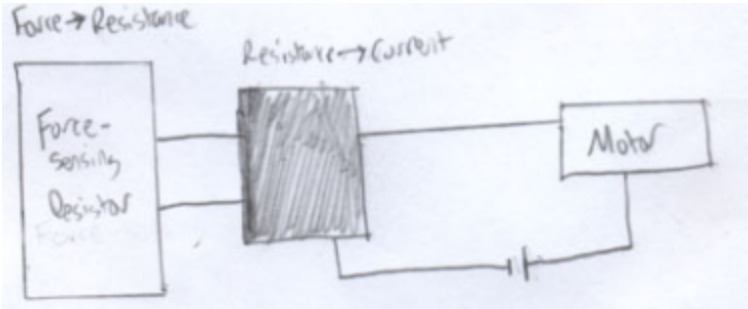
5.1.1 Rubber Research

Our product is designed to have a comfortable grip. We decided that a durometer hardness of 30 Shore OO rubber would achieve this goal. For a reference point of relativity, 30 Shore OO hardness lies somewhere between chewing gum and a racquet ball on the hardness scale. McMaster.com was used for durometer hardness ratings.

5.1.2 Force Sensing Resistor Research

The goal of adjustable spin speed can be accomplished through the utilization of a force sensing resistor. The resistor converts force into resistance, which is used to generate current. This extra current will power the toothbrush while under load. The user simply has to squeeze the brush, which will activate the

force sensing resistor. The force sensing resistor is priced at under a dollar (in large quantities), according to pololu.com. Information on the function of the resistor was found on Wikipedia.



5.1.3 Touch Plate Technology Research

Our toothbrush is to use touch plate switch technology. This requires two components: a touch plate, and a current mirror. The idea of touch plate activation revolves around the concept that humans offer resistance. This means that the toothbrush will have an open circuit which will be completed by the user's thumb. A current mirror is required so that the user isn't shocked while completing the circuit. The current mirror "reflects" the circuit in a way that the circuit can be completed on one side, thus giving current to the other side. A touch plate is needed for activation. A simple touch plate would involve two plates with a conductive material coated on the inside of each plate, separated by a non conductive material such as silica. When the user presses the plate, the silica will separate such that the conductive plates touch, allowing the user to complete the circuit. Research on pololu.com provided us with information in regards to price, and these pieces are very cheap, at well under a dollar (if ordered in large quantity). Resources used for the circuit information are digikey.com and Wikipedia.

5.2 Patent Research

Most of our product features have already been patented.

Patents for Electric Toothbrush

FUNCTION	Patent
Touch activation device	WO 2012030908 A1
Adaptive load sensor on toothbrush	WO 1997000650 A1
Replaceable brush head for electric toothbrush	WO 2012038501 A1
Electric toothbrush and charger	EP 1314401 A1

Charging mechanism	CN 2696141 Y

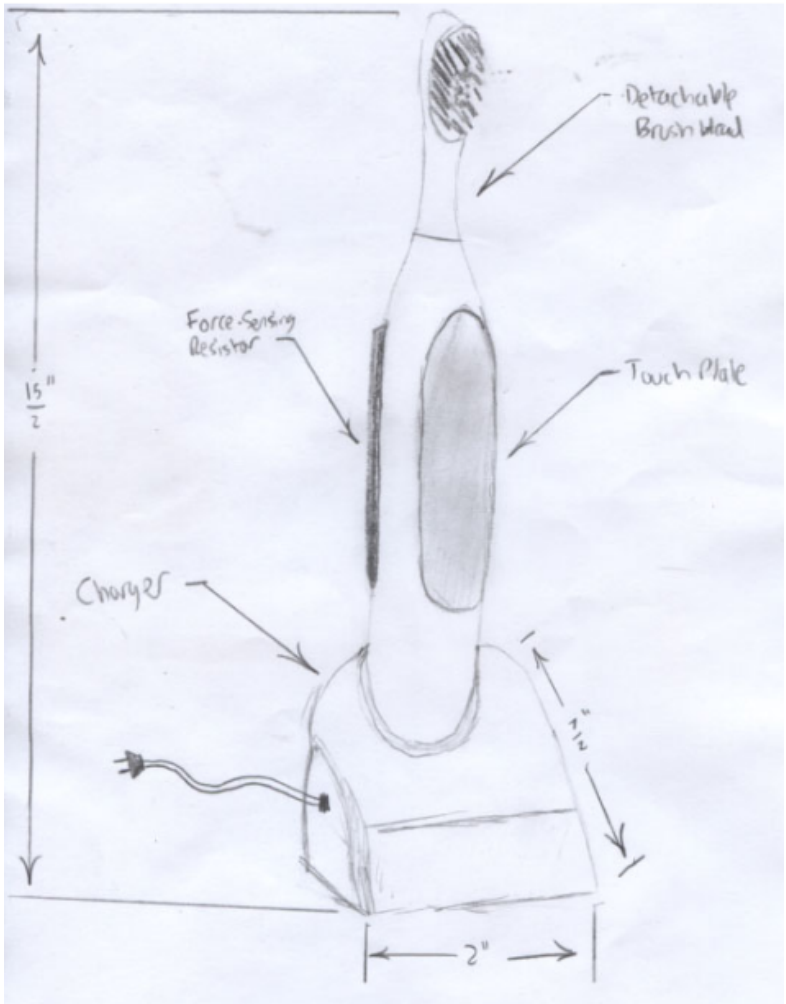
5.3 Global Issues

Americans are more willing to use discretionary income for aesthetically appealing products, rather than just functional ideas. Other places around the world such as China and Germany, are more inclined to buy a less expensive functional product without the “bells and whistles” with which many consumers in America are enamored. Furthermore, in developing countries in which poverty rates are high, there is less likelihood that they would be willing to spend a lot of money on a toothbrush. Furthermore, getting electricity to many citizens in developing countries, like The Congo and Haiti, can be a big task. Many of these countries do not have adequate access to energy (even if energy from their countries is used to supply energy to other countries). Without being able to recharge the toothbrush, it really is not a very economical option.

6.0 Final Design

6.1 Design Drawings and Parts List

Here is an isometric sketch of our final toothbrush.



Major parts are the brush head, which is mounted on top of the plastic body. On the back of the body is the force sensing resistor, and on the front of the body is the touch activation plate. The entire brush is held in the standing position by the charger. A detailed list of parts can be found below in the bill of materials.

6.2 Bill of materials

Part Number	Part Name	Qty	Function	Mass	Material	Dimensions (lxwxh)	Cost
1	plastic body	1	contains functioning parts, keeps water out	61.6 g	plastic	9/2x 3/2x 15/2	$0.18
2	touch plate	1	activates toothbrush when touched	10g	cheap metal/ conductive material/silica	2x1/2	<$0.50
3	force sensing resistor	1	converts force into resistance	.15g	various metals	3/10 x 3/10 x 3/200	<$0.50
4	charger	1	charges battery	200g	plastic/various materials	7/2x2.x1	$5.00
5	motor	1	spins brush head	40g	ferro-alloy	diameter-1/20 height- 1/2	$0.25
6	brush head	1	spins to clean teeth	20g	plastic	1/2x1/2/2	$1.00

6.3 How does it work?

The function of the brush is quite simple. The charger uses electricity from a wall socket to charge the toothbrush. When the toothbrush is picked up (when the touch plate is touched), the circuit is completed and the motor runs, thus spinning the brush head. When under load, the force sensing resistor in the back can be pressed for additional current, thus causing the brush to work harder.

7.0 Conclusions

Overall, our project was a success. It met the customer needs because it was engineered towards the needs specified by customers. We stayed true to our mission statement as well. It is reusable because it has a charger and replaceable brush heads. It is effective because it provides extra current under load. It is appealing to teens because it has touch activation technology, and teens desire products which implement more technology. It has unique features such as the increased spin power and touch activation, therefore it stands alone in the market. The product will be successful in the market, as it beats pricey competitors.

Referenced Websites

1. mcmaster.com (McMaster-Carr) used for durometer hardness ratings
2. alibaba.com used for parts pricing
3. pololu.com used for parts pricing
4. walmart.com used for parts pricing
5. Wikipedia used for information on force sensing resistors and touch activation technology
6. digikey.com for information on touch activation technology
7. learningaboutelectronics.com for information on touch activation technology