Water Distribution System

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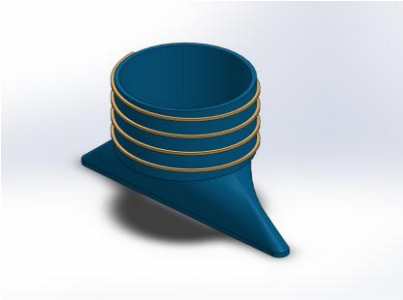

Engineering Design 100

Section 11

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Abstract

Siemens AG has approached Penn State University with the opportunity to make its campus more sustainable. University Park uses more than a billion gallons of water annually. This is enough to fill the bowl of Beaver Stadium ten times. With 14,500 students living on main campus, water consumption is a critical area to improve sustainability. Moreover, student water usage presents an opportunity to make the campus more environmentally friendly. This project looks to involve the average student in the process of water reduction. Sinks, showers and toilets are the main source of water consumption within residence halls. With this in mind, we seek to design a device that compels students to reduce their bathroom water usage. Our final design combats water wasted at the sink.

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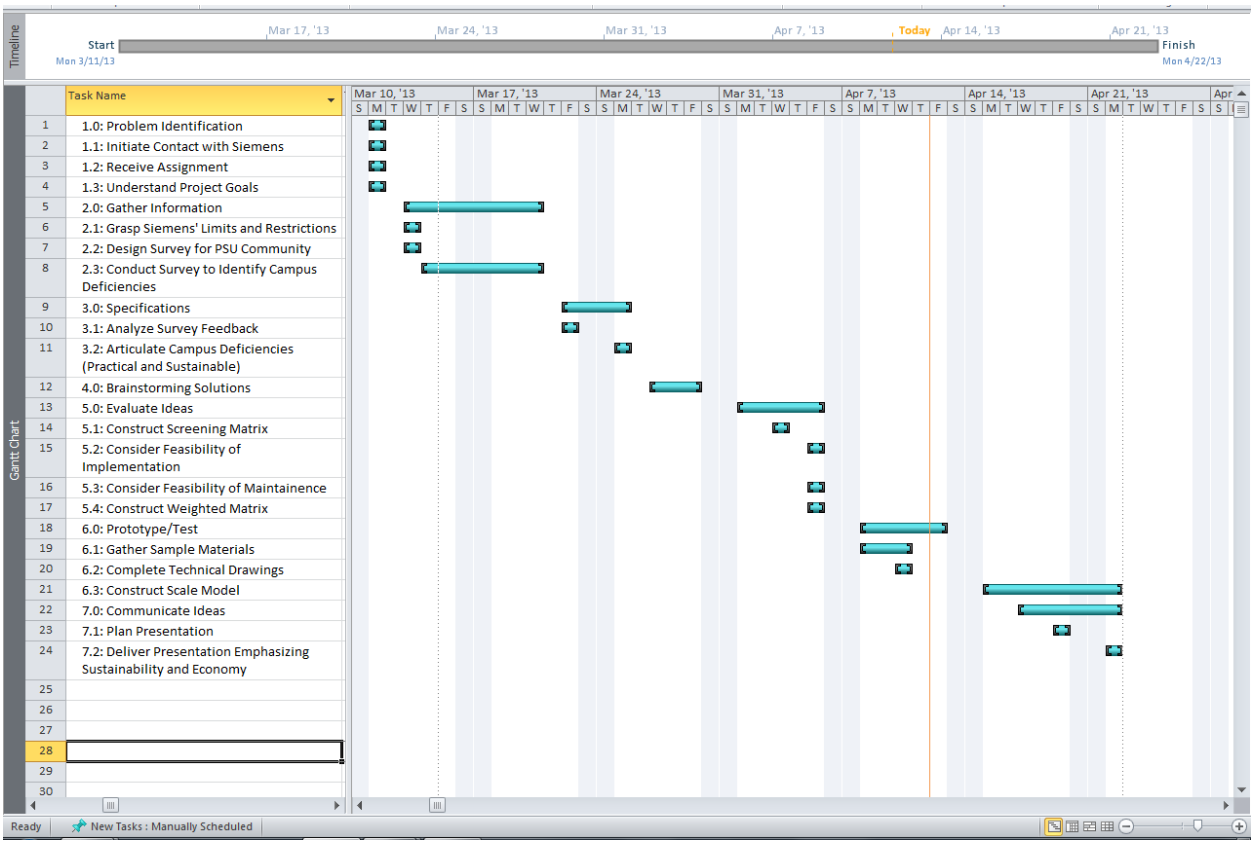
Introduction

Siemens AG is a global engineering company focusing on the fields of energy, industry, transportation and infrastructure. They have targeted Penn State University as the site for an innovative sustainability initiative. As part of a student engineering competition the firm has asked the University's EDSGN 100 students to conceptualize and design ideas to make the campus more sustainable. From the outset, this group defined a sustainable system as one that reduces the need for a natural resource; operates with little cost, maintenance and installation needs; is durable and requires little energy for operation; and yields consistent dividends toward making the structure more environmentally friendly. This group decided to investigate ways to reduce student water consumption on campus. Specifically, this group wanted to mitigate water usage in a typical Penn State dormitory. Since most of the water students use comes from bathrooms, it stands to reason that most water is also wasted there. The challenge became developing a device or system that altered wasteful human tendencies in the bathrooms. Additionally, the system needed to have a minimal impact on the users' experience using bathroom appliances. In short, the system could not be too intrusive. The system had to be low-cost, low-maintenance and easy to install. The system had to be made of durable materials that, over a long period of time, would not decline in performing its task. Finally, the system chosen to mitigate bathroom water waste needed to yield consistent results with little or no other harmful environmental effects.

Gantt Chart:



Concept of Operations

To make the project more manageable in scale, the group decided to focus on applying the solution to one specific location on campus. The group decided on Packer Hall in the East Halls residence area.

According to documents provided by the University's Office of Physical Plant, Packer Hall's 294 residents consume 315,000 gallons of water per month. A family of four uses

approximately 3,500 gallons per month. Packer's consumption is 90 times more water than a typical four-person family. According to the Portland Water Bureau, roughly fifteen percent of an American building's water consumption comes through faucets. In Packer, that means approximately 47,250 gallons per month pass through sinks. Meanwhile, the flow rate of water in a typical Packer sink was measured at .0157 gallons/sec. Through online surveys of college students, the group's research indicated that the typical individual washes his or her hands 4.5 times per day for roughly 30 seconds (see Appendix). The product of these two figures, the flow rate and the typical number of days per month yield a theoretical monthly water need at Packer's sinks (see calculations in Appendix). These figures would indicate that only 18,700 gallons per month (approx.) were required to wash the hands of Packer's residents. While a variety of factors may contribute to the 28,533 gallon-per-month delta in Packer's water consumption, it stands to reason that much of this water is simply wasted on, perhaps, bathroom surfaces instead of being put to use exclusively for typical sink functions.

Concept Development: Brainstorming and Evaluation

When considering Siemens' challenge, a decision had to be made about which aspect of campus energy consumption could be streamlined. The group had to consider both its definition for sustainability and its members' interests. A list was developed of possible themes for the project:

- Streamlining the campus transportation system to reduce human waste
- Reducing electricity consumption in dormitories

- Improving the treatment of waste water at specific campus location
- Mitigating water consumption in dorms

Based on interests and perceived effectiveness group efforts could have, the group decided to move forward in the design process by brainstorming ways to tackle the fourth theme above.

From there, group members collectively brainstormed ideas for strategies and systems that could be implemented to lessen the amount of water wasted in dorms. The first idea the group conceived was one that involved low-tech implementation. The University could sponsor competitions among dorms that are supervised by R.A.'s and other dorm leaders. At the end of each month, a prize would be given to the residents in the dormitory with the lowest water consumption per resident. The group reasoned that a competition like this would incentivize efficient water use -- the less water used, the less water wasted. The notion of a "marketing campaign and competition" has draw backs. Among them, the group found that participation and motivation in the campaign are not guaranteed. Moreover, the process was thought to lack a compelling force to make residents use less water.

The group proceeded to brainstorm a firmer solution. After a pre-programmed time allotment, the faucet or shower would mechanically shut off. Yet again, the group reasoned that when water supply is cut off in a finite time period, less water will be used, and less water will be wasted. This idea, unlike the first, would force resident to use less water. While one could see how this would make dorms more efficient, implementing it is both impractical and unpleasant for students. While most students use a sink, for example, for a relatively short and prescribed

time to wash hands, sinks do have other uses that would require longer, sustained activation of the faucet -- like washing dishes.

The group moved forward with brainstorming. The University-provided identification cards for each student are widely used. Their usefulness could be expanded into the resident hall bathrooms. An electronic swipe system could be installed at sinks and showers that would track each individual's water usage. To use a sink or shower each resident would have to swipe his or her card, and his or her consumption would be monitored. Room and board costs would cover a prescribed amount of water per student per semester. Each unit of water a student used over that amount would be billed to the student's bursar at the conclusion of each semester -- analogous to overage minutes on a mobile phone plan. The group reasoned, however, that the primary drawback to a system like this would be in social perception. It is widely believed that university students nationwide already pay far too much for their education and related costs. To "nickel-and-dime" students on their water use would be a disincentive for prospective students to attend Penn State.

Along the lines of dissuading the human compulsion to waste water, the group thought of ways to make running the faucet or shower for too long an unpleasant experience. One way was having the bathroom lights shut off automatically after a shower or sink was left on for too long. Another idea was installing noise-makers in the bathrooms to be activated for the same reason. The group also thought, however, that both of these ideas would make bathroom usage far too unpleasant for students -- something certainly worthy of avoiding.

The final idea the group conceived involved mechanically altering water flow out of a sink faucet. The group reasoned that the primary function of sinks in dormitories is washing

hands. The group thought that, perhaps, a device could be created that optimized water flow specifically for hand-washing. This device would be attached to the existing faucet head and would be inexpensive. The device's primary function would be to pan water in a wider, linear trajectory as it exits the faucet. This would allow water to make more contact with the hands in a shorter amount of time than conventional sinks. The group reasoned that when less time is needed to wash hands, less water will be used, and less water will be wasted. Continuing the brainstorming process, the group thought to couple this low-tech attachment with a monitoring device at each faucet.

For user-based research, the group drafted and published a survey online through SurveyMonkey. The survey asked specific questions about water usage habits in the bathroom, and it garnered numerous responses. While the responses were anonymous, they came from group members' Facebook friends, the vast majority of whom are college students at Penn State or other American universities.

The Pairwise Comparison found in the Appendix indicates that the group prioritized the following attributes of each idea in the following descending order: cost, practicality/ease of use, efficiency, durability, ease of implementation and manufacturing ease. From there, the weighted matrix and screening matrix quantify the group's otherwise qualitative evaluation process of each idea. The group reasoned that the faucet attachment would be the best idea of the ones considered. This is because the idea would be the most feasible, socially acceptable and likely to produce the best results toward reducing wasted water.

Concept Development: Water Spreader

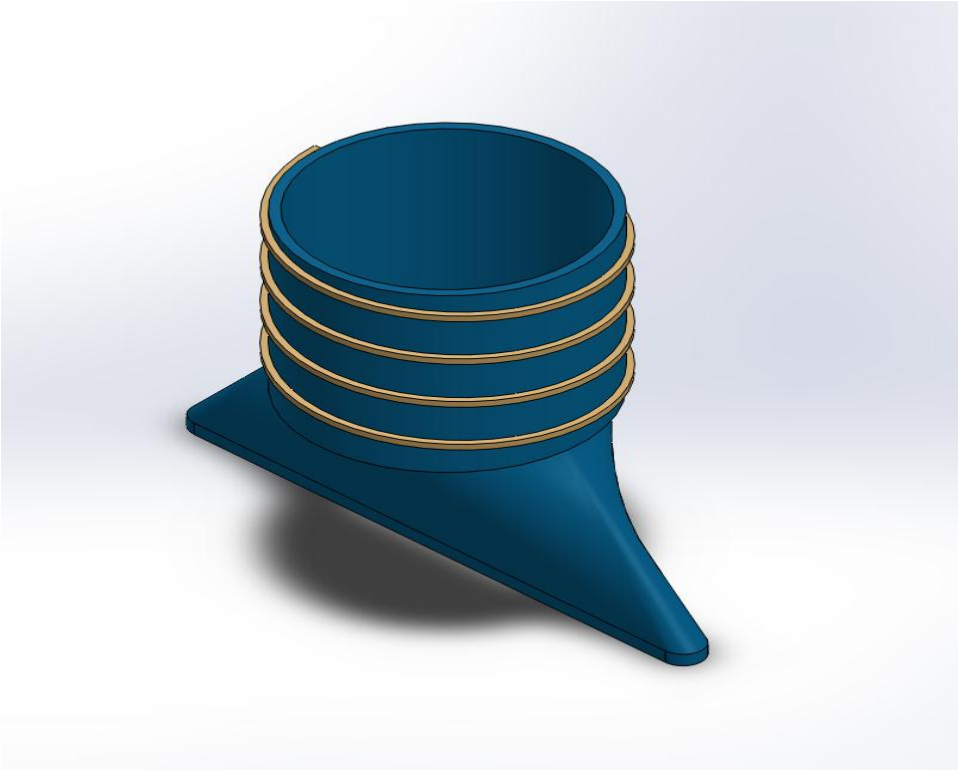
To make the project more manageable in scale, the group decided to focus on applying the solution to one specific location on campus. The group decided on Packer Hall in the East Halls residence area.

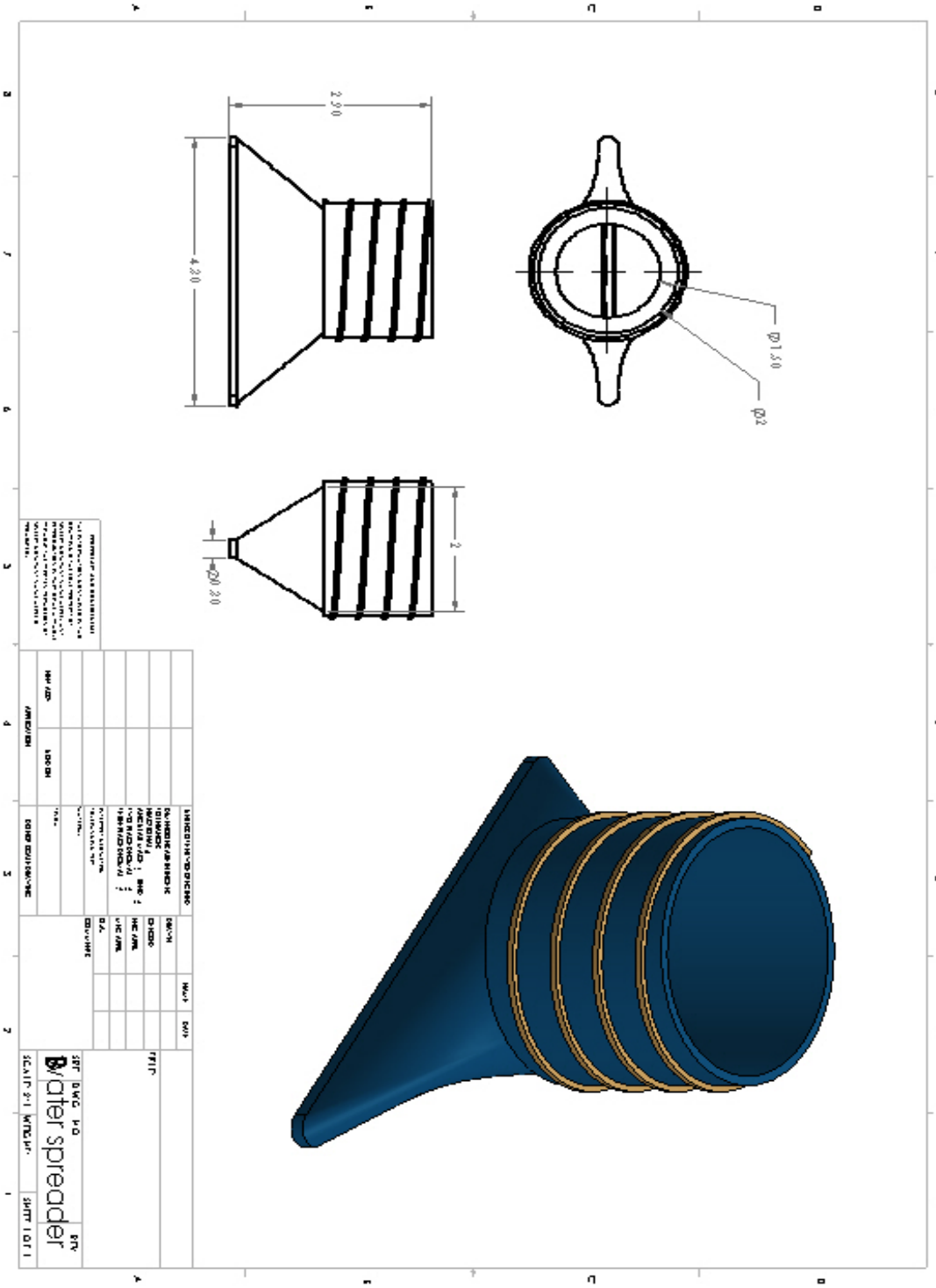
According to documents provided by the University's Office of Physical Plant, Packer Hall's 294 residents consume 315,000 gallons of water in a given month. According to Portland Water Bureau in Oregon, roughly fifteen percent of an American building's water consumption comes through faucets. In Packer, that means approximately 47,250 gallons per month pass through sinks. Meanwhile, the flow rate of water in a typical Packer sink is .0157 gallons/sec. Through online surveys of college students, the group's research indicated that the typical individual washes his or her hands 4.5 times per day for roughly 30 seconds. These figures would indicate that only 18,717 gallons per month were required to wash the hands of Packer's residents. While a variety of factors may contribute to the greater need for water at Packer's sinks, it stands to reason that much of this water is simply wasted on bathroom surfaces instead of being put to use exclusively for typical sink functions. The goal quickly became designing a faucet application that helped eliminate the 28,533 gallons of wasted Packer water per month.

The group started designing the faucet prototype by measuring the generic faucet dimensions in Packer. The dimensions became the basis for any dimensions of the final prototype. As had been conceived prior, the group envisioned an attachment that would redirect water flow along a linear path as it fell into the sink bowl. This contrasts with the typical circular design of a faucet. The group projects this will mitigate considerably the amount of water wasted through ineffective sink flow paths and relatively long periods spent washing hands.

The materials used for the attachment would be non-toxic, safe and inexpensive. The body of the attachment would be plastic, and the portion connecting to the existing faucet would be rubber. Based on current raw materials prices, the group projected raw materials for an individual unit would cost 30 cents. Ultimately, ancillary costs and a business' requisite profit margin would pump the price per unit up to approximately $2. At the current per-gallon price of water, the group projects installation and use of these attachments would save the University approximately $42.80 per month in Packer Hall alone. (This figure is based on the national average water cost at $1.50/1000 gallon). With 60 faucets in Packer, the cost to purchase the attachments would be more than accounted for after just three months of saving over $40 on the water bill.

Renderings and Dimensioned Sketches of Prototype:




Ø1.50
Ø2
2.90
4.20
2
Ø0.20
Water spreader

Conclusion:

With a specific goal of eliminating the over 28,000 gallon-per-month misuse of sink water in Packer Hall, the group conceived a design of a faucet application to redirect water flow in the sink. This device would optimize water flow for hand-washing. In turn, it would help reduce the time an individual needs to wash hands, resulting in a reduction in water consumption. Of all the brainstorming ideas considered by the group, the water-spreading faucet applicator proved to meet each of the group's design principles -- cast, durability, manufacturing ease, efficiency, ease of implementation, practicality/ease of use -- best. The group recommends this prototype design be developed, tested and implemented in Packer Hall, with the long-term plan of implementing it in restrooms and bathroom campus-wide.

Appendix:

Pairwise Comparisons

	A	**B**	**C**	**D**	**E**	**F**	**Row Totals**	**Row Totals/Total**
A	1	4	3	5	6	3	22	0.34
B	1/4	1	2	4	5	2	14.25	0.22
C	1/3	1/2	1	4	3	2	10.83	0.17
D	1/5	1/4	1/4	1	4	3	8.70	0.13
E	1/6	1/5	1/3	1/4	1	4	5.95	0.09
	1/3	1/2	1/2	1/3	1/4	1	2.92	0.05
						Total	**64.65**	

A – Cost

B – Practicality / Ease of Use

C – Efficiency

D – Durability

E – Ease of Implementation

F – Manufacturing Ease

Weighed Matrix:

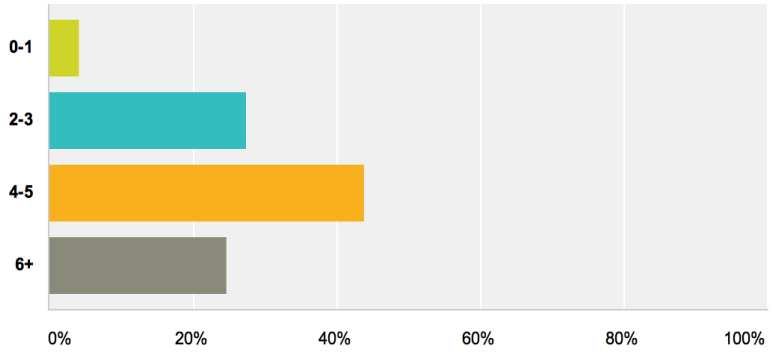
		Concepts											
		Competition/Marketing Campaign		Water Timing System		ID Audit System		Water Spreading Device		Electricity Blackout Plan		Flow monitoring System	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Cost	34%	4	1.36	2	0.68	3	1.02	4	1.36	3	1.02	2	0.68
Durability	13%	2	0.26	3	0.39	3	0.39	4	0.52	3	0.39	4	0.52
Manufacturing Ease	5%	4	0.2	2	0.1	2	0.1	3	0.15	3	0.15	3	0.15
Efficiency	17%	2	0.34	3	0.51	3	0.51	4	0.68	3	0.51	4	0.68
Ease of Implementation	9%	3	0.27	2	0.18	2	0.18	5	0.45	2	0.18	3	0.27
Practicality/ Ease of Use	22%	2	0.44	2	0.44	2	0.44	5	1.1	2	0.44	4	0.88
Total Score		2.87		2.3		2.64		4.25		2.69		3.18	
Rank		3rd		6th		5th		1st		4th		2nd	

Screening Matrix:

		Concept Variants					
Selection Criteria		Competition/ Marketing Campaign	Water Timing System	ID Audit System	Water Spreading Device	Electricity Blackout Plan	Flow Monitoring system
Cost		+	0	+	+	0	-
Durability		0	0	0	+	0	+
Manufacturing Ease		+	-	-	+	-	-
Effectiveness		-	+	+	+	+	+
Portability		+	-	-	+	-	+
Practicality / Ease of Use		-	-	-	+	-	+
	Pluses	3	1	2	6	1	4
	Neutrals	1	2	1	0	2	0
	Minuses	2	3	3	0	3	2
	Net Score	1	-2	-1	6	-2	2
	Rank	3rd	6th	4th	1st	5th	2nd
	Continue?	no	no	no	yes	no	yes

In a typical day, about how many times do you wash your hands?

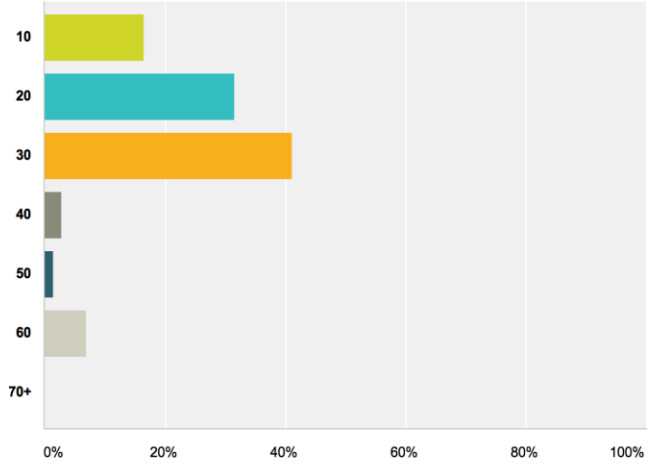
Answered: 73 Skipped: 0



Answer Choices	Responses	
0-1	**4.11%**	3
2-3	**27.40%**	20
4-5	**43.84%**	32
6+	**24.66%**	18
Total		73

What do you believe is the ideal amount of time to wash your hands (in seconds)?

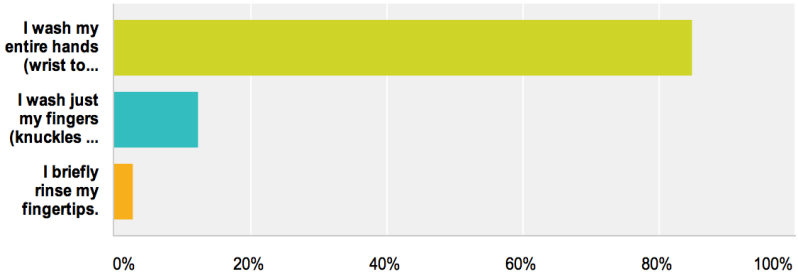
Answered: 73 Skipped: 0



Answer Choices	Responses	
10	**16.44%**	12
20	**31.51%**	23
30	**41.10%**	30
40	**2.74%**	2
50	**1.37%**	1
60	**6.85%**	5
70+	**0%**	0
Total		73

How thoroughly do you wash your hands?

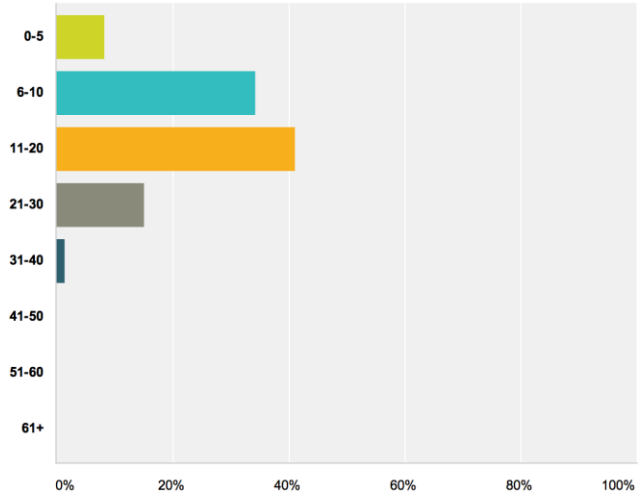
Answered: 73 Skipped: 0



Answer Choices	Responses	
I wash my entire hands (wrist to fingertips).	84.93%	62
I wash just my fingers (knuckles to fingertips).	12.33%	9
I briefly rinse my fingertips.	2.74%	2
Total		73

When you wash your hands how long do you take (in seconds)?

Answered: 73 Skipped: 0



Answer Choices	Responses	
0-5	8.22%	6
6-10	34.25%	25
11-20	41.10%	30
21-30	15.07%	11
31-40	1.37%	1
41-50	0%	0
51-60	0%	0

RESEARCH APPLICATION

- By applying this data, the ideal amount of faucet use is 18,717 gallons per month:
  - (4.5 hand washes per day)*(30 sec per wash)*(0.0157 gallons per second)*(294 packer inhabitants)*(30 days in a month)= 18,717 gal/month
- Consumption of water at the sink accounts for approximately 15% of the total water used in Packer
  - ((315,000 gal)x(0.15)) – (18,717 theoretical gal. used)= 28,533 gallons excess!
- The goal of our design will be to eliminate the 28,533 gallons that are wasted