WHAT CAN WE LEARN FROM STUDENT PORTFOLIOS? CURIOSITY MACHINE STUDENT DESIGN ANALYSIS

Richard Jung and Tara Chklovski, 2017

Curiosity Machine is a family focused, hands-on engineering design program in which the whole family comes together to learn about a specific application of a physics or engineering concept, and then works to apply that principle in a hands-on design challenge that uses very simple materials, such as cardboard, pipe cleaners, straws etc.

To an outsider, who may visualize sophisticated equipment and kits when thinking about nanotechnology, ocean engineering, aerospace or robotics, it often feels incongruous to see families learning about concepts from these fields using materials found around one's house. Our goal through Curiosity Machine is to help children and parents develop design thinking skills, creativity, curiosity, persistence and a sense of self-efficacy as an innovator. Our hypothesis is that these traits can be developed using very simple materials if the challenge is thoughtfully articulated.

Over the past two years, we have been looking at examples of student work through the learning process—diagrams of plans, photographs of initial prototypes and redesigns and reflections on the learning—with the aim to identify mile-markers or clear signposts of learning.

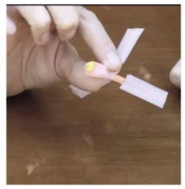
2015-2016

Our first big data set was from Schmitt Elementary school in Columbus, Indiana, which we worked at in partnership with Cummins. Ms. Carrie Green led 400 3rd–6th grade students who collectively

completed nearly 3,000 design challenges (such as the ones below), supported by the online Curiosity Machine interface. A total of 40 online mentors and 31 in-person mentors invested in over 300 hours to direct mentorship.

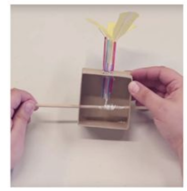
Balance a Dino

Build a Glider



Disperse Seeds Far & Wide

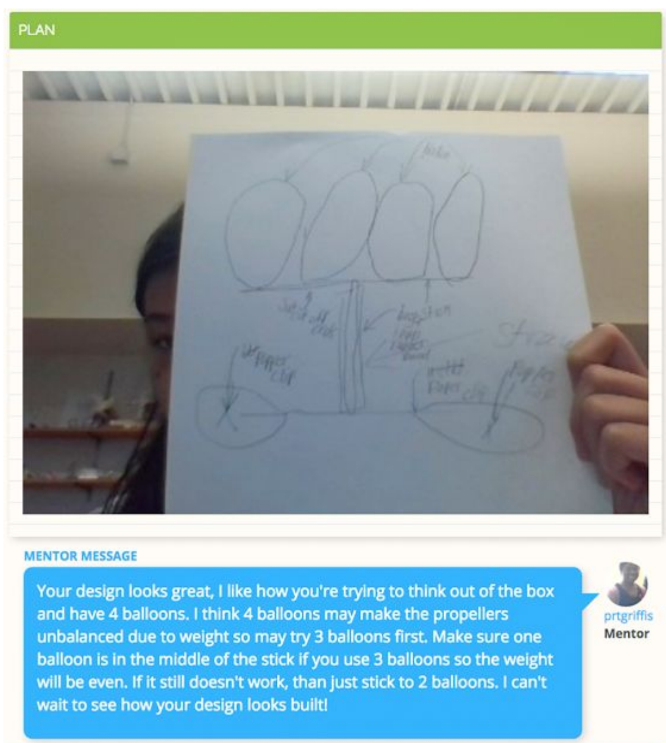
Engineer a Balloon Helicopter



Build a Blooming Flower

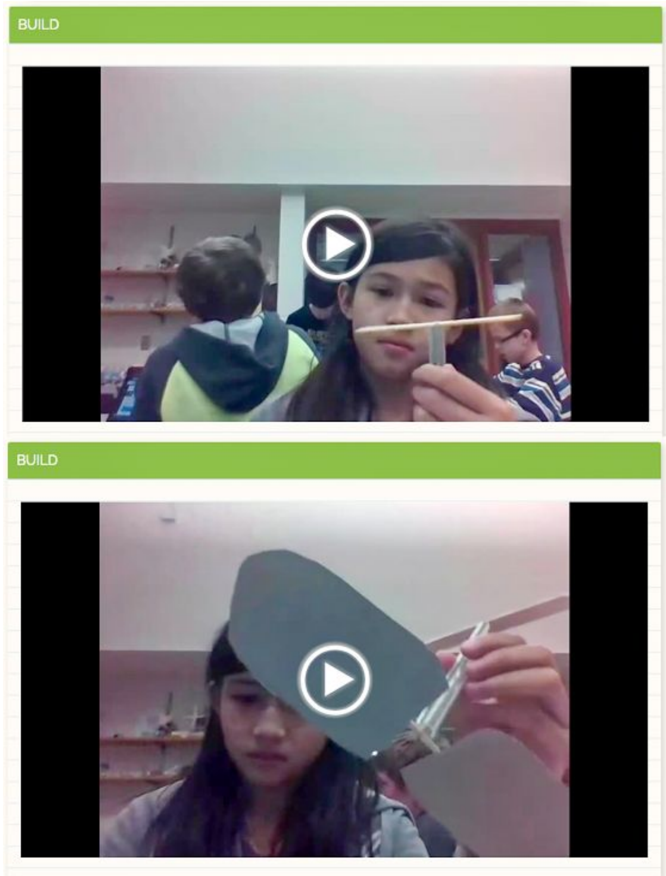
Build a Stomp Rocket

- **Students submitted 1312 design challenges onto the online Curiosity Machine interface.**
- **~65% of students watched an inspiration video on the online Curiosity Machine platform and/or planned their model.**
- **~20% completed the “Build” stage**
- **~15% completed the “Test” stage**
- **1% of students attained the Reflection stage**

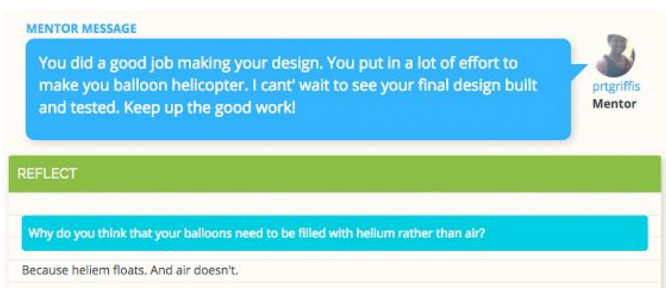


A student shares a plan for the Engineer a Balloon Helicopter design challenge, and receives a response from their mentor with

specific suggestions for improvement and encouragement.



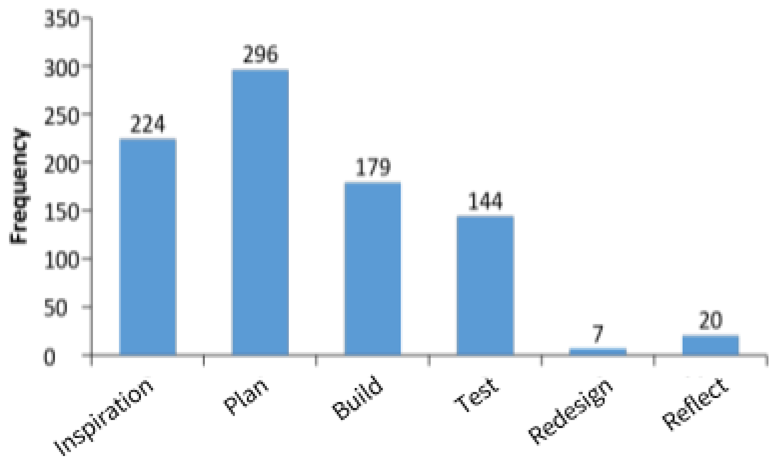
The student shares progress on building the propeller for the design and testing how well it spins before and after adding blades.



The mentor offers additional encouragement and asks to see the final design. The student does not submit a final design online, but does complete the reflection question.

Below is a graph showing the number of students submitting responses on the various stages of the design process (across all the design challenges that were taught at Schmitt): 1) watching the inspiration video; 2) Planning; 3) Building; 4) Testing; 5) Redesigning and 6) Reflecting

Cummins : Schmitt Highest Level of Attainment



Below is an analysis of the depth of engagement for each design challenge. Red signifies a high frequency or that a large number of students completed that stage and blue signifies a low frequency.

	Depth of Engagement							
	Insp. Video	Plan	Build	Test	Redesign	Reflection		
Type of Design Challenge	0	1	2	3	4	5	% of Students	Cumulative
Build a Blooming Flower	26	82	24	15		6	21.22	21.22
Build a Glider	17	68	45	13	2	2	20.39	41.61
Build a Stomp Rocket	76	27	21	22		1	20.39	62.00
Balance a Dinosaur	17	42	20	46	1	1	17.61	79.61
Disperse Seeds Far and Wide	39	28	18	9	1		13.18	92.79
Engineer a Redwood Tree	16	8	1				3.47	96.26
Build a Helicopter	4	4	2	1	1		1.66	97.92
Build a Cantilever	2						0.28	98.20
Build a Plane Powered by Stored Energy	1		1				0.28	98.47

Build a Self-Powered Rocket		2					0.28	98.75
Create a Circuit to Light an LED	2						0.28	99.03
Build a Mighty Machine	1						0.14	99.17
Engineer a Landing Device	1						0.14	99.31
Hack a Box	1						0.14	99.45
Invent a Bio-Bot	1						0.14	99.58
Make a Mechanical Stegosaurus Tail	1						0.14	99.72
Make a Pine Cone	1						0.14	99.86
Make a Signal Horn	1						0.14	100.00
% of Students	28.71	36.20	18.31	14.70	0.69	1.39		
Cumulative	28.71	64.91	83.22	97.92	98.61	100.00		

What students were learning through the design challenges

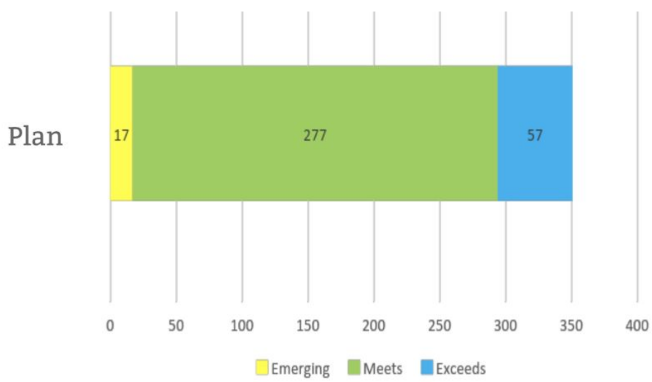
Design Challenge	Concepts	Reflection Questions
Balance a Dinosaur	Balance, center of mass center of gravity, counterbalance (counterweight)	How could you change your design to be twice as tall and st stand upright? If you made the dinosaur's head twice as large, how could y make sure it could still stand upright? (Hint: where will you have to plac the counterbalance?) How do you think you could change your design to be able t stand on 1 foot?
Robotic Arm	Robots, automation, force (action-reaction), bending moment	What type of "grabbing" mechanism did you use to make su the objects don't move away when your robotic arm touche them? What object was the hardest to move and why do you think that is? How did your robotic arm work for all three objects?
Lightweight Wing Structure	Reinforcing structures, load (weight), material strength & characteristics, failure deflection	How did you combine or arrange the materials to form a strong structure? What type of inner structure did you create to make your design even stronger? What materials can you use to make your wing even lighter
Build a Glider	Lift, glide, angle of attack, drag, gliding, wing, fuselage, tail, gravity, Newton's first law, balance, aspect ratio	How did you improve your glider to make it fly farther? Did either of your designs have curved wings that act like ar airfoil? Do you think this make your design fly farther? What would happen if you changed your glider's angle of attack? What would happen if the glider's wings were angle lower in the front than in the back? Why do you think so?
Powered Airplane	Energy, potential & kinetic energy, Newton's laws of motion, lift, thrust, balance, aspect ratio	How does your plane store energy? How can you make your plane store more energy? How can you change the design of your plane so it can fly farther and in a straighter path?

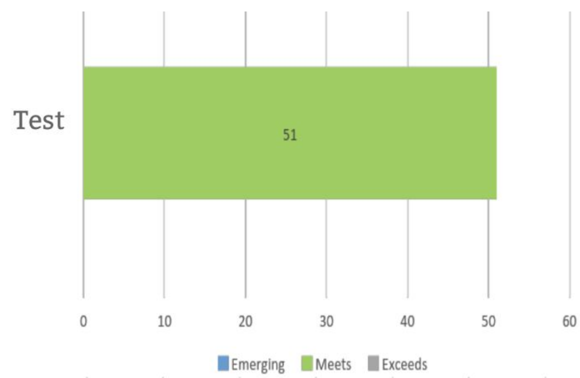
Each student's project was reviewed and scored with a simple rubric - emerging, meets expectations or exceeds expectations.

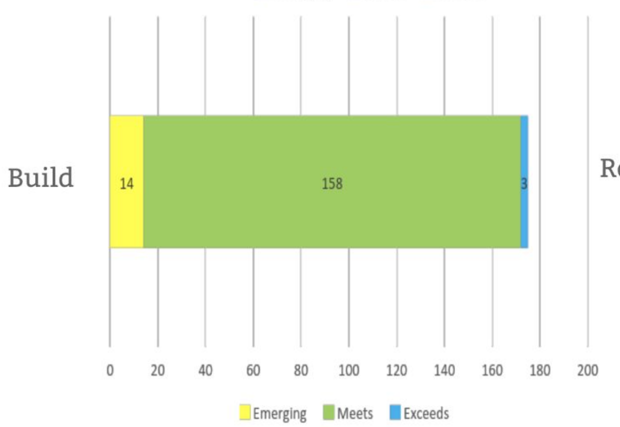
Student Dashboard

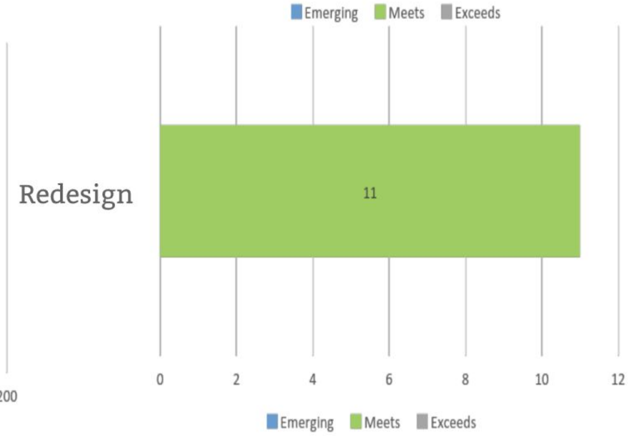
Emerging	Meets Expectations	Exceeds Expectations

student	DC	url	Plan	Build	Test	Redesign	Reflection	Ranking	Mentor Interactio	ghest Level Attain	Weighted Ranking	Last Date c
22abnerb	Balance a Dinosaur	https:/	x	x	x			3		3	3	01.21.16
22abnerb	Build a Glider	https:/	x	x	x			3		3	3	02.18.16
22abnerb	Engineer a Balloon Helicopter	https:/	x	x	x		x	4	2	5	4.7	04.16.16
22abnerb	Build a Blooming Flower	https:/	x					1	1	1	1	04.22.16
22abnerb	Build a Stomp Rocket	https:/	.	x	x			2		3	2.7	05.18.16
22abnerb	Disperse Seeds Far and Wide	https:/	.					0		0	0	
22abnerb	Create a Circuit to Light an LED	https:/	.					0		0	0	
22balle	Build a Glider	https:/	x					1		1	1	02.04.16
22balle	Engineer a Balloon Helicopter	https:/	x					1	1	1	1	04.04.16
22balle	Build a Blooming Flower	https:/	x					1		1	1	04.20.16
22balle	Build a Stomp Rocket	https:/	x	x	x			3		3	3	05.18.16
22batemanr	Build a Glider	https:/	x	x				2		2	2	02.18.16
22batemanr	Disperse Seeds Far and Wide	https:/	x					1		1	1	02.25.16
22batemanr	Engineer a Balloon Helicopter	https:/	x	x	x			3	3	3	3	04.13.16
22batemanr	Build a Blooming Flower	https:/	x	x	x			3	2	3	3	05.04.16
22batemanr	Build a Stomp Rocket	https:/	x	x				2	1	2	2	05.18.16
22batemanr	Balance a Dinosaur	https:/	.					0		0	0	
22baxleya	Balance a Dinosaur	https:/	x	x	x			3		3	3	01.21.16
22baxleya	Build a Glider	https:/	x	x				2		2	2	02.11.16
22baxleya	Engineer a Balloon Helicopter	https:/	x	x				2	1	2	2	04.06.16
22baxleya	Build a Blooming Flower	https:/	x	x	x			3	2	3	3	05.04.16
22baxleya	Build a Stomp Rocket	https:/	.	x	x			2		3	2.7	05.18.16
22baxleya	Build a Stomp Rocket	https:/	.					0		0	0	
22belloa	Balance a Dinosaur	https:/	x	x				2		2	2	01.29.16
22belloa	Build a Glider	https:/	x					1		1	1	02.05.16
22belloa	Disperse Seeds Far and Wide	https:/	x					1		1	1	02.26.16
22belloa	Engineer a Balloon Helicopter	https:/	x	x				2	2	2	2	04.07.16
22belloa	Build a Blooming Flower	https:/	x					1		1	1	04.21.16
22belloa	Build a Stomp Rocket	https:/	.					0		0	0	



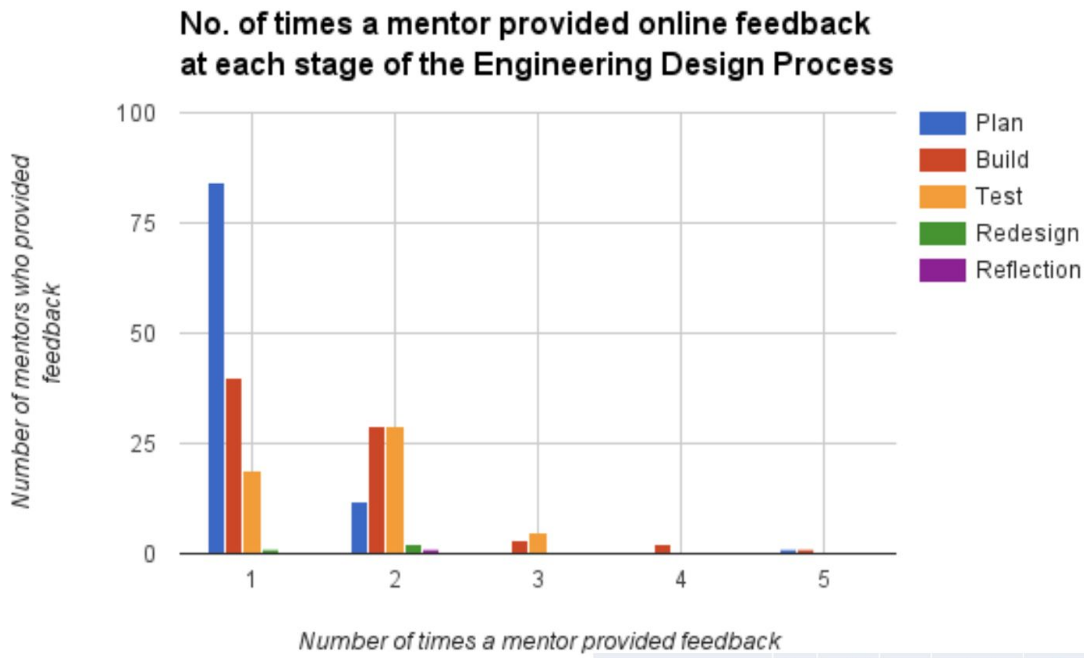






We also tried to determine if there was any connection between the number of times mentors

provided online feedback and the quality of the project. There were 57 "plan" submissions and only 3 student "build" submissions that exceeded expectations. Out of these, the mentor feedback instances were higher.



For Design Challenges with "Exceeds Expectations"

	Plan	Build	Test	Redesign	Reflection
No of mentor Interactions	2	5	2	0	0

2017

Following this analysis, we tried to evaluate students' projects with a better rubric of form, fit and function.

- **Form relates to physical parameters --size, shape, dimensions, mass, weight and other characteristics that distinguish or describe the design.**
- **Fit is how the components interface with each other to become an integral part of another design.**
- **Function is the action of the design/model that it was designed to perform.**

Students did not submit their projects online, but the teacher took polaroid photographs of the first build and attached it to their portfolio, which was subsequently scanned and sent back to Iridescent.

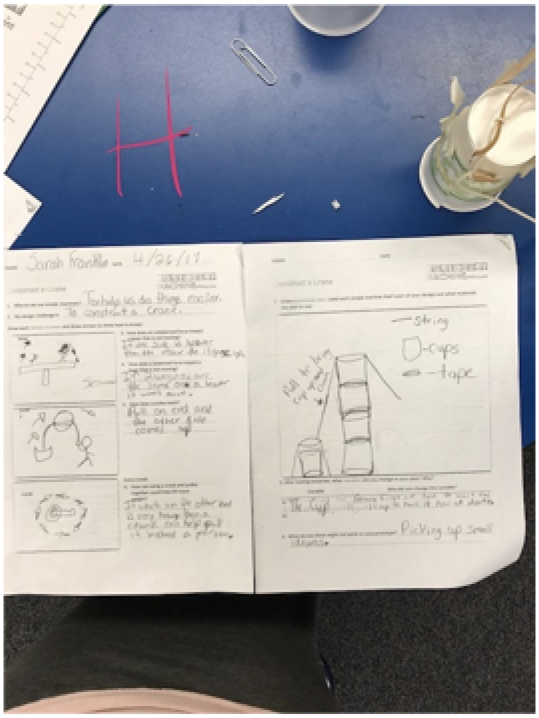
The photograph added significant information on the changes and modifications that occur from plan and design to actual build.

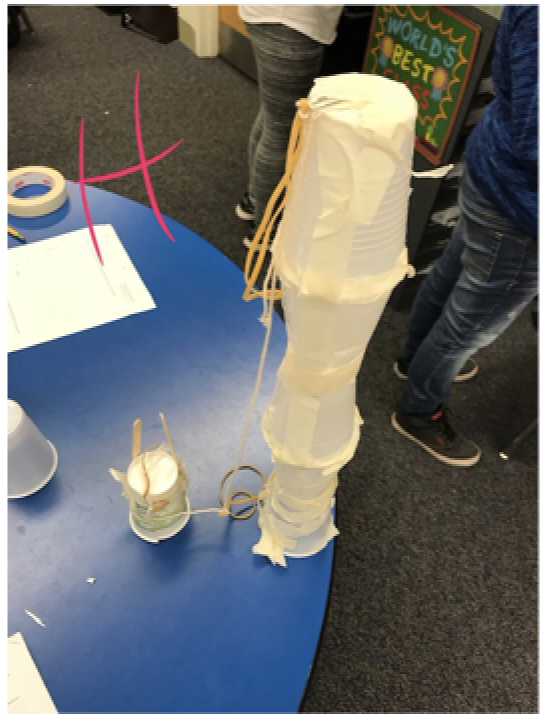
Of the design challenges "Construct a Crane" gave the most information. From the photographs, it was the easiest to see form, fit, and function. Photographs of other Design Challenges, such as the Robotic Face, did not easily show the mechanism on the backside of the face.

From ten submissions of the "Construct a Crane" design challenge, we saw an average of 2.9 changes made between plan to build (Range 1 to 4). These iterations included stabilization of the crane, modification of pulley system/lever, etc. These were all problems that would be normally encountered by practicing engineers.

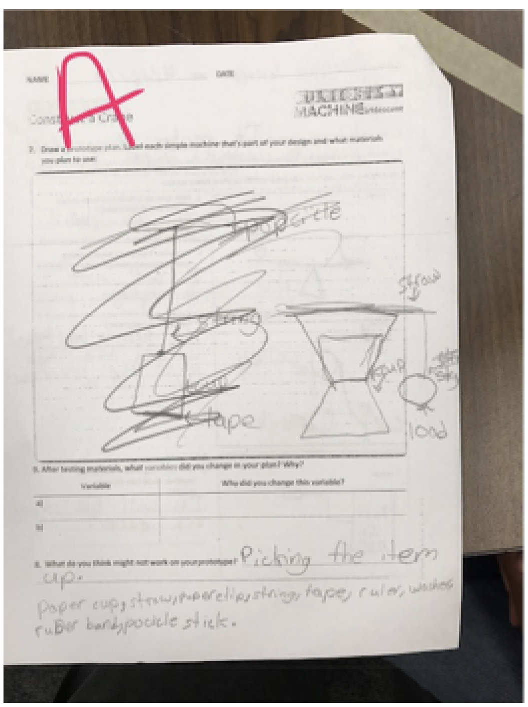
Incomplete	0
Emerging	1
Progressing	2
Accomplished	3

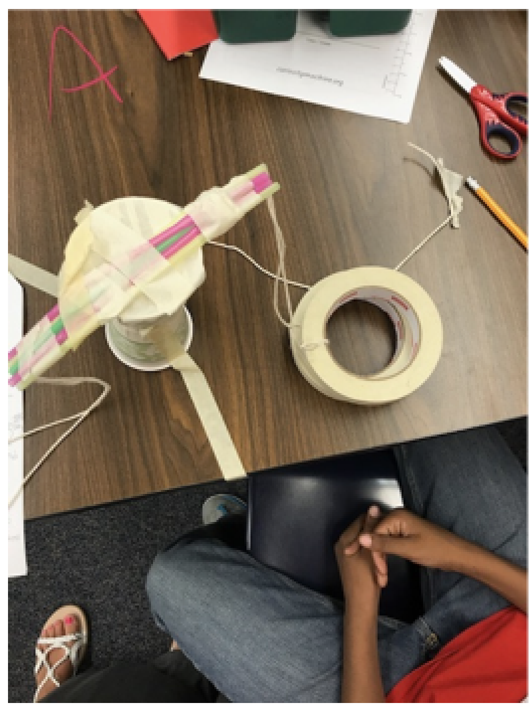
Plan	Build	Plan Similar to Build?	Differences	Number of Differences
3	2	Yes	Tape to stabilize when lifting load, Tape on cups strengthen cups, multiple straws to rigidize pull tape to support pulley system	4
3	3	Yes	Tape around towers to stabilize, pulley oriented deg, 2 pulleys instead of 1, hand required stabilize during operation,	4
3	3	Yes	Crane design defined, hand support needed wi load,	2
2	2	No	3 cup, hand support, straw pulley	3
2	3	No	8 cup, hand support, very extended cantilever w double straws and tape support, Design based inspiration video	3
3	3	Yes	pulley thru paper clip end, hand support, tape support between cups,	3
2	3	Yes	self-support short crane using ruler?, bottom c open end down for stability, taping between cups	2
2	3	Yes	Straw extensions on lever, ruler lever, cups tap together for support, bottom cup taped to table	3
3	3	Yes	Hand support, vertical taping absent, open end top, bottom end on table (reverse)	1
3	3	Yes	Cup taping method, lever design, securing lever crane, straw as sleeve for string	4



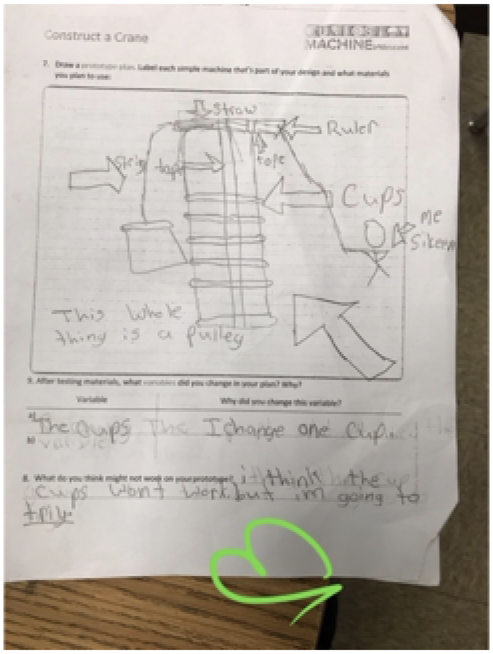


3 changes: pulley thru paper clip end, hand support, tape to support between cups





4 changes: Tape to stabilize when lifting load, Tape on cups to strengthen, multiple straws to stiffen the pulley, tape to support pulley system



1 Change: Hand support, vertical taping absent, open end on top, bottom end on table (reverse)

Future Work

An area that we are actively working in is to improve the reflection question in the Curiosity Machine platform, as well as design process. The question could represent real-world data that could be presented to the student in a multiple-choice format to make an informed decision on. This could be the next level of understanding and transfer. For instance in the cantilever design challenge, the reflection question could present some real load numbers and ask the student to predict how the beam would perform.

We have seen though that half of the challenge is addressed through a technological feature, and the remaining half is about motivating, training, and encouraging adoption by the educators, mentors, and parents!

Other areas of exploration are:

- **Photographic documentation of both the first build, and the followup redesign to further explore Form, Fit, and Function.**
- **Future expansion of the platform to guide the design challenge, including access to resources/internet. In this way, we could further measure increasing curiosity, creativity and perseverance.**
- **Incorporating CAD into the platform so the design occurs on the platform (include 3D effects/animation so design could be tested even before build.**