

Background



Image taken by Evan Wood

My brown LEGOs break frequently while I am playing with them. Other peoples do too. When LEGOs break it is annoying because you must order replacements from LEGO. I sent letters to three of LEGOs headquarters inquiring about the problem, two of them wrote back and acknowledged the problem and said that LEGO was trying to fix it. I also contacted the Steel City LEGO User Group (LUG) to ask for a donation of free parts, they agreed to give me the parts.

Research Questions

- **Question 1- Colors** What colors of LEGO® plates and 3D printed plates are the easiest to break?
- **Question 2- Color durability** Do the strongest and weakest colors change between LEGO® and 3D printed plates?
- **Question 3- Size** Is it easier to break bigger or smaller pieces?
- **Question 4- LEGO VS. 3D printing** Are the LEGO® plates easier or harder to break than the 3D printed plates?
- **Question 5- LUG VS LEGO** Do the LUG plates break more easily than the LEGO® plates?

Hypotheses

- **Hypothesis 1-** It will be easier to break the brown LEGO® plates than the other colors of LEGO® plates. I think that the brown 3D printed plates will also be easier to break than the other colors of 3D printed plates.
- **Hypothesis 2-** I do not think that the strongest and weakest colors will stay the same between 3D printed plates and LEGO® plates.
- **Hypothesis 3-** I think that it will get easier to break them as the plates get bigger.
- **Hypothesis 4-** I think that the 3D printed pieces will break even sooner than the LEGO® plates.
- **Hypothesis 5-** I think that the LUG brown plates will break before the LEGO brown plates.

Plate Breaking Procedure



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- Clamp a plate stud-side-down on a table with half of its studs hanging off the table.
- Drop a 3 lb. weight from approximately one foot above the table onto the half of the plate that is hanging off the table.
- Repeat until the plate breaks, record how many drops it took to break the plate.
- If it has not broken after 10 drops measure the degree of damage with a protractor and record.

3D Printing Procedure

- Go to FabLab at Carnegie Science Center.
- Find a pre-made design on Tinker-Cad and modified it according to my purpose.
- Export my design onto a USB stick
- Choose a filament to print with.
- Print the plate using a Dremel Digi Lab 365 3D printer and the selected filament.
- Watch plate print to make sure that it is going well.
- After the plate is done printing, examine plate and test compatibility.

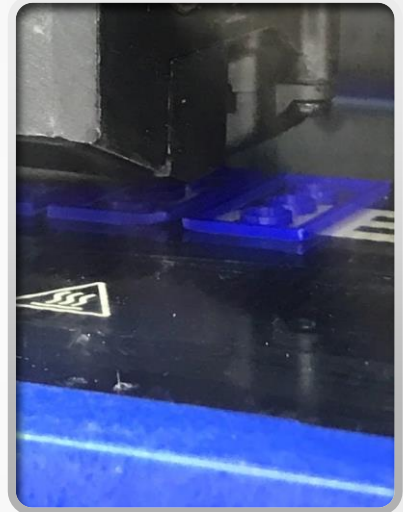


Image taken by Evan Wood

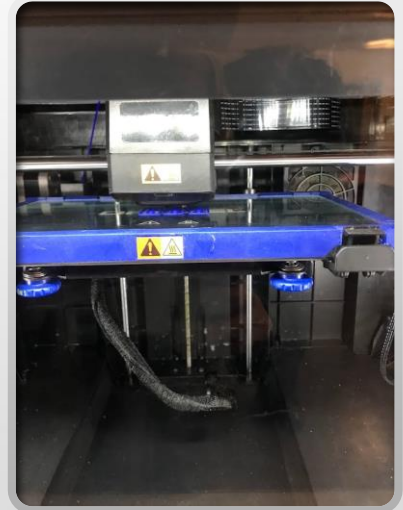


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Data Table for LUG plates

Color	Size	Number of drops	Degree of bending	Score
Yellow	2x4		18	7
Yellow	2x4		18	7
Yellow	2x4		10	8
Blue	2x4		30	6
Blue	2x4		19	7
Blue	2x4		11	7
Red	2x4	1		1
Red	2x4		20	7
Red	2x4		19	7
Green	2x4		19	7
Green	2x4	2		1
Green	2x4	8		4
Brown	1x4		broken by clamp	0
Brown	1x4		broken by clamp	0
Brown	1x4	1		1

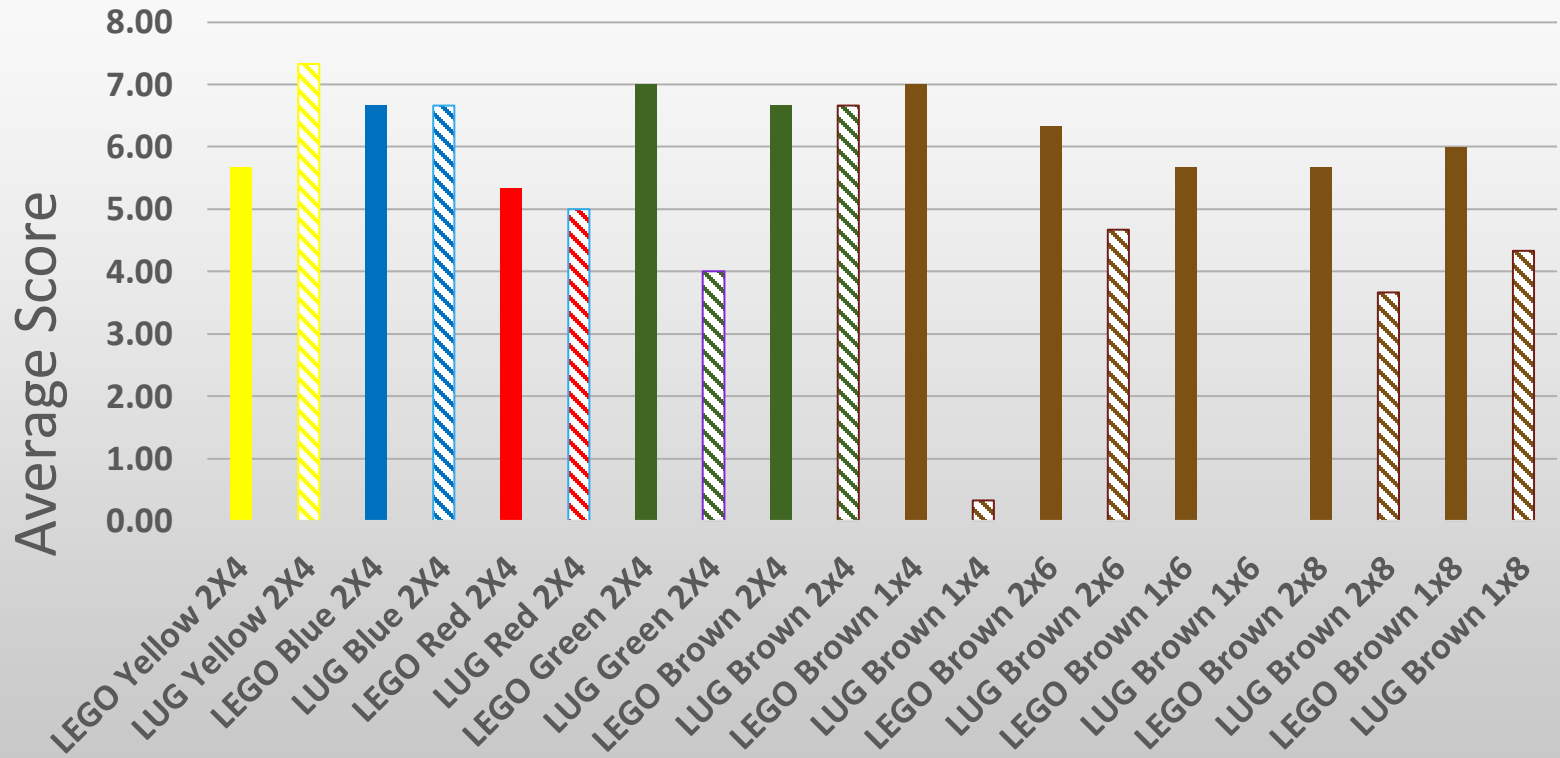
Color	Size	Number of drops	Degree of bending	Score
Brown	2x4		15	7
Brown	2x4		21	6
Brown	2x4		20	7
Brown	1x6		broken by clamp	0
Brown	1x6		broken by clamp	0
Brown	1x6		broken by clamp	0
Brown	2x6		20	7
Brown	2x6		broken by clamp	0
Brown	2x6		15	7
Brown	1x8		broken by clamp	0
Brown	1x8		20	7
Brown	1x8		24	6
Brown	2x8	5		2
Brown	2x8	2		1
Brown	2x8		37	8

Data Table for LEGO Plates

Color	Size	Number of drops	Degree of bending	Score
Yellow	2x4		9	8
Yellow	2x4		21	6
Yellow	2x4	6		3
Blue	2x4		18	7
Blue	2x4		15	7
Blue	2x4		27	6
Red	2x4		20	7
Red	2x4		25	6
Red	2x4	6		3
Green	2x4		19	7
Green	2x4		19	7
Green	2x4		20	7
Brown	1x4		20	7
Brown	1x4		19	7
Brown	1x4		19	7

Color	Size	Number of drops	Degree of bending	Score
Brown	2x4		29	6
Brown	2x4		12	7
Brown	2x4		16	7
Brown	1x6		33	5
Brown	1x6		25	6
Brown	1x6		30	6
Brown	2x6	10		4
Brown	2x6		12	7
Brown	2x6		9	8
Brown	1x8		29	6
Brown	1x8		21	6
Brown	1x8		23	6
Brown	2x8		30	5
Brown	2x8		20	6
Brown	2x8		19	6

Average Score by Plate Type



Scoring System

Protractor

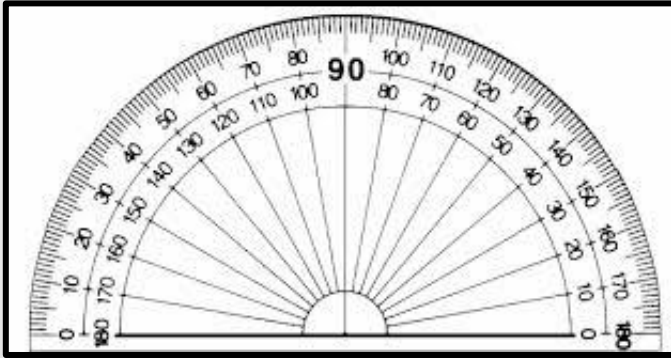
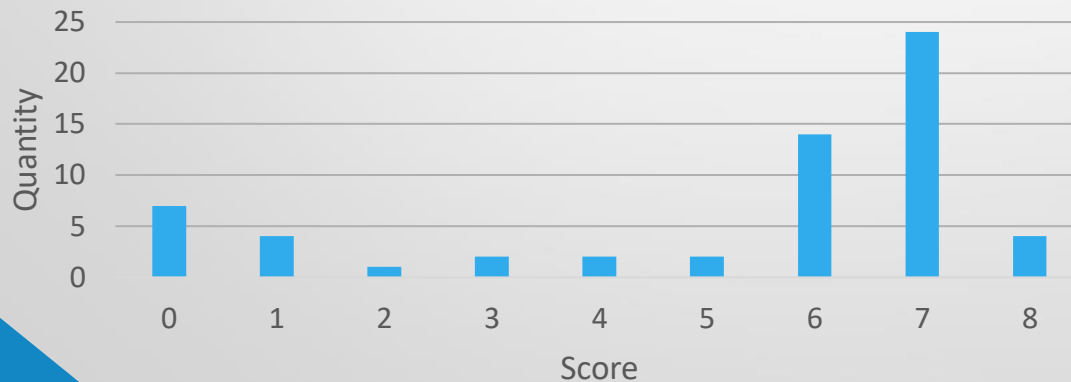


Image taken from clipart-library.com

Quantity for Each Score



Scoring Criteria

Broken by clamp=0

Broken in 1-3 tries=1

Broken in 4-5 tries=2

Broken in 5-7 tries=3

Broken in 8-10 tries=4

Bent $31-40^\circ = 5$

Bent $21-30^\circ = 6$

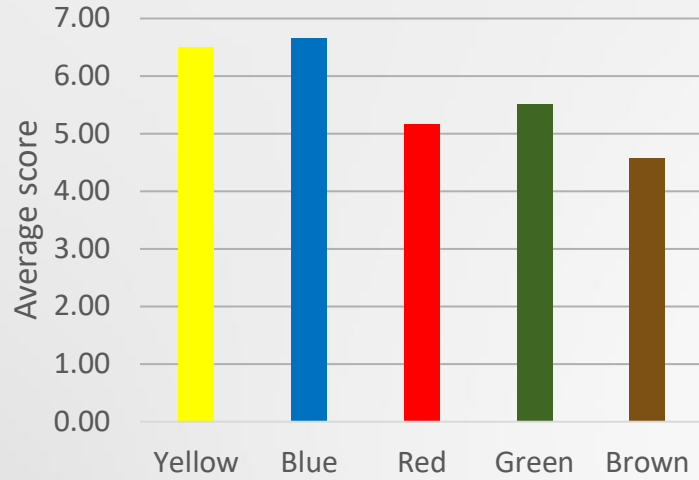
Bent $11-20^\circ = 7$

Bent $1-10^\circ = 8$

Conclusions

- **Conclusion 1-** Yellow and Blue were the strongest colors of plates overall, and the weakest were Red and Brown. For 3D printing I was unable to reach a conclusion. See chart *Average Score by Color* below.
- **Conclusion 2-** I was unable to reach a conclusion due the difficulty of 3D printing LEGOs.
- **Conclusion 3-** Plates that were two studs wide were about the same between brown and colors .The plates which were 1 stud wide in brown were much worse. My hypothesis was wrong. See chart *Average Score by Plate Size* below.
- **Conclusion 4-** I was unable to reach a conclusion due the difficulty of 3D printing LEGOs.
- **Conclusion 5-** The LEGO brown and colors were about the same. The LUG colors were only a small bit less than the LEGO though the LUG brown was much lower than the first three. See chart *LUG VS. LEGO* below.

Average Score by Color



Bad 3D printing

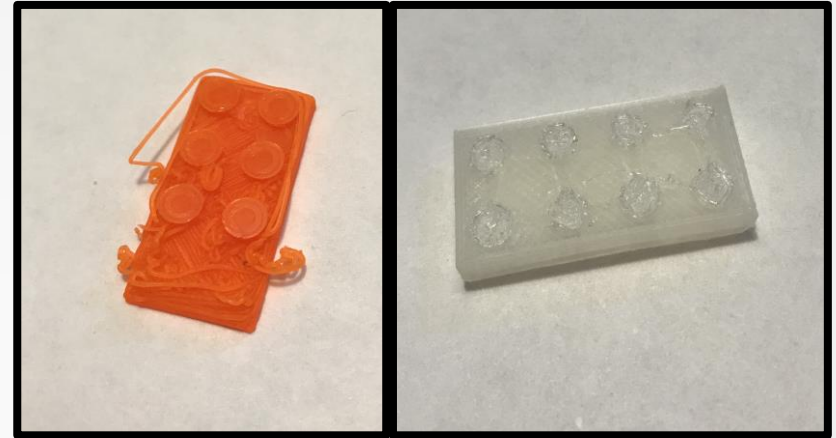
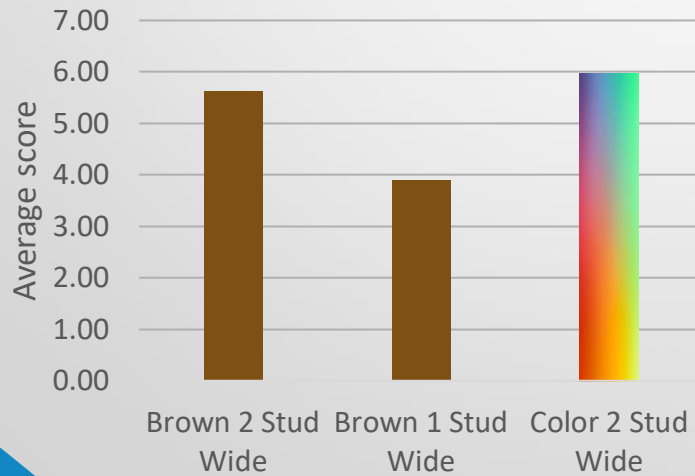


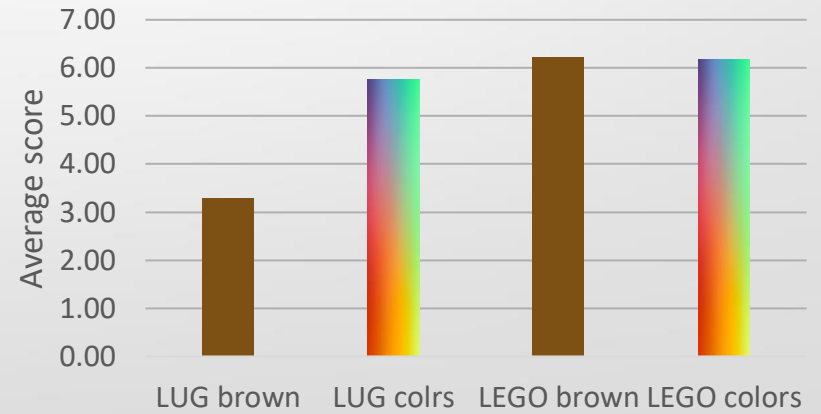
Image taken by Evan Wood

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Average Score by Plate Size



LUG VS. LEGO



Next Steps and New Questions

Can I modify the 3D printing design to make that plates interlock with each other and other real LEGO plates and bricks?

Do other shades of brown break as easily?

Do plant-based LEGOS break easier or are they stronger?

Is there a better way to simulate how LEGOS break while you're playing with them than my procedure?

Did LEGO fix their weak reddish-brown plates?

How do different types of plastics compare to each other in strength?

Are LEGO bricks stronger than LEGO plates or vice versa?

Is it easier or harder to 3D print LEGO bricks or plates?

Can I collect more data on 3D printed plates to compare them to LEGO plates and LUG plates?