The Effects of an Adhesive on Different Types of Wood

Biology Honors Period 4

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Abstract

The purpose of this experiment was to find out which adhesives to use in certain crafts because in previous ones, they always fell apart. We wanted to know which type of wood Gorilla glue would work best with, so in the future when it comes to craft making, this problem could be avoided. Our question for this experiment was, “How do different types of wood affect the strength of an adhesive”? Our original hypothesis was that if we attach a weight to two pieces of wood and glue them together using Gorilla Glue then oak would last the longest because it’s a harder grade wood. In order to determine what wood would work best with the Gorilla Glue we used four different types of wood, pine, fir, oak and cedar. We glued them together using Gorilla Glue and let them hang from strings attached to weights. Over the days we left them hanging, they slowly separated. After 24 hours, we observed that the cedar was the most separated out of the other types of wood. The data of the statistical test for the first round results were 1.4190. This means that our hypothesis was not supported by our results in the experiment we performed. The second round results were 1.4787. The major change we made between the two rounds was the amount of time it was weighted, first round being 24 hours, second round being over 5 days. The second round results also did not support our hypothesis. This means that the difference in time hung didn't interfere with the fact that the oak was the one that didn’t spread us much. We can confirm that the cedar wood is the least likely to stay together when using adhesive in it.

Researchable question

How do different types of wood affect the strength of adhesives?

Hypothesis

First round: If we attach a weight to two pieces of wood and glue them together using Gorilla Glue then oak would last the longest because it's a harder grade wood.

Second round: If we attach a weight to two pieces of wood and glue them together using Gorilla Glue then cedar would last the longest because it has more cracks and imperfections which makes it so that the glue doesn't have as much as a grip.

Background research

When you were a kid you probably did tons of projects with glue. Maybe, sometimes, you were sad when your project came apart because the glue didn't hold it together well enough or the tape on it came off. For us, we were always so curious on why it did not work as well on some projects as it did others. That is why we decided an interesting topic to explore for our experiment would be testing adhesives. In order to make this experiment the most accurate as we could, we decided to test the adhesive on wood because it is strong and there are many different types of wood we could test them on. Our research question looks into this by experimenting on "how do different types of wood affect the strength of adhesives". People say that the best adhesive is glue, cement, mucilage, and paste (Wikipedia, The Free Encyclopedia). We decided to do an experiment to test this question. Instead of using Elmer's glue, we are going to use

Gorilla glue and instead of using popsicle sticks, we are going to use it on different types of wood planks.

We can find the use of wood all around us. Carpenters use wood everyday in their jobs. The most commonly used woods are fir, pine, oak, and spruce. In America, the most common woods here are maple, cedar, fir, hemlock, pine, and redwood. However, in other countries the most commonly used woods vary from walnut, maple, maghoney, and oak (Falk, 82). Wood that is commonly used for making buildings locally are cedar, redwood, and pine. These woods can all be found at Home Depot with prices that vary. For all woods to have the same measurements being 19 mm by 89 mm by 184 mm, the price for cedar is $10.52. The price for pine is $14.05, oak is $32.10, fir is $14.81, and maple is $32.82. We decided to use oak, pine, fir, and cedar because they are more commonly used globally and within our budget.

Different types of adhesives have been proved as more useful than others, depending on the project. For example, waterborne adhesives work particularly well on freshly prepared wood surfaces. Wood is a great material for adhesives because of its large surface area which allows the adhesive to spread out and cover it more, which then just leads to a better stick, and it works the way you want it to (Frihart 3). After the adhesive has been applied to the wood, it needs to be given time to form a bond with the substrate in which it is applied on. This allows many hydrogen bonds to form between the surface of the wood and the actual adhesive itself. These hydrogen bonds are then able to provide a strong substance that will keep the two pieces of wood together for long periods of time. Many studies showed that when you wet the wood with the adhesive on it, the bonds would have difficulty forming, meaning that the adhesive that was once strong and durable before, will be weakened by the water, destroying its full potential. The author of the article in *USDA Forest Service Journal,* Frihart, illustrates, “The

resorcinol-formaldehyde (RF) adhesive provided durable bonds independent of whether the wood was acetylated or not. The MF adhesive lost both dry and wet strength adhesion as the degree of acetylation increased. An emulsion polymer isocyanate adhesive maintained dry strength, but lost wet strength adhesion as the degree of acetylation increased. The epoxy–polyamide adhesive lost some dry strength with acetylation, but regardless had poor bond strength under wet conditions" (Frihart 2). This experiment provides us with the information that each certain type of wood had a similar but different reaction with the different types of adhesives when applied with water or left dry. This is useful because it provides us with knowledge that when the wood is wet or dry, it is likely to have a different reaction with the adhesive, meaning that we need to be sure that all of our wood is kept at a dry state in order to provide fair trials where the wood is not in different states.

The structure of wood defines a lot of its abilities. Wood is basically a bunch of cells that are joining together. This means that adhesives should perform fairly well on wood. It is shown that when wood is scarred, which impacts the reactions to the cells, the adhesives do not work as well when compared to wood that has no imperfections (Frihart 247). This reaction that happens when the wood is fractured is just a failure of the cellular layer near the top of the wood. Once this has happened the adhesive cant penetrate itself into the wood as it could before, which weakens the bond between the wood and between the adhesive, or glue. The level in which the fracture of wood is placed at is called the nanoscale level. The nanoscale level happens to be the most difficult layer in the wood to examine. The author determines, "It also should be noted that in the construction of cell walls, the diameter of the cellulose fibers, hemicellulose domains, and lignin domains are generally on the scale of tens of nanometers" (Frihart 245). With this

information you can conclude that the outside wall of the cell is very small, making this a difficult thing to experiment on, especially when the wood is damaged or fractured.

For the adhesives, we decided that glue would be the best to use because it is one of the most commonly used adhesives by carpenters for building (Tandy Young, 18). However, we need to know which glue would be the strongest. Out of the many types of glue, the two types we looked at were Gorilla glue and Elmer's glue. These are both commonly used and can be found at grocery stores, online stores, home improvement retail stores, or even drug stores. The prices for Gorilla glue usually have a price around $7.00. For Elmer's glue the price is usually around $1.00. We decided to use gorilla glue because it is a stronger glue compared to Elmer's glue. Gorilla glue is supposably the strongest glue ever. According to commercials, Gorilla glue has "an incredibly strong bond" and is "for the toughest jobs on planet earth". Carpenters suggest using gorilla glue (The Gorilla Glue Company 2015, 13 August, *Gorilla Glue Commercial,* Youtube) . By performing this experiment, we will be able to see if the gorilla glue is able to live up to its name by seeing if it will be strong enough to keep two pieces of wood together while a weight is attached.

Adhesives are commonly used for building, crafts, projects, etc. Throughout time, the usage of adhesives have not changed much. They were always needed and back then they were used for building weapons, tools, caskets, architecture, etc. Adhesives were used world wide, first originating from The Netherlands. Adhesives led to many new inventions. Glue allowed the creation of rubber, surgical tape, resin, rubber cements, etc. Many people used glue that came from animal hides. There are many different types of adhesives. There are two types of adhesives that harden when dry. These are called solvent-based adhesive and polymer dispersion adhesives. Polymer dispersion adhesives are also known as emulsion adhesives and are PVAc (polyvinyl

acetate). It is mainly used in woodworking and packaging and can also be used for fabric and engineering (Tandy Young, 27). The solvent based adhesive is several ingredients, normally polymers, dissolved in a solvent. While the solvent in the mixture vaporizes, the adhesive hardens. Another type is a pressure sensitive adhesive. This adhesive forms a bond and hardens when pressure is applied to the material (Tandy Young, 25). There is another called a contact adhesive. This type of adhesive is commonly used in projects that require a strong force to make it stick together. However, they often take a long time to dry but do not require pressure. Another popularly used adhesive a bvre hot adhesives. Hot adhesives form a strong bond between the materials they are sticking together. Hot adhesives are most widely known as hot glue guns. The hot adhesives melt to a solid so that the adhesive will stick (Tandy Young, 26). Although, in our experiment we will not be using all these types of adhesives, it is still important to know because it gives us more background information on adhesives and it will help answer the question on why some work better than others.

It is also shown that modified wood reacted differently with the adhesives as well. The many produced wood adhesives we have today are made to react a certain way with certain types of wood, and if the wood is to be modified or man made, then the adhesive is likely to not work as well as it would with normal wood. The authors implied, “research in this area is greatly aided by a paper that studied the bonding of 18 different adhesives to yellow poplar acetylated at different modification levels” (Frihart, Brandon, Ibach, Hunt, Gindl-Altmutter, 3). In this experiment they were able to test the adhesives with wood held to multiple different modification levels, and see how they reacted to each one. The results of this experiment concluded that the more they abstractly modified each piece of wood, the less the adhesive was able to keep its

strength with the wood. This allows us to see that natural wood is more likely to work best when put together with a certain adhesive.

We discovered that in the 1900's there was an American chemist named Spencer Silver who was well known for taking part in the creation of the sticky note. He wanted to work on creating a pressure sensitive adhesive. He did this by making a "low-tack" adhesive, meaning the adhesive isn't super strong, but is still strong enough to stick to the surface it is placed upon. He wanted to make sure the paper would not be torn when it was stuck to another, but it still was strong enough to stay on the paper without falling right off. Before his invention of the sticky note, he also attempted to make a very strong adhesive that could be used for things like aircraft construction, however, he was not successful. From the invention of his adhesive, he was able to lead a man named Arthur Fry to develop a bookmark that could stick to the book without falling out. He was able to make sure that it left no sticky residue on the inside of the book, but it wasn't easy to fall out. Arthur Fry is a former American inventor and scientist. He became very successful because of his invention of the sticky note, which he created by taking some of Spencer Silver's adhesive and then applying it to the back of a paper. From this, they created Post-it Notes (Wikipedia, The Free Encyclopedia).

An experiment performed by Charles R. Frihart demonstrated that a wood adhesive did not work as well after applied to wet conditions. After adding moisture to the wood that was stuck together by glue had water applied to it, Frihart was able to see that the glue swelled up, and did not work as well. The ends of the wood seemed to be "sticking out" compared to the already dry wood that was just normally applied together with glue. This means that the glue is applied to less parts of the wood than it was before. The experiment showed, "Weakening of the bond under the swelling condition is clearly demonstrated by the often-observed decrease in the

percentage failure within wood relative to that in the adhesive under wet conditions" (Frihart 606). This showed that over time, while the water was applied to the adhesive, the wood reacted to it, causing the wood to expand away from the adhesive. According to the journal, swelling, while it still isn't good, only does up to 10% of damage to the wood, causing it to lose just that little bit of grip on the glue. It is also stated that, while the swelling can't fracture that bond between the wood and glue, that it is still possible for the glue to become weakened, as well as the bond between the two. When they tested how the wood would react to a wet liquid, they found that the plywood did poorly, and that the bond between the plywood and the glue was weakened a significant amount. After this trial, they then did another trial but with a different adhesive to see if the same reaction of wood swelling up and losing the bond with the glue would happen again. It was found that after their new trial with a new adhesive, that the same thing happened, so they were able to prove for the most part that water does in fact weaken the grip that the glue has with the wood compared to when it was first applied, and the glue was able to cover the full surface of the wood.

After much research, we were able to determine that we are very capable of performing an experiment and will be able to receive accurate results from it on the topic of the strength of adhesives on wood. Our question, which is, "how do different types of wood affect the strength of adhesives", to our knowledge, has not been done before and will be useful overall.We will explore this by using the four different types of wood to see if they work better with the adhesive. The one out of the four that holds the weight that we will be attaching to the wood plank will be determined as the best to work with that adhesive. This information will be useful when it comes to architecture and crafts, which can help many people who are interested in these areas, making it an experiment that is less likely to be performed. In order to perform this

experiment, we will need a 19 mm by 89 mm by 184 mm plank of each of the four different types of wood, those woods being pine, oak, fir, and maple which can be bought at home depot. The total price of these supplies will be within a reasonable price range. The Gorilla glue can be bought from Walgreens. If we wanted to change our experiment we could use a different type of adhesive or different types of wood, natural and man-made. Another question from this that could be explored is "how does the hardness or softness of the wood affect how well the adhesives work"? This would be a good question to use because it still involves adhesives and wood, which could still be used for crafts and building. People with jobs that work with these materials, such as carpenters, construction workers, artists, etc., could find this information extremely useful. For this experiment, the materials you would need to use are three different types of wood with different measurements. For example, a 19 mm by 89 mm by 184 mm plank of wood. Then you could use a different type of adhesive to test the question.

Materials

- Gorilla glue
- 2 planks of oak wood (19 mm by 89 mm by 184 mm).
- 2 planks of elm wood (19 mm by 89 mm by 184 mm).
- 2 planks of fir wood (19 mm by 89 mm by 184 mm).
- 2 planks of pine wood (19 mm by 89 mm by 184 mm).
- Rope
- Fence
- 4.5 kg weights x4
- Timer

- Drill
- Drill bits
- Gloves
- Goggles
- Clamps

Operational Definitions:

0 to 5 scale: A scale we used to measure the separation of the wood, with 0 being no separation at all and 5 being complete separation between the two wood planks.

Procedures:

1. We placed the two oak planks on a table to drill nails into.
2. We marked the areas in which we were drilling nails into, 2 on each plank of wood.
3. We drilled 2 10mm holes on both sides of the wood.
4. Repeated steps one through three for elm wood.
5. Repeated steps one through three for fir wood.
6. Repeated steps one through three for pine wood.
7. We then tied rope onto both sides of oak wood using the nails to keep it steady.
8. Repeated step seven for elm wood.
9. Repeated step seven for fir wood.
10. Repeated step seven for pine wood.
11. We applied 236.6 milliliters of the gorilla glue to one side of one of the planks of oak wood.

12. Repeated step six but with elm wood.
13. Repeated step six but with fir wood.
14. Repeated step six but with pine wood.
15. We put each type of wood together and clamped them.
16. Allowed wood to dry for 24 hours before starting the experiment.
17. Once wood was allowed full time to dry, we hung the 4 types of wood from the fence using one side of rope.
18. We then attached the 4.5 kg weight to the other side of the rope.
19. Started a timer.
20. We checked every 30 minutes for up to 5 days recording our observations (when not at school or sleeping)
21. We then filled out the data table with our observations on whether the planks were able to stick together, and recorded them on a scale of 0-5 with 5 being the most separated and 0 being no separation at all.
22. We analyzed the data.
23. We then compared the two rounds together to see if they came up with similar results.

Results

First round raw data table:

	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	Standard deviation	Averages:
fir	1	2	1	1	2	0.5477225575	1.4
oak	2	3	2	2	1	0.7071067812	2

cedar	3	4	3	4	4	0.5477225575	3.6
pine	1	2	1	1	1	0.4472135955	1.2
control	0	0	0	0	0	0	0

Second round raw data table:

	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	Standard deviation	Averages:
fir	2	2	3	2	2	0.4472135955	2.2
oak	1	1	3	1	2	0.894427191	1.6
cedar	4	4	4	3	4	0.4472135955	3.8
pine	2	2	2	1	2	0.4472135955	1.8
control	0	0	0	0	0	0	0

First round summary table:

summary table		
type of wood	average separation	Standard deviation
fir	1.4	0.547722557
oak	2	0.7071067812
cedar	3.6	0.5477225575
pine	1.2	0.4472135955
control	0	0

Second round summary table:

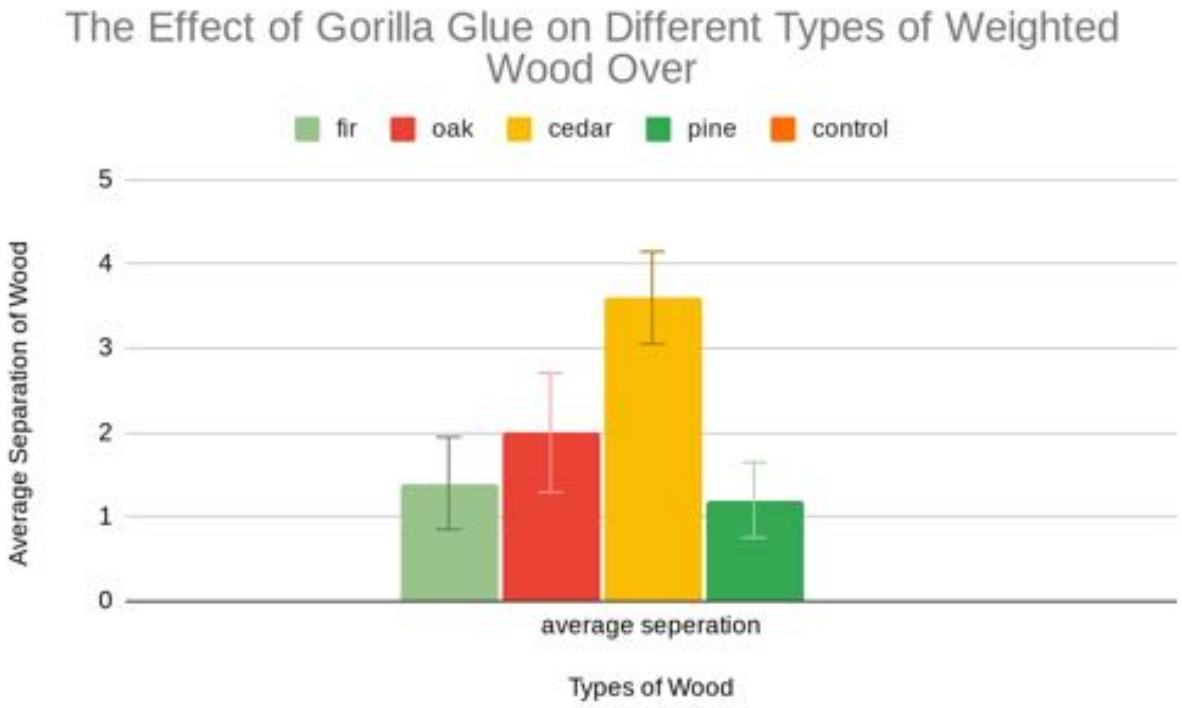
summary table		
type of wood	average separation	Standard deviation
fir	2.2	0.4472135955
oak	1.6	0.894427191
cedar	3.8	0.4472135955
pine	1.8	0.4472135955
control	0	0

Rounds one and two combined summary table:

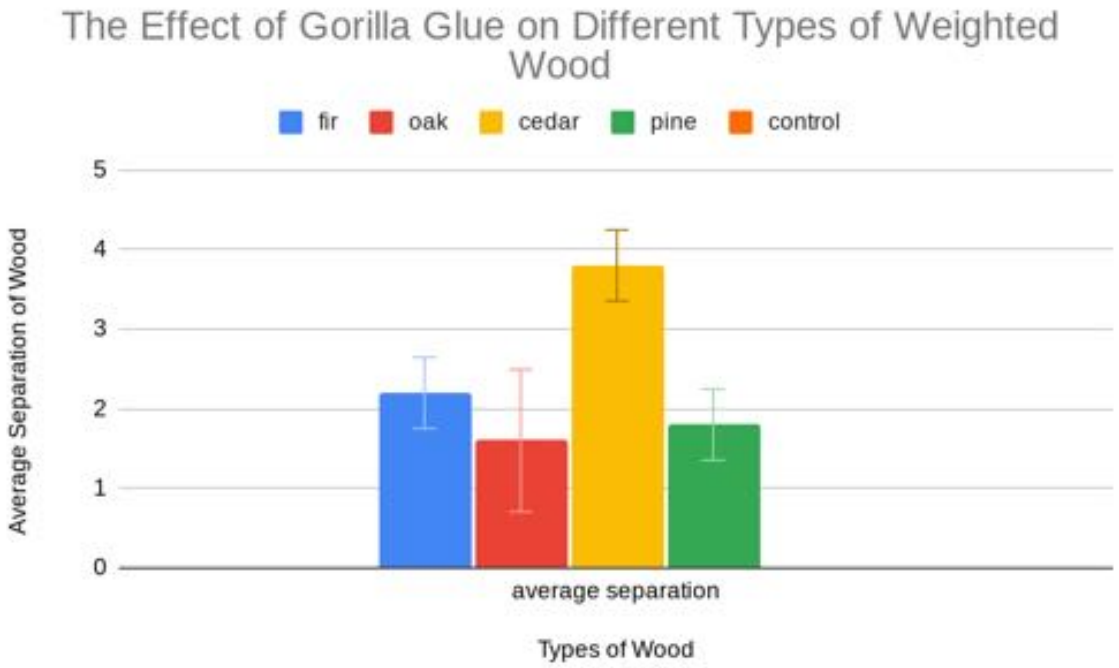
summary table		
type of wood	average separation	Standard deviation
fir	1.8	0.632455532
oak	1.8	0.7888106377
cedar	3.7	0.4830458915
pine	1.5	0.5270462767

control	0	0

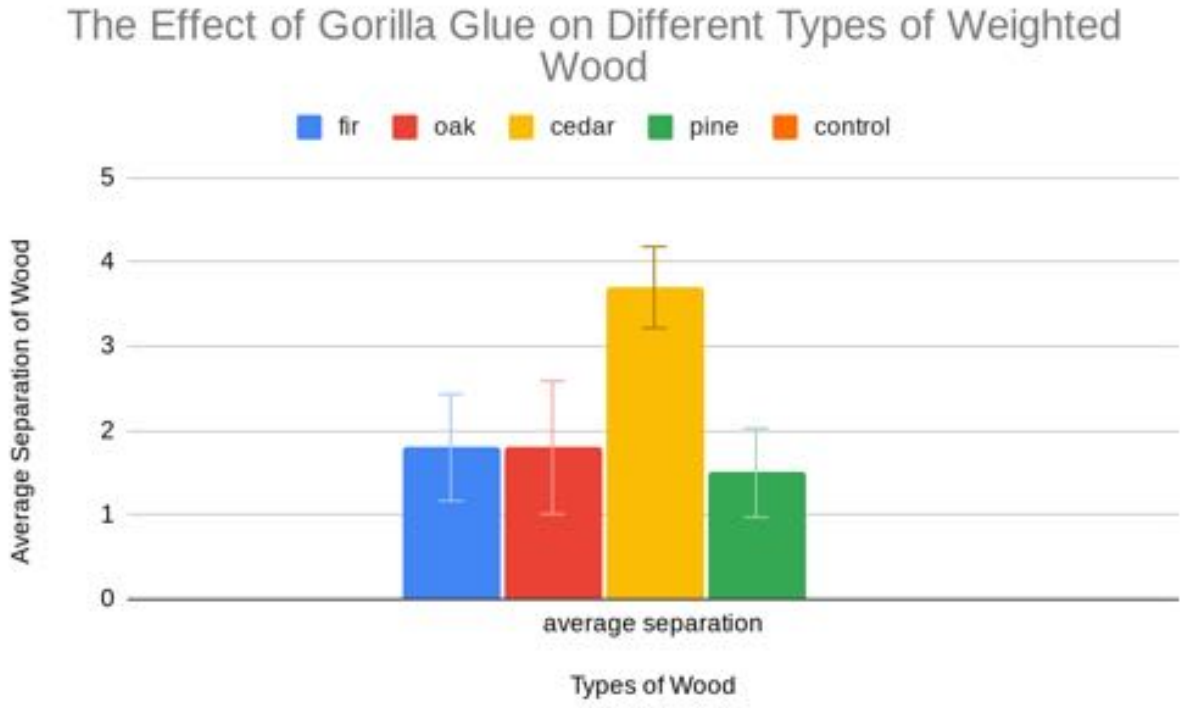
First round bar graph:



Second round bar graph:



Rounds one and two bar graph combined:



One Way ANOVA Test first round results:

Input data

Treatment →	A	B	C	D	E
Input Data →	1.0	2.0	3.0	1.0	0.0
	2.0	3.0	4.0	2.0	0.0
	1.0	2.0	3.0	1.0	0.0
	1.0	2.0	4.0	1.0	0.0
	2.0	1.0	4.0	1.0	0.0

Results of ANOVA test

source	sum of squares SS	degrees of freedom ν	mean square MS	F statistic	p-value
treatment	34.5600	4	8.6400	33.2308	1.4190e-08
error	5.2000	20	0.2600		
total	39.7600	24			

Tukey HSD Test

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.6312	0.3698978	insignificant
A vs C	9.6476	0.0010053	** p<0.01
A vs D	0.8771	0.8999947	insignificant
A vs E	6.1394	0.0026159	** p<0.01
B vs C	7.0165	0.0010053	** p<0.01
B vs D	3.5082	0.1349557	insignificant
B vs E	8.7706	0.0010053	** p<0.01
C vs D	10.5247	0.0010053	** p<0.01
C vs E	15.7870	0.0010053	** p<0.01
D vs E	5.2623	0.0105040	* p<0.05

One Way ANOVA Test second round results:

Input data

Treatment →	A	B	C	D	E
Input Data →	2.0	1.0	4.0	2.0	0.0
	2.0	1.0	4.0	2.0	0.0
	3.0	3.0	4.0	2.0	0.0
	2.0	1.0	3.0	1.0	0.0
	2.0	2.0	4.0	2.0	0.0

Results of ANOVA test

source	sum of squares SS	degrees of freedom ν	mean square MS	F statistic	p-value
treatment	37.0400	4	9.2600	33.0714	1.4787e-08
error	5.6000	20	0.2800		
total	42.6400	24			

Tukey HSD Test

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.5355	0.4061166	insignificant
A vs C	6.7612	0.0010053	** p<0.01
A vs D	1.6903	0.7309843	insignificant
A vs E	9.2967	0.0010053	** p<0.01
B vs C	9.2967	0.0010053	** p<0.01
B vs D	0.8452	0.8999947	insignificant
B vs E	6.7612	0.0010053	** p<0.01
C vs D	8.4515	0.0010053	** p<0.01
C vs E	16.0579	0.0010053	** p<0.01
D vs E	7.6064	0.0010053	** p<0.01

Rounds one and two ANOVA test combined

Input data

Treatment →	A	B	C	D	E
Input Data →	2.0	1.0	4.0	2.0	0.0
	2.0	1.0	4.0	2.0	0.0
	3.0	3.0	4.0	2.0	0.0
	2.0	1.0	3.0	1.0	0.0
	2.0	2.0	4.0	2.0	0.0
	1.0	2.0	3.0	1.0	0.0
	2.0	3.0	4.0	2.0	0.0
	1.0	2.0	3.0	1.0	0.0
	1.0	2.0	4.0	1.0	0.0
	2.0	1.0	4.0	1.0	0.0

Results of ANOVA test

source	sum of squares SS	degrees of freedom ν	mean square MS	F statistic	p-value
treatment	69.3200	4	17.3300	56.5109	1.1102e-16
error	13.8000	45	0.3067		
total	83.1200	49			

Results of tukey HSD test

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	0.0000	0.8999947	insignificant
A vs C	10.8498	0.0010053	** p<0.01
A vs D	1.7131	0.7197869	insignificant
A vs E	10.2787	0.0010053	** p<0.01
B vs C	10.8498	0.0010053	** p<0.01
B vs D	1.7131	0.7197869	insignificant
B vs E	10.2787	0.0010053	** p<0.01
C vs D	12.5629	0.0010053	** p<0.01
C vs E	21.1285	0.0010053	** p<0.01
D vs E	8.5656	0.0010053	** p<0.01

Photos of Experiment

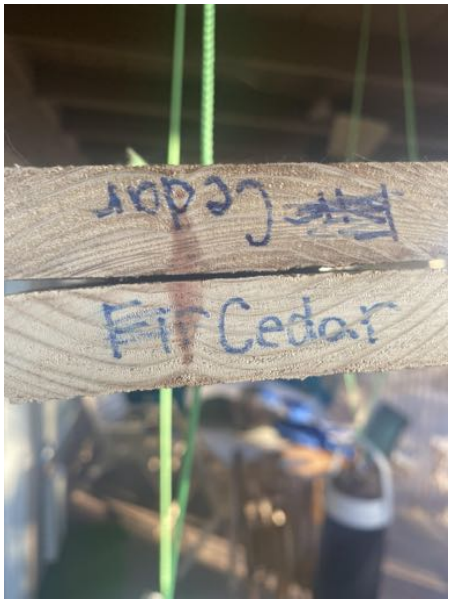
Round one experiment photographs:

Pine wood after 24 hours of being weighted (first round):

Fir wood after 24 hours of being weighted (first round):

Oak wood after 24 hours of being weighted (first round):

Cedar wood after 24 hours of being weighted (first round):



Round two experiment photographs:

Pine wood after 24 hours of being weighted (second round):

Fir wood after 24 hours of being weighted (second round):

Oak wood after 24 hours of being weighted (second round):

Cedar wood after 24 hours of being weighted (second round):

Conclusions

In our experiment, we tested which type of wood an adhesive would work best with. The adhesive we used to test this was Gorilla Glue. In the first round, pine stayed the most together. In the second, oak stayed the most together. Our original hypothesis was if we attach a weight to two pieces of wood and glue them together using Gorilla Glue then oak would last the longest because it's a harder grade wood. Our hypothesis ended up being incorrect, so our revised hypothesis for the second round was if we attach a weight to two pieces of wood and glue them together using Gorilla Glue then cedar wouldn't last the longest because it has more cracks and imperfections. The first round results p value was 1.4190x10^-8. The second round results p value was 1.4787^-8. The round combined p value was 1.1102^-16. All three of our results were much less than 5%. The trends were consistent throughout both the first and second round. In the Tukey HSD test, it showed us that there was no significant difference but between only 3 pairs. The error bars showed us that

When looking at the first round of results, our hypothesis was not supported. We hypothesized that "if we attach a weight to two pieces of wood and glue them together using Gorilla Glue then oak would last the longest because it's a harder grade wood". However, our

results did not support this, but rather supported that the cedar wood would fall quicker when compared to all of the other woods. We thought that because the oak wood was the heaviest wood, it would fall quicker due to gravity. It actually ended up being one of the lightest woods. It felt lightweight so we thought that this would stay together the longest because of that. From these results we were able to revise our hypothesis into “if we attach a weight to two pieces of wood and glue them together using Gorilla Glue then cedar would last the longest because it has more cracks and imperfections”. The wood itself had more craters and holes that were naturally made into the wood. The other planks didn't have this. They were all smooth for the most part. The second round results are able to support this hypothesis because it was still the wood that separated the most out of the rest.

Some of the errors that we could have made was cutting the wood into the perfect size. There is no way to make the two wood planks exactly the same so we had to work with what we had and make it as perfect as possible. If some of the planks were a little bigger than the others then this might have affected the results we obtained. While we did get similar results in both rounds, there were some minor differences between the numbers. We believe that finding a better way to measure how much the wood spread would have been better. We were estimating based on our prior knowledge on how much they spread. If we wanted to do this again, we might have gotten heavier weights so there is more of a difference in the separation between the two. We might also try to measure the distance in which they split to the best of our abilities using a ruler.

Carrying out this experiment only gives us a little bit of insight on which type of wood works well with gorilla glue. From both rounds we can see that oak and fir were the ones that stayed together for the longest. The only way we can find out more about the best type of woods is to test it on all types of wood. There's also combinations of wood. Some people like to use two

woods in one product, such as oak and fir; these might stay together better than if you were to combine cedar and pine together. From this test we can further hypothesize that if we combined oak and fir together, they would stay together longer than if we compared cedar and pine together because of the structure.

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