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| **Chemistry of Coatings: Teacher Guide****A scientific inquiry lesson: Answer Key** |

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| **Objective** |
| The goal of this inquiry lab is to use your knowledge of the scientific method and engineering design matrix and come up with an process to determine the optimum ratio of epoxy to hardener to create the strongest resin bridge in the most cost effective way. Make sure you view the [rubric](https://docs.google.com/document/d/1jZzeuwSjmU7KmdUTUXq9FDieknSCVf_yy9dzBcPebe8/edit?usp=sharing) for how you will be graded in terms of the use of the engineering design matrix. |

**Tips:**

* Students should be limited to 10mL of epoxy and hardener using any ratios that they decide to test.
* Ideally the experiment would occur on a Friday so there is a weekend for the epoxy to cure.
* Split the class into two groups
	+ One group will be assigned the engineering design matrix and the other will be the scientific method
* At the conclusion of the testing, have a class discussion to compare the results from using both methods and see how they are connected and really complement each other.
* Extension-Two possibilities
	+ If there is time, students may be assigned to redesign and test their experiment using their data and findings.
	+ The chemistry of epoxy resins can be further investigated.

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| **Discover-Homework** |
| Think about it: “How are great discoveries made?” [Watch this video](https://sites.google.com/site/mrsdiazstudentresources/1-21-gigawatts)! Notice the process Doc Brown goes through to address the problem of how to send Marty back in time. Cite two pieces of evidence that Doc Brown and Marty used to figure out how to send him back to the future. |
| **Answer:**Answers can vary. Students should recognize that Doc Brown realized he needed much more energy. Marty made an observation that they should somehow be able to harness that energy. The hypothesis formed from Doc Brown was that if they could harness the energy from the lightning storm next Saturday, then they should have enough energy to send Marty back to the future. |

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|  **Learn-Homework** |
| All scientists need to know about the Scientific Method and the importance of the steps for any experimental design. Engineers follow a similar process using the engineering design matrix. Compare and contrast the steps of the scientific method and engineering design process by clicking on the links below. Make sure to make AT LEAST two comparisons and two differences between the two. [Overview of the Scientific Method](http://www.sciencebuddies.org/science-fair-projects/project_scientific_method.shtml#overviewofthescientificmethod) and [Overview of the Engineering Design Process](https://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml). |
| **Notes:**Similarities* Both involve background research
* Brainstorming is required for both processes.
* Redesigning should occur in both processes. For engineering it would depend on the prototype and based off of the data and conclusion for the scientific method.

Differences* The scientific method has variables and controls whereas the engineering design matrix
* The scientific method requires a set amount of trials and tests to come to a conclusion and the engineering design matrix tests the prototype and then redesign if necessary.
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| **Pre-Lab Questions**To help answer these questions, see the attached links provided. |
| 1. Define a [polymer](https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/polymers.htm).

A polymer is a substance that has a molecular structures of a large number of similar units bonded together. Link: [All about epoxy resins](https://www.thoughtco.com/what-is-epoxy-resin-820372)1. How is an epoxy resin an example of a polymer?

An epoxy resin is a type of thermosetting polymer resin where the resin molecules contains one or more epoxide groups.1. List three industries/products where epoxy resins are used.

Answers may vary. Industrial coatings, adhesives, non-skid coatings, etc.1. What is the most common epoxy: hardener ratio commonly used in epoxy resin systems?

The most common formulations are 1:1 or 1:2/2:1.[Scientific Method and Engineering Design](https://www.sciencebuddies.org/engineering-design-process/engineering-design-compare-scientific-method.shtml)1. Identify whether the following prompts should use the scientific method or engineering design matrix:
	1. Why are some tomato plants and tomatoes larger than others? Scientific Method
	2. I need a better support frame for my tomato plants. Engineering
	3. How can I capture the sun’s energy to heat water? Engineering
	4. Is it possible to turn soil into energy with a microbial fuel cell? Scientific Method
	5. How does changing the level of oxygen affect the exothermic oxidation of iron powder? Scientific Method
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| **Purpose**In one sentence state the purpose of this experiment. |
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| **Hypothesis (Sci Method)**Using an “if, then” statement, state a testable hypothesis. |
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| **Variables and Controls (Sci Method)**List all appropriate variables and controls that will used in this experimental design. |
| **Independent:** Ratio of epoxy to hardener**Dependent:**Strength of epoxy beam**Controls:**Same time curing, same time mixing, 10 mL total every time, same testing apparatus, using the same ruler to measure the distance, etc. |

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| **Procedure/Design**List your procedure in number/bullet format |
| **Scientific Method****Engineering**Important Criteria:1. You must not use more than 10 mL total of part A and part B
2. Part A costs $0.10/1mL and Part B costs $1.00/1mL.
3. In order to have a successful structure it must not fall/bend beyond 15% of the original height. If it goes past this point it will fail!
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| **Data/Prototype**Come up with your own data table to record all relevant measurements and information. |
| **Sample Data**The following are sample ratios between hardener and resin that were tested.

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| **Type** | **Hardener (mL)** | **Resin (mL)** | **Property** | **Height from middle 2 min (cm)** | **Pass or Fail?** |
| **A** | **5** | **5** | **Best-cured** | **16.70**  | **Pass** |
| **B** | **3** | **7** | **Bendy** | **14.80** | **Fail** |
| **C** | **7** | **3** | **No cure** | **X** | **Fail** |
| **D** | **4** | **6** | **Bendy** | **16.60** | **Pass** |
| **E** | **6** | **4** | **No cure** | **X** | **Fail** |

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| **Conclusion** |
| **Scientific Method**State whether the hypothesis was accepted or rejected. Make sure to cite specific examples and supply potential sources of error.**Engineering Design**State whether the beam you designed passed or failed. Make sure to cite specific examples and supply potential sources of error. |

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| **Post-Lab Questions** |
| 1. Why do you think the hypothesis was accepted or rejected?
2. What is the ideal ratio between epoxy and hardener after conducting this experiment?
3. How would knowing what the engineering group tested be helpful in your design of the epoxy? (Use the class discussion to guide this answer)
4. Extension: What would you do next time you would design this beam? Be specific!

These answers will really vary and be dictated by the findings and class discussion! |

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| **Extension: Redesign****Test and redesign as necessary. Make sure to indicate all of the modifications made.** |
| If you have time and choose, you may assign this as an extension for students to complete using their findings. Ideally this section would occur  |