Bioengineering with CRISPEE

A Curriculum Guide for introducing Bioengineering in Early Childhood

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This project is funded by the generous support of the National Science Foundation (IIS-1149530)

CRISPEE Learning Objectives & Standards

Learning Objectives Overview

The CRISPEE tangible bioengineering tool was designed to inspire the next generation of innovators by exposing young children (ages 5-8 years) to these emerging areas at the intersection of science and technology. In addition to introducing early elementary aged children to concepts of science and technology, the Bac2Mars game was also designed to foster development of basic reading comprehension, mathematics skills, creative problem-solving, collaboration, and more. In order to do this, the Bac2Mars game and all educational support materials were designed to align with state and national standards for education including: Next Generation Science Standards, Common Core Standards, P21's Framework for 21st Century Learning, and more. This document walks you through an overview of each of these standards and how the design of CRISPEE aligns with them. Finally, this document also provides you with a breakdown of each educational CRISPEE video and game, as well as the tool itself, and how specific CRISPEE content ties into the learning objectives.

In some cases, our educational content ties in with standards for older children in places where no early childhood standards exist for a given topic. We do this because we believe there is a need to re-envision what children can and should be learning in Kindergarten, particularly in the area of STEM education. For decades early childhood curriculum has focused on literacy and numeracy, with some attention paid to the natural sciences. However, in today's world, science and technology are combined in new and creative ways and thus the range of concepts traditionally explored in school needs to be extended. While understanding the natural world is important, developing children's knowledge of the surrounding human-made world of technology and engineering is also valuable. Biological engineering is an example of an emerging field that integrates life sciences and engineering, the natural world and the human-made world that children can and should begin to learn about from an early age.

Why Bioengineering in Early Elementary School?

While a significant amount of research focuses on STEM education for the later elementary, middle and high school, and college years, little research is focused on learning abstract scientific concepts in the foundational years. We know, however, both from an economic and a developmental standpoint, that educational interventions that begin in early childhood are associated with lower costs and stronger, more durable effects than interventions that begin later in childhood. Additionally, we know that women and minorities are still underrepresented in many STEM fields. Prior work demonstrates the importance of piquing the interest of girls and minorities during their formative early childhood years before stereotypes regarding these traditionally masculine fields are ingrained in later years. Therefore, it is critical to continue developing engaging STEM-focused tools, games, and materials, such as BactoMars, to begin engaging children from their earliest schooling years.

The CRISPEE tangible and curricular content are designed to align with the following standards:

Next Generation Science Standards (NGSS)

The Next Generation Science Standards (NGSS) are K–12 science content standards. Standards set the expectations for what students should know and be able to do. The NGSS were developed by states to improve science education for all students. CRISPEE specifically connects to NGSS standards related to Life Science and Ecosystems, as well as Engineering, Technology, and Applications of Science. While the BactoMars game is targeted to early elementary school students, it addresses some science themes that are typically not introduced until middle or high school. BactoMars attempts to introduce these concepts in a playful and easy-to-follow way that is developmentally appropriate for elementary school children, even though many of the standards we link to are for older children. Find out more about NGSS standards here: https://www.nextgenscience.org/

International Technology and Engineering Educators Association (ITEEA)

The Standards for Technological Literacy: Content for the Study of Technology, also called STS, identify engineering and technology content necessary for K-12 students, including knowledge, abilities, and the capacity to apply both to the real world (https://www.iteea.org/Publications/StandardsOverview.aspx). STL were designed by the International Technology and Engineering Educators Association (ITEEA), and articulates what needs to be taught in K-12 laboratory-classrooms to enable all students to develop technological literacy. As a technological prototype to model current trends in biotechnology, CRISPEE is itself a novel technology to support children's learning about technological advances in new and emerging STEM fields.

Computer Science Teachers Association (CSTA) Standards

The Computer Science Teachers Association (CSTA) is a professional association that supports and encourages education in the field of computer science and related areas. Started in 2004, CSTA supports computer science education in elementary schools, middle schools, high schools, higher education, and industry. CSTA standards for computer science education (https://www.csteachers.org/page/standards) were updated as recently as 2017 and include introductory lessons that begin as early as kindergarten and span through high school. These lessons are divided into concepts, sub-concepts and practices. CRISPEE's hardware and software components support children's developing computational thinking skills, as well as computer science practices of writing and iterating on programs.

Putting it into Practice

Below is a breakdown of each lesson of the CRISPEE curriculum and educational support materials, as well as supplemental activities that are linked to specific learning standards.

Table 1
Lesson Summary

	Theme	***Content***
Day 1	What is Bioengineering?	Children are introduced to the CRISPEE tool by reading the Adventures in Bioengineering storybook. They explore light mixing and the engineering design process, and learn that genes are like a coding language for living bodies.
Day 2	What is Science Observation?	This lesson focuses on science inquiry and observation. Children engage in life science center activities, and research bioluminescent animals found in nature.
Day 3	What is Ethical Engineering Design?	Children are introduced to concepts of "values" and "ethics", and learn about how we can use these to guide decisions that we make. They also explore "consequences", and consider positive and negative consequences of our engineering designs.
Day 4	Bioengineering a Helpful Animal	In this lesson, children are introduced to the concept of biosensors, which are genes that give special instructions based on the animal's environment. Children combine all that they have learned about bioengineering to collaboratively design a way to help humans find toxic gas that only animals can sense.

Table 2

Sample Timeline

Time	**Tuesday** What is Bioengineering?	**Wednesday** What is Science Observation?	**Thursday** What is Ethical Engineering Design?	**Friday** Bioengineering a Helpful Animal
8:30-9:15	**Outdoor Play**			
9:15-10:00	*Welcome Circle* Read <u>Adventures in Bioengineering</u> Storybook	Guided group play with CRISPEE Science Activity: Observing and Documenting	Group Activity: Values & the Engineering Design Process	Group Activity: Design a Helpful Animal
10:00-10:30	**Snack**			
10:30-11:15	Centers: 1. CRISPEE Free play 2. Light table	Design a glowing animal (worksheet) Build your animal with CRISPEE	Ethical Design Activity CRISPEE + Plushie free play	Hands-on Fun Centers: - Chemistry table - Light Table with large animals - CRISPEE free play
11:15-12:00	Centers: 1. CRISPEE Free play 2. Light table 3. Glow books Finish Storybook	Centers: 1. CRISPEE Free Play 2. Glow books scavenger hunt 3. Additive vs. Subtractive Color Mixing	Centers: 1. Microscopes + cells 2. Glow art	*Closing Circle* *Distribute Design Journals to take home*
12:00	**Lunch**			

Curriculum & Learning Objectives

The following table walks through how each lesson of the CRISPEE curriculum, educational support materials, and supplemental activities are linked to specific learning standards.

Table 3

CRISPEE curricular content and connections to learning standards

Bioengineering Curricular Content Goals	**Learning Domains**	**Connection to Learning Standards**
1. Introduce basic concept of genetic codes as the underlying instructional language for the building blocks of all living things	Life Science	*NGSS K-LS1-1.* Use observations to describe patterns of what plants and animals (including humans) need to survive *NGSS K-ESS3-1.* Use observations to describe patterns of what plants and animals (including humans) need to survive
2. Introduce computer programming/coding as a metaphor for altering genetic instructions in living things	Computer Science	*CSTA K-2 1A-CS-02.* Use appropriate terminology in identifying and describing the function of common physical components of computing systems (hardware) *CSTA K-2 1A-AP-11.* Decompose (break down) the steps needed to solve a problem into a precise sequence of instructions. *ITEEA K-2 3.3.A.* The study of technology uses many of the same ideas and skills as other subjects
3. Introduce the foundations of biological engineering as a field that applies engineering design to living biological materials	Engineering Life Science	*NGSS K-2-ETS1-1.* Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool *NGSS MS-ETS1-1.* Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions *ITEEA K-2 3.A.* The study of technology uses many of the same ideas and skills as other subjects
4. Facilitate the design of genetic programs that	Engineering	*CSTA K-2 1A-AP-12.* Develop plans that describe a program's sequence of events, goals, and expected outcomes

create a desired output	Computer Science	*ITEEA 6-8 3.F.* New technologies and systems can be developed to solve problems or to help do things that could not be done without the help of technology *ITEEA K-2 9.B.* Expressing to others verbally and through sketches and models is an important part of the design process
5. Engage children in creative problem-solving to aid animals in relatable story-based challenges (e.g. finding home when lost)	Language Arts Social Studies	*NGSS K-ESS3-3.* Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment *ITEEA 3-5 5.C.* The design of technologies can impact the environment in good and bad ways *ITEEA K-2 9.B.* All products and systems are subject to failure. Many products and systems, however, can be fixed

Day 1: What is Bioengineering?

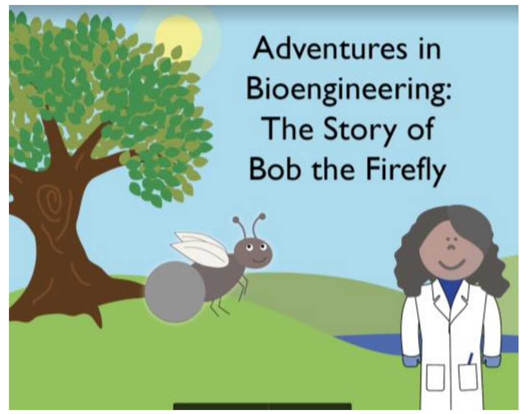
Overview: On Day 1, children will be introduced to bioengineering and learn, through an original storybook, one example of how bioengineering can help solve problems. Children will also explore light physics and practice building light programs with the CRISPEE tool for the first time.

<table>
<tr><th>Prior Knowledge</th><th colspan="3">Objectives</th></tr>
<tr><td rowspan="2">Familiarity with the colors produced by mixing solids (e.g. paints and crayons)</td><td>Students will understand…</td><td>Students will be able to…</td><td>Bioengineering Powerful Ideas:</td></tr>
<tr><td>Bioengineers are special engineers who build things out of living parts
Bioengineers use science as well as engineering
Light colors are produced from a mixture of red, green, and blue light</td><td>Define and utilize the key vocabulary introduced
Identify the fact that light and paint mixes differently</td><td>Representation
Inquiry
Algorithms
Control Structures</td></tr>
</table>

Materials	Vocabulary
- CRISPEE Storybook: Adventures in Bioengineering: The Story of Bob the Firefly - Light Table - CRISPEE Kit - Storybooks: - Rosie Revere, Engineer by Andrea Beaty - Ada Twist, Scientist by Andrea Beaty - Glow by W. H. Beck	- Engineering: Building things to solve problems - Biology: The study of living things - Bioengineering: Modifying the genes of a living organism - Bioluminescence: The quality of glowing animals - Bright vs. dim - Color names: red, blue, green, white, magenta, yellow, cyan

Warm Up (10-15 minutes): Gather into a circle to welcome children and do introductions. Begin by asking children what they already know about science, engineering, and ask if they have heard of bioengineering. After a physical ice-breaker, such as “The Wind Blows”, explain that we are going to to read a book together to learn more about bioengineering.

Framing Activity (20-30 minutes): Bioengineering Storybook
Make sure children are sitting in spots where they can see the book, Adventures in Bioengineering: The Story of Bob the Firefly. Before beginning the book, ask the children about the cover; see if they have any predictions about what the book is about or if they have any questions about the words of the title.



Adventures in Bioengineering was written in tandem with the creation of CRISPEE, and it introduces all of the key bioengineering concepts and vocabulary. This overview introduces the concept of DNA or genes as a coding language. Genes give our bodies the instructions it needs to know how to grow. Throughout the story, call children’s attention to the vocabulary introduced in the book. Additionally, encourage dialogue about the choices presented in the story. Some guiding questions are:

- What is coming from the bodies of the fireflies in the story? Have we seen glowing animals like that in real life? Do we know of other animals that glow?
- Why do you think Bob is nervous about using CRISPEE to change his light color?
- What is bioengineering? What kind of things can we do with bioengineering?
- What kind of things do we think have genes? What kind of things can genes help our bodies do? Do genes change how we think or feel about things?

Since the book is long, it may be a good idea to divide the book into two readings.

Free Play in Centers (60-75 minutes): Allow children to break into small groups to explore the following center activities:

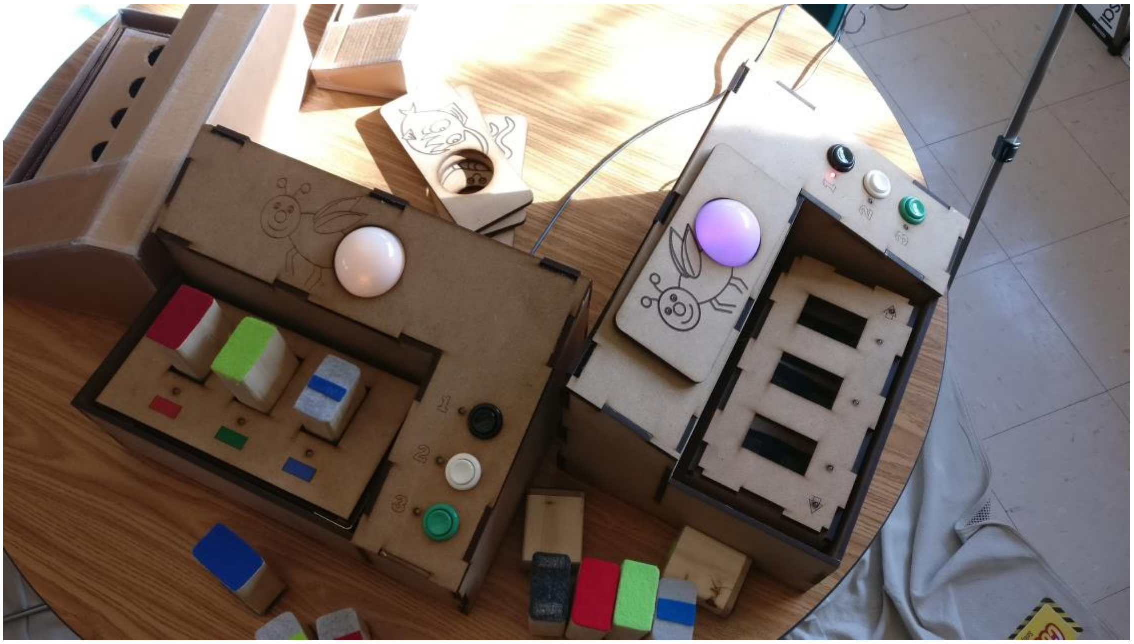
Light Table: The light table provides the opportunity for children to explore the concepts of light mixing. Because CRISPEE applies the concepts of light mixing to bioengineering, the children will need a firm understanding of light mixing in order to fully grasp the logistics of CRISPEE itself.

Activity: Discuss natural light and ask children about the words that they use to describe different types of light during the day. The students will likely be familiar with the primary and secondary colors: red/yellow/blue and orange/green/purple. However, the fundamental colors of light pigments are different: red/green/blue. This may be very confusing for children to understand, which is why the light table is an easy and fun way to explore these ideas and the surprises that this light mixing might bring.

Take it further: Introduce further concepts about light mixing and how it compares to paint mixing. The children could compare paint-mixing to light-mixing by providing small samples of paint and allowing them to compare the similarities and differences in the way that color mixes.

Scale it back: Eliminate the light-related vocabulary and simply leave the light table out as a free-play station.

<u>CRISPEE Free Play</u>: At this station, children will have the opportunity to explore free play with CRISPEE. They should be familiar with the general concepts through the CRISPEE Storybook, yet they might still be unsure of how the tool works. This is absolutely fine, that is the purpose of this exploration! The purpose of this station is for children to explore their own inquiry.



Activity: Leave CRISPEE out for free play. Allow students to explore the tool and develop an understanding of how the controls work. Prompting questions include:

- How did you make that color?
- What do you think the blocks do to the color?

Reflection and Wrap-up (15 minutes): End with a discussion of the day's events and address any questions children may have. Offer time to let them share what they made or worked on. Time permitting, you may read one of the day's storybooks or invite children to work on an activity sheet from their design journals.

In order to keep families involved, you can send home a note to update them about what children worked on through the day. Sample Day 1 note below:

Dear Families:

<table>
<tr><td>What we did today:</td><td>Today we had a very busy day! We learned about many of the things we will explore throughout the week, including the science of biology (or the study of living things), engineering (building things to solve problems) and a special kind of person called a bioengineer who uses engineering and biology to solve problems. We also read an original storybook about a firefly named Bob and his bioengineer friend named Pam.

We also learned that some animals glow! This natural phenomenon is called bioluminescence and helps animals in many ways. We also met and played</td></tr>
</table>

	with CRISPEE for the first time. CRISPEE can help us learn how to use bioengineering to change the color of an animal's light.
How to continue the learning at home:	To bring **engineering** home, offer opportunities to notice the human-made world and how different objects were designed and built. Engineers are involved in building everything from furniture to electronics to clothing! You can also find examples of glowing animals in the world. Going to a pet store or aquarium and finding the animals in real life would be best, but you can also find videos or pictures of glowing animals online. Recommended Reading: Rosie Revere, Engineer and Ada Twist, Scientist by Andrea Beaty; Glow by W. H. Beck

Day 2: What is Science Observation?

Overview: It's time for the students to become scientists! In this lesson, students will make observations about artifacts from nature by using as many of their senses as possible.

<table>
<tr><th>Prior Knowledge</th><th colspan="3">Objectives</th></tr>
<tr><td rowspan="2">Genes are like instructions inside of our bodies that tell us how to grow
Bioengineers can use special machines to change genes</td><td>Students will understand…</td><td>Students will be able to…</td><td>Bioengineering Powerful Ideas:</td></tr>
<tr><td>Scientists use their five senses to make observations about the world
Scientists document their observations
Living things all have genes but they are different instructions and/or in a different order
There are two different forms of color mixing</td><td>Utilize more than one sense in order to make observations and make predictions or guesses about things that they cannot observe
Explain that animals have different genes than humans
Consider the result of different forms of color mixing in their environment</td><td>Representation
Inquiry
Algorithms
Control Structures
Debugging
Design Process
Trade-offs
Systems Thinking</td></tr>
</table>

<table>
<tr><th>Materials</th><th>Vocabulary</th></tr>
<tr><td>Living and non-living natural artifacts
Magnifying glass
Observation document
Easel with paint/markers
Storybooks:
Our Family Tree by Lisa Westburg Peters
Optional: The One and Only Me by 21andMe Inc.</td><td>Observe: to notice or perceive something
Document: record of something in written, photographic, or other form
Prediction: a guess or estimate about something that will happen in the future, often because of something else
Senses: The ways that the body learns about the environment. These include sight, smell, hearing, taste, and touch</td></tr>
</table>

	• Additive color mixing: in light mixing, different all colors are combined to create white • Subtractive color mixing: With solids, all colors are combined to create black

Framing Activity (20-30 minutes): What is a Scientist?
Beginning in a circle, ask the children what they think scientists do. Discuss what they think a scientist can be. Next, ask the students which senses they can use to make observations. Briefly discuss what it means to *document* observations and why this is important for scientists to do.

Free Play in Centers (60-75 minutes): Allow children to break into small groups to explore the following center activities:

Observation Station pt. 1, Five Senses: Allow children to explore various living and non-living materials using their five senses. Encourage them to use multiple senses to observe a single object (avoiding taste or smell for toxic items). Help children remember to record their observations in their Engineering Design Journals (see Curricular Materials). Some ideas for materials to explore include:

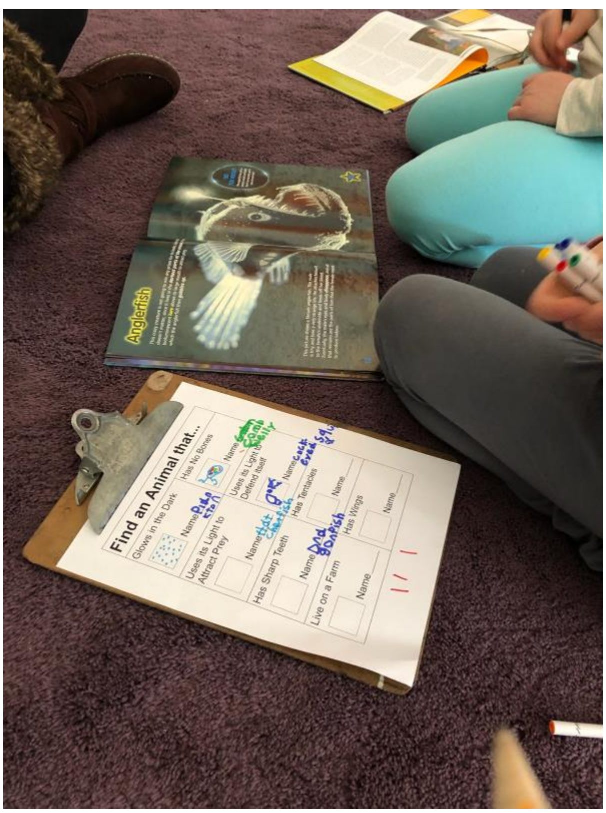
- Coffee beans
- Tea leaves
- Cinnamon sticks
- Sand
- Flour
- Leaves and branches
- Seashells and marine artifacts
- Living plants or animals (e.g. a class pet), if available

Encourage children to use gentle care when handling materials, especially if they are observing living things.


CRISPEE Free Play: In this activity, CRISPEE is again offered as a free-play station. Children should have a stronger concept of bioengineering and will be able to consider CRISPEE as a bioengineering tool, rather than a light mixer. Encourage the children by asking prompting questions such as:

- Do you think glowing animals have genes like these blocks inside their bodies?
- Why do you think CRISPEE is confused by a program with a Off and an On gene of the same color?

Encourage children to explore the animal faceplates. Notice with them that the genes function the same way no matter which animal they are using.



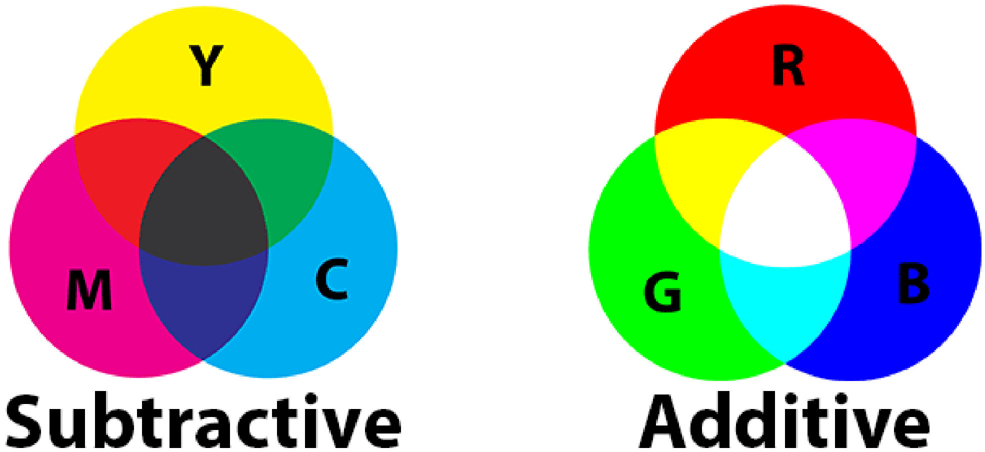
Glow Books Scavenger Hunt: Using their design journals, students will explore the unique biological qualities of animals by looking through the books about glowing animals and searching for animals with special qualities. This activity will give the students a foundation for understanding how bioengineers can build solutions with natural animal traits. This activity will encourage them to think of the differences between animals and reiterate the fact that most (if not all) of their characteristics come from their genes.

Allow children to explore books about genes, animals, and bioluminescence (see materials for book list). Adults can read through part or all of the worksheet with children beforehand to know what they're looking for.

Additive vs. Subtractive Color Mixing: This station allows children to explore the differences between light color mixing and solid color mixing. After their exposure to the light table on Day 1, students may be confused about mixing red, green, and blue rather than the primary colors that they may have been exposed to in art classes. Additive colors combine red, green and blue together to form white (as seen in the light table). Subtractive colors, on the other hand, combine cyan, magenta and yellow to create black (as children can prove with paint mixing).

Provide each child with two printed worksheets with three-ring venn diagrams; allow children to track the light color mixing patterns on one sheet and paint/solid color mixing in the other.

Example of additive vs. subtractive color mixing diagram



https://www.maketecheasier.com/why-printer-use-cmyk/

Reflection and Wrap-up (15 minutes): End with a discussion of the day's events and address any questions children may have. Offer time to let them share what they made or worked on. Time permitting, you may read one of the day's storybooks or invite children to work on an activity sheet from their design journals.

Sample Day 2 note to families below:

Dear Families:

What we did today:	Today we played with science tools like **magnifying glasses** to help us **observe** living things. We learned about **biology**, the study of living things, and how biologists and other scientists learn about animals by observing them. We also learned about how bioengineers solve problems by re-sequencing **genes**, or *instructions (like a program or a recipe) inside of the bodies of*

	living things. Bioengineers can make things like medicines and learn about animals by exploring their genes.
How to continue teaching at home:	To help your child continue to use their **biology** skills, you can help them notice the natural wildlife surrounding your home or in your yard. Ask your child questions about the important features of the animals and their corresponding habitats. To help your child remember these lessons you can ask them to explain what genes are and why living things look different. All living things have genes, including humans! Children can think about genes by noticing things about animal families that are similar from parents to their babies, and special traits that different animals have. What kinds of genes do you think they have? Recommended Reading: Our Family Tree by Lisa Westburg Peters; The One and Only Me by 21andMe Inc. (Note: 23andMe Inc. is a gene sequencing company)

Day 3: What is Ethical Engineering Design?

Overview: Children will begin this lesson by thinking about how engineers build things using the engineering design process. They will also learn about ethics and values, and consider how our values can help us make choices and think about consequences of our choices. Finally, students will put everything they've learned to use to ethically design their own helpful animal.

Prior Knowledge	**Objectives**		
● Genes are like instructions inside of our bodies that tell us how to grow ● Bioengineers can use special machines to change genes ● Bioengineers use science as well as engineering	Students will understand…	Students will be able to…	Bioengineering Powerful Ideas:
	● Ethics are very important for bioengineers at every stage of their work ● Bioengineering is a tool for problem-solving ● Some animals have different senses than humans	● Justify a decision based on a specific value ● Consider bioengineering as a problem-solving tool to give animals senses from others	● Inquiry ● Algorithms ● Debugging ● Design Process ● Representation ● Trade-offs ● Systems Thinking

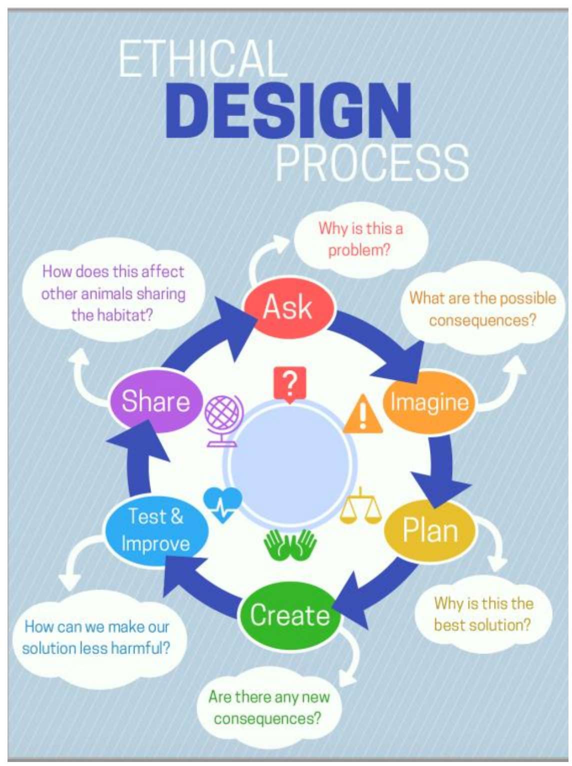
Materials	Vocabulary
● Ethical Design Process poster ● Microscopes and slides ● Storybooks: ○ Meet Bacteria by Rebecca Bielawski ○ The Invisible ABCs by Rodney P. Anderson	● Value: Something you care about and might be the most important thing to you in life ● Ethics: Values that we use to help us make decisions. ● Microscope: A tool used for viewing very small objects, such as animal or plant cells ● Cell: Tiny building blocks of any living thing, typically only viewable through a microscope

Framing Activity (20-30 minutes, may be broken up across the day): First gather in a circle where everyone can see the teacher. Begin by asking the students if any of them have heard of the word "value" and asking if someone can share what it means. Next, ask the students to each share one thing that they value - one thing that they care about. Offer examples such as family, friends, nature and the environment, animals, school, etc.

Introduce Engineering Design: Introduce students to the engineering design process. Start by moving through the major steps (ask, imagine, plan, create, test and improve, and share). You can read books (e.g. If I Built a Car by Chris Van Dussen) to reinforce the concepts. For students who have previously been introduced to the engineering design process, you may want to move on immediately. For students who are new to the concept, you may decide that waiting until later in the day to revisit the engineering design process is necessary.

Introduce Ethics: Begin by discussing the concept of values, or things that we care about and even love. You can leverage body-syntonic learning by describing a value as a feeling of caring that comes from our hearts. You can use the values worksheet from their bioengineering design journals to help children identify their own values.

Introduce the Ethical Design Process: If the students are already familiar with the engineering design process, then the transition to the ethical design process should be a smooth one. For many students, this may be their first introduction into conversation about ethics, so it is easiest to connect the ideas to things that they value and care about, such as family/friends and love/kindness.



After you have introduced both engineering design and ethics, you can move on to the Ethical Engineering Design Process by showing them the Ethical Design poster. (Alternatively, you can simply add ethical questions to each of the steps on an engineering design process poster.) Explain to the students that bioengineers must make sure that they are making ethical decisions throughout every step of this process, which means that they have to choose a value that is important to them and their designs. They may "ask" how to build a solution that helps humans, or that does not hurt animals. Remind students that when we "imagine" solutions, we can also imagine ways the solution can have *consequences*, or results that happen because of something else. At the "planning" stage, a bioengineer would decide which animal has a gene that could help this problem and whether it is safe to use that gene. Ask ethical questions at every stage of the engineering design process.

Free Play in Centers (60-75 minutes): Allow children to break into small groups to explore the following center activities:

CRISPEE Free Play: In this activity, CRISPEE is again offered as a free-play station.

Activity: By now, children should be very comfortable building and testing programs on CRISPEE and explaining how CRISPEE simulates gene editing. You may choose to further support their free play in these areas, or to foster their curiosity about how CRISPEE was built. Encourage them to remember their five senses from the previous lesson on science observation, and prompt them with some questions:

- How do you think CRISPEE was built? Who built it?
- What do you feel/smell/see? What clues do your observations give you about the materials that CRISPEE is made out of?

Children may notice the burned edges of wood on the CRISPEE casing, the wires on the interior that power the lights, or the bulb that glows in many colors. Offer a computer with videos that show how engineers use laser-cutters to cut wood, soldering irons to make circuits, and how LED lights can be programmed to change colors.

Take it further: You can explain that CRISPEE is a *prototype*, or an engineer's first try at making something. Invite them to look for "bugs" or errors to fix, or other ways to improve CRISPEE. Have them record their observations using pictures and words so that other engineers can benefit from their helpful observations.

Observation Station pt. 2, Microscopes: In this activity, students can explore life at a tiny scale using microscopes. This activity works very well as a station with one or two students per microscope. Prep the microscopes with a slide already positioned to view clearly through the lens.

Activity: Open by asking students if they have heard of a microscope before, or can guess what it does. What do they think a microscope can be used to see? Invite them to observe slides with just their eyes, and then show the same slides under a microscope. Reinforce that a microscope can show us things that are so small that we almost can't see them! Before the students have the opportunity to begin exploring with the microscope, give them a quick demonstration on adjusting the lens and being very careful with sharp or fragile glass materials. After they are ready, leave the microscopes open for supervised free exploration.

Take it further: Students may wish to draw their favorite slide and keep it as an observation for their Bioengineering Design Journals.

Scale it back: Some students may struggle with adjusting the microscope and can only view blurry shapes. It is helpful to have an adult involved with the technical implementation of the station.

Glow Art: Students will have the opportunity to work with glow-in-the-dark tape, stickers, crayons, or paints to freely create their own artwork. This will allow students to engage with and express themselves through glowing light.

Activity: Leave pieces of glow in the dark tape and colored sheets available for students to freely create artwork. Encourage students to compare glow in the dark materials with bioluminescence. You can draw children's attention to the fact that glowing tape was made by engineers, but they may have gotten inspiration for glowing things by learning about bioluminescence in plants and animals.

Take it Further: Allow children to look at picture books about bioluminescent animals to inspire their artistic exploration.

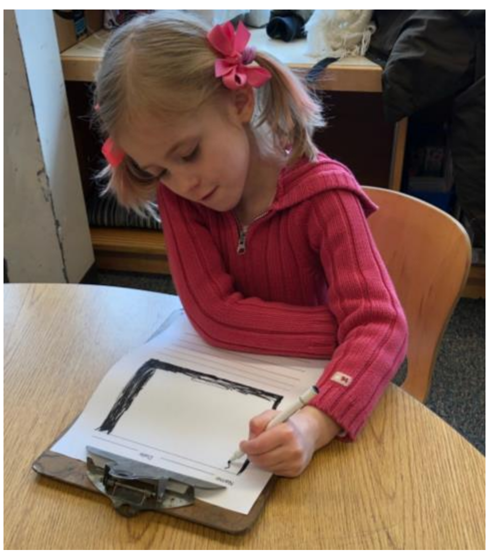
Group Activity: Ethical Design (30-40 minutes)

Group Activity: Remind them of the Adventures in Bioengineering storybook and the Ethical Design Process. Explain that today, we will use ethical design to solve a problem together as a group.

Begin by walking through the ethical design process steps together using the familiar example provided by the storybook. To expand on the storybook, ask the students if they can think of any consequences that could have arisen from bioengineering Bob's light. For example, is there any particular reason that one color would be better than another for Bob? What kinds of things could we test and improve to help Bob? As a group, walk through the design process and think carefully about the consequences of every design step. Reiterate the importance of testing and improving, because no one ever comes up with a perfect solution the first time.

Ask the students if they can think of a different problem that can be solved with bioengineering. This conversation will likely need support and scaffolding, so listen closely to their ideas and help point out ideas that they can grow into bioengineering solutions. After having a brief conversation about these problems as a group, divide into one-on-one pairs with children and adults. Some examples that children might come up with include:

- Pollution in natural habitats
- Medicines that humans need
- Animals that are endangered of going extinct



Individual Activity: Give students time to choose one problem they want to focus on, and try to develop their own solution. Encourage them to think of ways bioengineering can help. For example, can they think of another animal that has solved the same problem somehow? What genes might they have that can be borrowed?

Always consider whether or not your solution is harmful (to humans, animals, the environment, etc.), and if so, revise the design to become less intrusive and harmful.

Reflection and Wrap-up (20 minutes): End with a discussion of the day's events and address any questions children may have. Offer time to let them share what they made or worked on. Time permitting, you may read Meet Bacteria by Rebecca Bielawski and invite children to make connections from the storybook to their explorations with the microscopes.

Sample Day 3 note to families below:

Dear Families:

What we did today:	Today, we discussed **values**, or *a person's beliefs about what is important*. We thought about our own values, and noticed that many of us have some values that are the same and some that are different. We'll keep talking about values as we explore ethical questions of bioengineering throughout the week. We read the book Meet Bacteria by Rebecca Bielawski, and explored bacteria on our own using **microscopes** to see tiny cells and organisms. We also played with different iterations of CRISPEE and learned how **prototypes**, or test versions of products, can be made with techniques like **laser cutting**. Finally, we discussed the ethical design process, and how bioengineers think about **consequences,** or *things that happen because of something else*, and **tradeoffs,** or *corresponding positive and negative outcomes from a decision.* Finally, we began to think about the consequences of creating bioengineered animals and releasing them into natural habitats.
How to continue teaching at home:	To help your child explore animal senses, you can help your child observe animals in the real world and discuss how their genes are different from ours. To connect to our ongoing ethical discussions, we recommend that you invite children to consider both positive and negative **consequences**, or results, of choices (their own or someone else's). To support our discussion about **values**, you can talk about shared priorities that are important to you, your family, or your culture. Remind children that other people may have different or similar values, and that we can still be friends and get along by talking about our values. Recommended Reading: Meet Bacteria by Rebecca Bielawski; The Invisible ABCs by Rodney P. Anderson

Day 4: Bioengineering a Helpful Animal

<u>Overview</u>: The students will work together as a group to bioengineer Bob to change colors in various environments. This gives the students an opportunity to apply their knowledge of light color mixing, gene editing and the ethical design process in the simulation of a real world bioengineering application. This will be a good activity to wrap up the curriculum and all the topics covered.

Prior Knowledge	**Objectives**		
• Familiarity with Bioluminescence • Familiarity with CRISPEE	Students will understand…	Students will be able to…	Bioengineering Powerful Ideas:
	• How bioengineers can use ethics and values to help them to solve problems	• Consider the consequences of bioengineering designs	• Inquiry • Algorithms • Control Structures • Design Process • Representation • Trade-offs

Materials	Vocabulary

• Ethical Design Process poster
• Microscopes and slides
• Oversized CRISPEE Animal Poster
• Light Table
• CRISPEE
• Food dye (various colors)
• Graduated cylinders
• Test tubes
• Waterproof bin
• Storybooks:
    ○ <u>Stronger Than Steel: Spider Silk DNA</u> by Bridget Heos
    ○ <u>Gregor Mendel: The Friar Who Grew Peas</u> by Cheryl Bardoe
	• Biosensor: Special genes that give our bodies new instructions depending on what information is coming to our senses. Biosensors work like an "If statement" in computer science.
	• Toxic/Toxin: Toxic means poisonous or harmful to living things. Toxins are materials (like food, water, or gases) that are toxic to humans or animals.

<u>Group Activity: Design a Helpful Animal (30-40 minutes)</u>

Activity: Recall prior conversations with students about their senses, and explain that some animals have different senses. For example, pigeons can use sight to identify certain kinds of diseases (e.g. breast cancer) in humans even when medical machines cannot. Sometimes these senses cause their bodies to change physically in different environments. Usually this happens without the animal trying or realizing. Discuss why animals might have these special abilities. Explain that this is caused by a special gene, called a *biosensor*, that can change how an animal's body looks depending on what it can sense about its environment.

Distinguishing between extraordinary senses and biosensors

Extraordinary senses	Biosensors
• A dog's strong sense of smell • An hawk's ability to see • A bat's exceptional hearing	• A chameleon changing color • Coal miners used canaries for years because canaries were better at detecting toxins than humans. (You may want to discuss the consequences of this solution.)

After this discussion, provide the following example: in an imaginary forest, there is a toxic (or poisonous) gas that is harming the animals and plants that live there. Humans are trying to clean it, but they cannot see or smell the toxin. How can we bioengineer Bob to help humans find the toxins?

Work with students towards a solution that involves changing Bob's light to indicate to humans when he senses a toxin. Ask students to choose colors for each type of environment (toxic and non-toxic). Record these choices with a CRISPEE planning sheet.

You can use the oversized animal posters and light table for this activity, or a CRISPEE placed in the middle of the circle to give children a visual to follow along. To make this more interactive, you can assign students to different roles:

- Toxin-holder: One or more children can hold different objects, such as oversized test-tubes of colored water, to represent a toxic material in the environment. Invite them to stand in different spots around the carpet/room holding their "toxin".
- Bob the Firefly: Allow children to role-playing as Bob, and to walk near and far from the "toxins". As they approach the different environments, how should Bob's light change? Students can carry large posters or papers of different colors to show off their glowing firefly light, or other children can program his light with the Light Table or CRISPEE.
- Gene Programmers: Some children can decide on Bob's light programs. Help them consider that they need a program for each environmental circumstances (e.g. what color is his light in toxic environments? Non-toxic?). The gene programmers can change the light table accordingly as Bob moves near and far from the toxins.

At the end of the activity, discuss with students both the positive and negative ethical consequences of bioengineering Bob. What could have happened if we had chosen a different color?

Take it Further: Encourage children to think about predators or prey who may not be used to certain light colors, to consider camouflage, etc. Focus on intended as well as unintended consequences that we can predict. You can end with a discussion of what questions bioengineers need to ask when they build gene programs like this.

Free Play in Centers (60-75 minutes): Allow children to break into small groups to explore the following center activities, and any others from earlier in the curriculum that were favorites with children. (CRISPEE should always be available as a free-play station.)

Chemistry Table
Activity: The students will work with water and dye to explore a different form of color mixing. Set up tubes with water and drops of different colored food dye. Provide child-size safety equipment like lab coats, gloves, and goggles. Allow for free play with the water tubes. Encourage students to discuss the difference between the food dye mixing and color mixing.

Take it Further: As students work with the dye, they may have questions about why the colors are mixing differently. This is a good opportunity to discuss the difference between light and other types of color mixing, such as paint mixing.

Oversized Animals Activity
Activity: This can be a free-play extension before or after introducing the Collaborative Engineering Activity. Set up the oversized animal poster board with the light table and encourage free play. You can offer conversation prompts about how the colored knobs on the light table compare to CRISPEE blocks.

Take it further: Set up CRISPEE next to the light table and ask students to recreate the light. Discuss with students whether there any consequences to changing an animal's light.

Reflection and Wrap-up (15 minutes): End with a discussion of the week's events and reflect on how much everyone has learned. Offer time to let students share what they made or worked on. Time permitting, you may read one of the day's storybooks or invite children to work on an activity sheet from their design journals. Allow them to take their Bioengineering Design Journals home after the final circle. If appropriate, this can be a special time for glow-in-the-dark prizes and treats!

Sample day 4 note to families below:

Dear Families:

What we did today:	Today, we put all the steps of our ethical engineering design process to work! The *ethical* **engineering** design process consists of six steps: 1) **Ask**: *Why is this a problem?* 2) **Imagine**: *What are the possible consequences*? 3) **Plan**: *Why is this the best solution?* 4) **Create**: *Are there any consequences for the animal?* 5) **Test & Improve**: *How can we make our solution less harmful?* 6) **Share**: *What are the consequences for the habitat or to other animals?* Bioengineers can use special genes to engineer animals that change when their bodies sense things in the environment, such as toxins or other animals. We also learned about animals that change colors when they sense specific things.We can know just by looking at their light color if the air is safe to breathe or if the water they're swimming in is warm! We used everything we have learned throughout the week to create a final group project with CRISPEE. We applied the engineering and ethical design process to design animals that can sense things like toxins in the environment, find their friends, and glow different colors to alert humans to changes in the environment. We also revisited a variety of play activities from the first day of the curriculum to see how our understanding of engineering, science, and ethics has grown. Today we also did hands-on playful science activities using **pipettes, lab coats, beakers** and other chemistry tools to explore properties of water and oil. We also made **glow-in-the-dark art** using glowing tape! Finally, we were all very excited to share our work in a final share-out circle! We focused on the importance of explaining our decisions and talking about our ethical engineering choices.
How to continue teaching at home:	We really want to thank you for allowing us to go on this journey with your child. Your help and contributions have aided your child and our research immensely. To progress our teachings for your child we recommend that you continue discussing observational skills as well as how to ethically justify their problem solving decisions. Some of our favorite reading and viewing from the week, and other suggestions: The Invisible ABCs by Rodney P. Anderson Stronger Than Steel: Spider Silk DNA by Bridget Heos Meet Bacteria by Rebecca Bielawski Glow by W. H. Beck Gregor Mendel: The Friar Who Grew Peas by Cheryl Bardoe Octonauts cartoon: "Octonauts and the Long-armed Squid" (Season 2, Ep. 11)

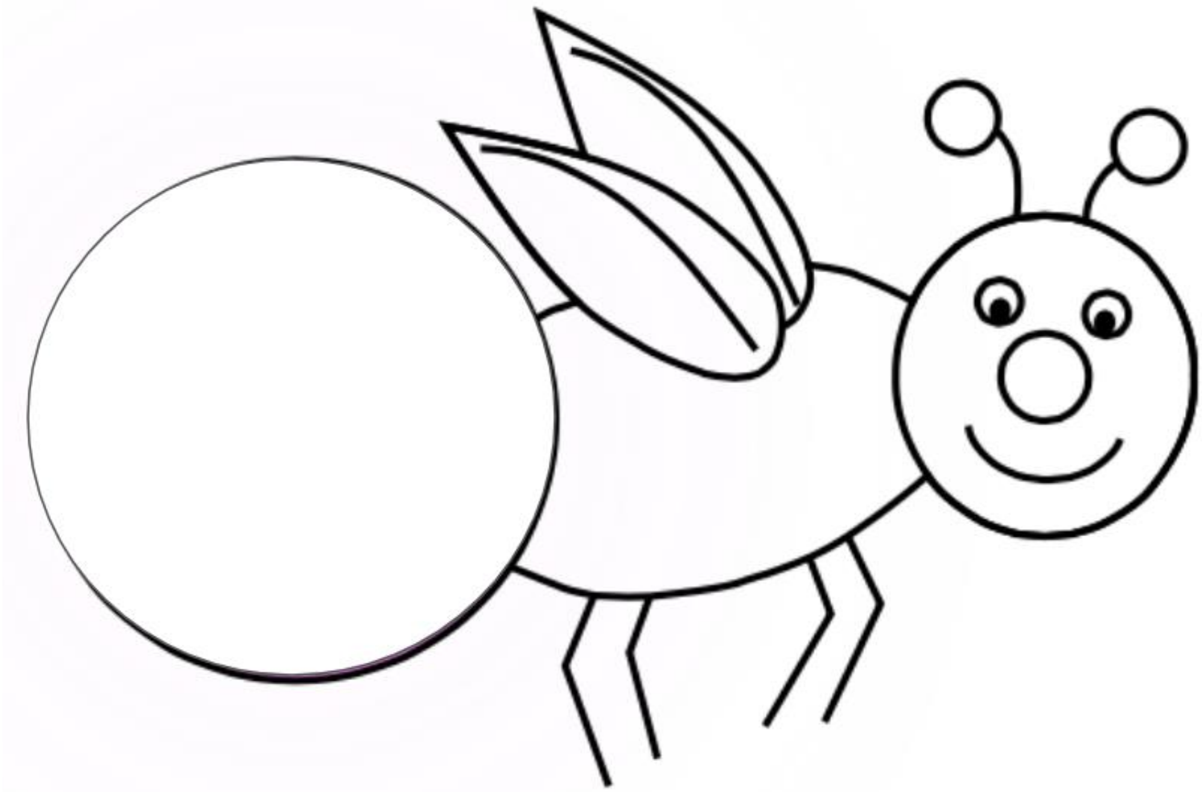
Curricular Materials

In the following sections, you'll find:

- Ethical Design Process Poster
- Bioengineering Design Journal Pages, including
    - Science Investigation worksheets
    - CRISPEE Program Planning Sheet
    - Picture Book Scavenger Hunt: Bioluminescent Animals
    - My Values Worksheet
    - Helpful Animal Worksheet
    - Bioengineering Word Search
    - Bioengineering Coloring Sheets


ETHICAL
DESIGN
PROCESS
Why is this a problem?
How does this affect other animals sharing the habitat?
Ask
What are the possible consequences?
Imagine
Share
Plan
Test & Improve
Create
Why is this the best solution?
How can we make our solution less harmful?
Are there any new consequences?

My Bioengineering Journal



Name: ____

name: ______________________________

Scientist use their senses to investigate.

looks like:	feels like:
smells like:	sounds like:

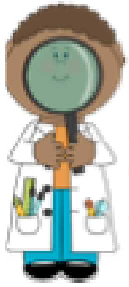
Write a sentence about your object.

____

____

____

Name____Date____________________

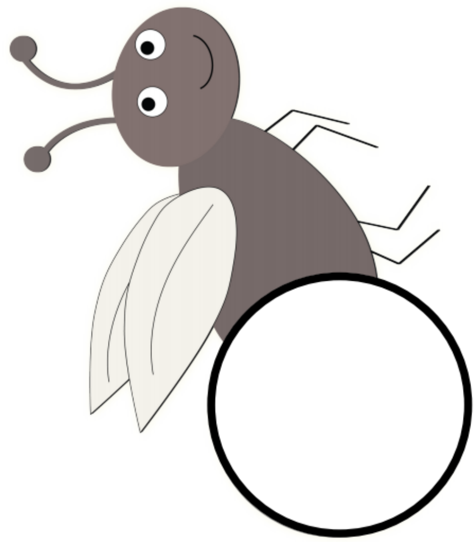


OBSERVATION STATION RECORDING SHEET

Scientist's use their eyes and hands to **observe** matter. Choose an object to observe like a scientist. Record your findings in the chart below.

I am observing a(n) ___________________________________

color(s)	
pattern/design	
size	
shape	
texture	
sketch	



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Find an Animal that...

Glows in the Dark ☐ Name:______	Has No Bones ☐ Name:______
Uses its Light to Attract Prey ☐ Name:______	Uses its Light to Defend itself ☐ Name:______
Has Sharp Teeth ☐ Name:______	Has Tentacles ☐ Name:______
Live on a Farm ☐ Name:______	Has Wings ☐ Name:______

Draw...

The Scariest Animal

Animal Name: _______________

The Silliest Animal

Animal Name: _______________

Your Favorite Animal

Animal Name: _______________

My Values

Values are a person's beliefs about what is important. Everyone has different values, and we may have some that are the same! What are some of your values?

 Family	 Friends
 School	 Animals
 Helping people	 Honesty

Name: _________________________

My Helpful Animal

My problem is: _______________

____

____

____

____

____

My animal: ___________________________

Name: ______________________

Why this animal solves this problem: _______________

____

____

____

____

One reason my idea might be helpful is

____

____

One reason my idea might be harmful is

____

____

NAME:______________________________ DATE:____________

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Bioengineering Word Search

Y	J	I	C	H	F	I	R	E	F	L	Y	N	V	W
E	N	L	Y	V	T	H	S	C	I	E	N	C	E	E
L	L	H	L	T	Z	E	B	R	A	F	I	S	H	K
L	I	B	I	O	B	R	I	C	K	C	W	Q	I	M
O	G	B	I	J	E	L	L	Y	F	I	S	H	U	G
W	H	R	D	O	M	H	W	H	I	T	E	E	S	E
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J	M	I	A	Q	Y	N	U	X	G	R	I	E	J	E

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BLUE
CRISPEE
CYAN
DNA
DROPPER
FIREFLY
GENE
GREEN
JELLYFISH
LIGHT
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