Engineering in Middle School with Phenomenal Instruction

Egg drop and more! Learn how to take this activity, and other projects to the next level with phenomenal problem-based learning. Teachers engage in student-driven Engineering Internships that incorporate all aspects of the new Science & Engineering Practices from the Michigan Science Standards as well as Disciplinary Core Ideas from the domains of earth, life and physical sciences. This exciting session will inspire educators with hands-on activities, digital tools, active reading, dynamic discussion, and reflection on their own teaching practices. Teachers will leave armed with the ability to integrate phenomena-based science instruction around real-world problem solving into their classrooms.

Resource Folder: https://jmp.sh/ilAjhX5

Objectives

- Support teachers with a deeper understanding of the Science and Engineering Practices.
- Engage teachers with phenomena-based instruction, model units and lessons.
- Provide teachers with usable free resources.

Amplify Connection: Middle School Engineering Internship Units

21st-century science students need deep dives into the application of science in real life and how it is instrumental in addressing major challenges that confront society today. Each Engineering Internship unit of Amplify Science has students designing solutions for a real-world problem that requires them to figure out how to help those in need through the application of engineering and design practices. The units emphasize compassion, sympathy, and the consideration of the needs of diverse peoples, from tsunami victims in Sri Lanka to the special needs of premature babies.

The Engineering Internship units invite students to take on the role of engineering interns in a fictional company called “Futura Engineering.” In the first lesson, a fictional project director appears in a video to introduce students to their design challenge and present them with some important background information. Importantly, this is also where students are introduced to the competing design criteria and limiting constraints they are going to have to balance in their designs. Students quickly learn that in the Engineering Internships, there is not one right answer. Rather, they are going to have to work together to iteratively design the best solution that they can justify through data they've collected.

- There are two Engineering Internship units per year.
- The Engineering Internship units contains a total of ten lessons, each designed for a minimum 45-minute session.
Metabolism (Life Science)

How can we design health bars that meet the metabolic needs of patients or rescue workers?

Anchor phenomenon: Designing health bars with different molecular compositions can effectively meet the metabolic needs of patients or rescue workers. Students act as food engineering interns to design a health bar to feed people involved in natural disasters, with a particular emphasis on two populations who have health needs beyond what can be provided by emergency meals: patients and rescue workers.

Natural Selection (Life Science)

How can we design treatments for malaria that don’t lead to drug resistance?

Anchor phenomenon: Designing malaria treatment plans that use different combinations of drugs can reduce drug resistance while helping malaria patients. Students act as biomedical engineering interns to design a malaria treatment plan.

Earth’s Changing Climate (Earth/Space Science)

Why is the ice on Earth’s surface melting?

Anchor phenomenon: The ice on Earth’s surface is melting. In the role of student climatologists, students investigate what is causing ice on Earth’s surface to melt in order to help the fictional World Climate Institute educate the public about the processes involved.

Plate Motion (Earth/Space Science)

How can we design an effective tsunami warning system?

Anchor phenomenon: Patterns in earthquake data can be used to design effective tsunami warning system. Students act as mechanical engineering interns to design a tsunami warning system for the Indian Ocean region.

Phase Change (Physical Science)

How can we design portable baby incubators that use phase change to keep babies at a healthy temperature?

Anchor phenomenon: Designing portable baby incubators with different combinations of phase change materials can keep babies at a healthy temperature. Students act as chemical engineering interns to design an incubator for low-birthweight babies.

Force and Motion (Physical Science)

How can we design delivery pods that are damaged as little as possible when dropped?

Anchor phenomenon: Designing emergency supply delivery pods with different structures can maintain the integrity of the supply pods and their contents. Students act as mechanical engineering interns to design delivery pods—pods of emergency supplies that will be dropped in areas experiencing a natural disaster.
1 **Scientific and Engineering Practices**
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

2 **Crosscutting Concepts**
1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change
3 Disciplinary Core Ideas

**Physical Sciences**
PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

**Life Sciences**
LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity

**Earth and Space Sciences**
ESS1: Earth’s place in the universe
ESS2: Earth’s systems
ESS3: Earth and human activity

**Engineering, Technology, and Applications of Science**
ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society
Background

The new Michigan K-12 Science Standards, based upon the Next Generation Science Standards, replace the standards adopted in 2006, commonly known as the Grade Level Content Expectations and High School Content Expectations for Science. The new standards are really a set of student performance expectations. These performance expectations incorporate three main elements:

- Disciplinary Core Ideas (science specific concepts in the life, earth, and physical sciences),
- Science and Engineering Practices (the practices of engaging in scientific investigation to answer questions, and engineering design to solve problems),
- Cross-Cutting Concepts (conceptual ideas common to all areas of science).

These expectations are also interwoven across disciplines, including connections to language arts and mathematics.

The adoption of new standards provides a tremendous opportunity in Michigan not only to improve science learning, but also to improve literacy and thinking skills of all children.

MSTA DEMO ACCOUNT

To get started, go to: learning.amplify.com
Click on the Log in with Amplify button
Teacher account: t.MSTA2020@tryamplify.net
Master password: AmplifyNumber1
Student account: s1.MSTA2020@tryamplify.net
Master password: AmplifyNumber1
After you log in, you will be taken to the Amplify Curriculum.
Day 1: Welcome to Futura!

Hello interns,

Welcome to Futura’s Mechanical Engineering Division! I’m Nisha Kar, your new project director.

We will work on a project for International Disaster Aid. They want to use helicopters to drop packages of water, food, and first-aid supplies in hard-to-reach places hit by natural disasters. You will use what you know about force and motion to design a supply pod that addresses three criteria. We want to:

1. minimize cargo damage;
2. maximize shell condition; and
3. keep costs low.

Today you’ll learn more about collisions and impact forces by exploring the SupplyDrop Design Tool and reading the Futura Mechanical Engineer’s Dossier. Note: Dossier (DAW-see-ay) is a term professional engineers sometimes use for a set of related documents. It includes a glossary to support you if you need help with unfamiliar words.

Deliverables

- Annotations for Chapter 2: “Collisions and Impact Forces”
- After-Hours: Annotations for Chapter 1: “Request for Proposals”

I’m excited to be working with you,

Nisha

Nisha Kar, Project Director
Futura | Mechanical Engineering Division
International Disaster Aid is an organization that provides relief during natural disasters. One way it does this is by using helicopters to drop emergency supplies in areas that have been affected by natural disasters like earthquakes or floods. The emergency supplies must be packed in containers called supply pods that protect the supplies as they hit the ground. International Disaster Aid has issued a Request for Proposals (RFP) for the development of supply pods to hold emergency supplies as they’re delivered to people in need. Successful proposal designs will address the following three criteria:

1. **Minimize cargo damage**
   The supply pods must be designed so that they protect the supplies when the pod hits the ground. Broken or damaged supplies will not help the people who need them.

2. **Maximize shell condition**
   The shell of the pod should be reusable after the drop. If the supply pod has almost no damage, the whole outer shell may be used as a shelter for up to three people, protecting them from the sun and rain.

3. **Keep costs low**
   The cost of the pod must be low so that International Disaster Aid can help as many people as possible. The lower the cost of each pod, the more pods International Disaster Aid can build and deliver.

In addition to meeting the above criteria, the design of the supply pod should take into account the constraints, or limits to the possible solutions. These constraints include:

- Supply pod must be delivered by helicopter.
- Supply pod must be dropped from the same height for each test.

This helicopter is bringing relief supplies after a natural disaster in Indonesia.

After disasters, people sometimes build temporary shelters out of whatever materials are available. The shell of a supply pod can be reused for this purpose, as long as it remains in good condition after the drop.
You may be familiar with collisions. These are events in which two objects hit each other, such as a bug hitting the windshield of a car or a soccer player kicking a ball. Every collision exerts an equal-sized force on each object involved in the collision. These forces can change the objects’ velocity, or speed in a particular direction.

A dropped supply pod hitting the ground is another example of a collision. Earth and the pod experience the same amount of force during the collision, but because Earth is so big, it’s barely affected. The pod, on the other hand, can be damaged by the force of the collision because it experiences a big change of velocity—to zero! Engineers are not concerned with how the collision affects Earth, so they focus on only one of the equal forces exerted during the collision: the force exerted on the pod. This force is called the impact force.

To keep the contents of the supply pod safe, engineers aim to keep the impact force as small as possible. The greater the force when the pod hits the ground, the more likely the materials are to break. Three factors affect the size of the force when the supply pod hits Earth: how long the collision lasts, the velocity of the pod on impact, and the mass of the pod.

### Changing the Time of Collision

When a supply pod hits the ground, the collision seems to happen in no time at all. However, if we could use a special slow-motion camera, we could see that some collisions last longer than others. The longer the collision takes, the smaller the impact force on the object. It might seem strange to think that a longer collision would do less damage to the object, but that’s exactly what happens. This is why there are pads wrapped around the goal posts at football and rugby games—if a player collides with the post, the pads compress, or squish down, during the collision. Due to the padding, the time of collision is slightly longer, and the force is spread out over a longer period of time, making the player’s collision with the pole hurt less!
Chapter 3:

Velocity, Mass, and Impact Forces

Changing the time over which a collision happens isn’t the only way engineers can design for impact forces. Both the velocity and the mass of an object affect the impact forces involved in a collision.

Changing the Velocity of the Pod on Impact

The faster objects are moving when they collide, the more force they experience during the collision. If you can slow an object down, it collides with less force. How can you slow a falling object? Imagine taking two identical pieces of paper, crumpling one into a ball, and then dropping both pieces from the same height. The crumpled piece of paper would have a greater velocity than the flat piece (and would hit the ground much sooner). Both pieces of paper have the same mass, so why does one move faster than the other? The flat piece is more spread out and more of its surface interacts with the air as it falls—it slows down due to air resistance, a type of friction caused by air molecules.

Just as friction slows objects down as they move across surfaces, air resistance slows objects down as they fall through the air. The more of the surface of the object interacts with air molecules as it falls, the more air resistance it experiences. Engineers can slow falling objects and reduce impact forces on objects by increasing the amount of the objects’ surfaces that experience air resistance. However, this doesn’t work in space. In places where there are no air molecules (like in space), there is no air resistance.
Changing the Mass of the Supply Pod

Objects with more mass collide with more force. Imagine that a soccer ball rolls off a table and falls on your foot. Next, imagine a bowling ball rolls off that same table and falls on your other foot. You will feel that there is more impact force with the bowling ball—ouch! Many people think that the bowling ball must be moving faster than the soccer ball because it hits your foot harder. However, since the objects are about the same size and shape, they experience a similar amount of air resistance as they fall. They fall at the same velocity. (In fact, this is true for any two objects, no matter what their mass, if air resistance is not a big factor. When dropped from the same height, they will land at the same time.) Changing an object’s mass does not change the speed at which it falls; it only affects the impact force.

Designing for Impact Forces

Our pod designs are a bit like that soccer ball and bowling ball—in each test, the shell is the same size, but the contents have a different mass. The contents of the shell and the materials used to build it determine its mass, but do not change its velocity on impact. In order to change velocity, the pod would need something that increases the surface that interacts with the air, like a parachute or flaps.

Engineers can decrease the impact forces by decreasing the mass of the pod, decreasing the velocity of the pod, and increasing the time over which the collision occurs.
Egg Drop Design

1. **Plan**: Choose the materials for your Egg Drop Model. Sketch and label your initial design in the space below.

2. **Build**: Make your design.
   - Before you test, record the mass of your Egg Drop Model in the Plan and Build section below. Be sure your egg is inside!

3. **Test**: Bring your Egg Drop Model to the test site. After you test, record the results.

4. **Analyze**: Reflect on your design in the Design Analysis (on page 7).

**PART 1: DESIGNING AN EGG DROP MODEL**

**Plan and Build**: Draw your design. Record your Egg Drop Model’s mass.

Mass of the Egg Drop Model (grams): __________

Describe your design:

_____________________________________________________________________________________
_____________________________________________________________________________________

**Test Results**: Record your results in the space below. Sketch or describe what happened to the pod and to the egg when it collided with the ground.

_____________________________________________________________________________________
_____________________________________________________________________________________
PART 2: ANALYZE YOUR EGG DROP MODEL

Design Successes: Which parts of your design worked? Why do you think they worked?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Design Failures: Which parts of your design did not work? Why do you think they did not work?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

PLAN YOUR NEXT ITERATIVE TEST

Draw and describe your revised design.

What would you change?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Why would you make these changes? Describe the science concepts that support your decisions.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
Project Summary: Defining the Problem

Summarize your understanding of the project by answering the following questions. You may wish to review the Dossier to help you respond to the questions.

1. What is the engineering problem you are trying to solve?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

2. Describe the first criterion—minimize cargo damage—and why it is important.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

3. Describe the second criterion—maximize shell condition—and why it is important.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

4. Describe the third criterion—keep costs low—and why it is important.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

5. Based on your research so far, which criterion do you think is most important for a successful drop pod design? Why?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

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Each engineering intern team will design a pod that has four basic parts:

1. an outer shell that helps protect the cargo and holds everything together
2. inner padding that increases collision time and protects the cargo
3. top add-ons that can slow the pod’s velocity while falling
4. bottom add-ons that increase collision time to help reduce collision forces on impact

Supply pods have four parts that can be selected in different combinations to get different results in testing: padding inside, a hard outer shell, and two kinds of add-ons. Add-ons to the top can reduce a pod’s velocity while falling, and add-ons to the bottom can increase the collision time.
**Outer Shell**
The hard outer shell of the supply pod holds the supplies and the padding together and protects them. Depending on the shell’s condition after impact, it can be used to build a temporary shelter.

### OUTER SHELL MATERIALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Shell Mass</th>
<th>Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>10 kg</td>
<td>$400</td>
<td>Acrylic, commonly referred to as plexiglass, is a plastic-like material known for being strong and flexible.</td>
</tr>
<tr>
<td>Aluminum</td>
<td>20 kg</td>
<td>$100</td>
<td>Sheets made out of aluminum metal are often used for lightweight construction projects. Aluminum is the most common metal on Earth.</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>1 kg</td>
<td>$200</td>
<td>Fiberglass is made by mixing small pieces of glass and plastic into a “fabric” that hardens into a strong, lightweight material.</td>
</tr>
<tr>
<td>Steel</td>
<td>30 kg</td>
<td>$50</td>
<td>Steel is a metal made from iron and carbon. It is strong and relatively inexpensive, but quite heavy.</td>
</tr>
<tr>
<td>Wood</td>
<td>5 kg</td>
<td>$150</td>
<td>Wood is harvested from trees and can be shaped into a flexible and lightweight shell.</td>
</tr>
</tbody>
</table>
**Inner Padding**

Between the supplies and the outer shell of the supply pod, a layer of padding protects the supplies during the pod’s collision with the ground.

### PADDING MATERIALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass per Unit</th>
<th>Cost per Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air bags</td>
<td>0.4 kg</td>
<td>$3.50</td>
<td>Air bags are bags made of plastic. The bags are filled with air to create a cushion.</td>
</tr>
<tr>
<td>Feathers</td>
<td>0.7 kg</td>
<td>$10.35</td>
<td>Feathers are commonly used as insulation in coats and jackets and as padding for beds and pillows. They are lightweight, and lots of air can fit in the spaces between feathers when they are piled together.</td>
</tr>
<tr>
<td>Metal foam</td>
<td>0.3 kg</td>
<td>$194.80</td>
<td>Aluminum metal can be made into a foam. Gas trapped inside the foam leaves air holes, which make the foam lightweight and able to compress while staying very strong. Metal foam is often used in airplanes and space shuttles.</td>
</tr>
<tr>
<td>Packing peanuts</td>
<td>0.2 kg</td>
<td>$2.25</td>
<td>Foam packing peanuts are a common material used to prevent damage during shipping. They are spongy and filled with pockets of air that allow them to compress during impact.</td>
</tr>
<tr>
<td>Paper pads</td>
<td>3.7 kg</td>
<td>$23.60</td>
<td>Paper pads are made of several layers of thick paper. They look just like cardboard. Two outer layers are separated by a third layer that zigzags through the pad, leaving air space for the material to compress. Compared to an equal mass of steel, paper pads are stronger and cost less to manufacture.</td>
</tr>
</tbody>
</table>
### Top Add-Ons: Velocity-Reducing Accessories

Adding features like parachutes and flaps to the top of the supply pod can help slow the pod down as it moves toward the ground, reducing the collision force it experiences and making it more likely to survive the collision.

#### TOP ADD-ONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (kg)</th>
<th>Cost ($USD)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaps</td>
<td>20</td>
<td>250</td>
<td>Flaps can reduce the velocity of a falling object. They work like the metal fins on an airplane wing to increase air resistance and slow falling objects. They are cheap to build but are also heavy.</td>
</tr>
<tr>
<td>Parachute (large)</td>
<td>15</td>
<td>1000</td>
<td>A parachute is a large sail made of fabric that catches the air as an object is falling. This gives the object much more air resistance and allows it to fall more slowly. Parachutes can fail if used on an object that has too much mass.</td>
</tr>
<tr>
<td>Parachute (small)</td>
<td>7</td>
<td>600</td>
<td>Small parachutes reduce the collision forces of an impact by slowing down falling objects, but they offer less air resistance than large parachutes because they catch less air. Parachutes can fail if used on an object that has too much mass.</td>
</tr>
</tbody>
</table>
Bottom Add-ons: Impact Force Reducers

Adding features like springs, foam blocks, and special landing legs to the bottom of the supply pod can help lengthen the time of the collision, which reduces the impact force the pod experiences and may help it survive the collision better.

## BOTTOM ADD-ONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass</th>
<th>Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam blocks</td>
<td>3 kg</td>
<td>$100</td>
<td>Large foam blocks provide an extra layer of cushioning around the outside of the pod’s shell. They reduce the force of the impact by increasing how long the collision takes to occur.</td>
</tr>
<tr>
<td>Springs</td>
<td>5 kg</td>
<td>$200</td>
<td>Landing legs made out of springs absorb energy as the pod lands and slow down its impact with the ground. Springs can fail if the impact force is too great.</td>
</tr>
<tr>
<td>Trestles</td>
<td>10 kg</td>
<td>$500</td>
<td>Trestles are legs that come out of the pod’s base to add stability and absorb energy when the pod lands. Trestles can fail if the impact force is too great.</td>
</tr>
</tbody>
</table>
Results Analysis

<table>
<thead>
<tr>
<th>SHELL CONDITION</th>
<th>FORCE AND MOTION ENGINEERING INTERNSHIP—DAY 5</th>
<th>© 2016 The Regents of the University of California</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Force (N)</th>
<th>Mass (kg)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Watertight Shelter</th>
<th>Shade-Only Shelter</th>
<th>Building materials</th>
<th>Not reusable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL POD COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>($$)</td>
</tr>
<tr>
<td>$3000</td>
</tr>
<tr>
<td>$2000</td>
</tr>
<tr>
<td>$1000</td>
</tr>
<tr>
<td>$0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CARGO DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(%)</td>
</tr>
<tr>
<td>60%</td>
</tr>
<tr>
<td>50%</td>
</tr>
<tr>
<td>40%</td>
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<tr>
<td>30%</td>
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<tr>
<td>20%</td>
</tr>
<tr>
<td>10%</td>
</tr>
<tr>
<td>0%</td>
</tr>
</tbody>
</table>
Trade-Offs Reflection

A trade-off happens in a situation where a design has good results for one criterion but not for another. Look at your optimal supply pod design. Describe some of the trade-offs you noticed while designing your incubator.

1. Which criterion did you prioritize? (check one)
   - [ ] Minimize cargo damage
   - [ ] Maximize shell condition
   - [ ] Keep costs low

2. Why did you prioritize this criterion?

_____________________________________________________________________________________
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_____________________________________________________________________________________
_____________________________________________________________________________________
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3. When you prioritized this criterion, what were some of the trade-offs? Describe what happened to the results of the other two criteria.

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**Scientific & Engineering Practices Self-Reflection**

Science and engineering practices are the practices that scientists and engineers use when investigating real world phenomena and designing solutions to problems. There are eight science and engineering practices that apply to all grade levels and content areas.

1. Read the scientific and engineering practices.
2. Use the chart to indicate your perception about how you promote these practices in your classroom.
3. Discuss these practices with your table partners/group.
4. At the bottom of the page reflect on your own practice with the guided questions.

### Scientific and Engineering Practices

<table>
<thead>
<tr>
<th>Practice</th>
<th>Never</th>
<th>Sometimes</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions (for science) and defining problems (for engineering)</td>
<td></td>
<td></td>
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<td>Developing and using models</td>
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</tr>
<tr>
<td>Obtaining, evaluating, and communicating information</td>
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</tbody>
</table>

**Reflection**

What can I do to increase the fostering of these practices? Which SEPs could I address more easily as a starting point? Which ones will be challenging for me and I could use more support?