Professional Development Situation: In-person or Virtual Training

Engineering Practice: Balancing Criteria and Constraints

Time Required: 60 min

BALANCING CRITERIA AND CONSTRAINTS

Participants will understand the definitions of criteria, constraints and trade-offs in the context of engineering and reflect on the skill of balancing criteria and constraints in lessons/activities.

Agenda

5 min	Welcome and Introductions
10 min	The Engineering Mindset: Exploring Criteria and Constraints
30 min	The Catapult: Designing with Criteria and Constraints in Balance
10 min	Exploring the Practice with Video and Reflection.
5 min	Closure and Resources

Workshop Materials

- Pencil/Paper
- Computer/Internet/Projector/Speakers
- Card Sort Set
- Juice Box

Engineering Challenge Supplies

- Measuring Tape
- Marbles
- Masking Tape
- Popsicle Sticks
- Bulldog Clips
- Foil
- Rubber Bands
- Bottle Caps
- String
- Index Cards
- Pipe Cleaners
- Engineering Design Process Graphic

Before the Session

- Read this training guide to become familiar with the content and personalize the activities to suit your presentation style. Watch videos and read informational materials.
- Send a reminder email about the training. Determine if any participants require accommodations (sight; hearing; etc.). *If virtual, send the link to attend with date and time and a list of the supplies needed.*
- For in-person training, gather all materials needed for the engineering task and put on a separate table covered with a cloth. This will add some anticipation to the activity and model how to manage a group of youth who typically just dive in and create without any previous imagining and planning. Cut card sort cards into a deck. (Appendix B)
- Review any terms or concepts that may be unclear to you. Post these concepts and provide a graphic of the Engineering Mindset (Appendix A) and the Engineering Design Process. (Appendix C) as handouts.
- Develop a list of possible questions (and potential responses) participants might have during the training.
- On the day of the session, test any equipment you'll be using and any video links.

Training Outline

Welcome and Introductions

- Greet participants at the door and invite them to make a table name tent at their seat.
- Introduce yourself and the focus of the training: *Balancing Criteria and Constraints*
- Share general info helpful to participants – bathrooms, snacks, etc.
- Ensure that everyone is here for active learning encourage equal sharing of ideas from the collective wisdom in the room.
- If virtual, have participants introduce themselves including program site and pronouns. Review any features of the virtual platform (Chat, Screen Share, Mute, etc)

The Engineering Mindset: Exploring Criteria and Constraints

- **Engineering Mindset Graphic**: Show the graphic (Appendix A) and define the intention behind its' development of ten practices that identify the values, attitudes and thinking associated with engineering. Explain that today's training will focus on one of the ten practices: *Balancing Criteria and Constraints*
- **Criteria and Constraints Card Sort**: Explain that the group will spend time clarifying their ideas and prior knowledge with the concepts of criteria and constraints as it relates to an engineering challenge. (Appendix B).

- Distribute the card deck face up across a table and gather the group around it.
- On one end of the table set up a tent card that says “CRITERIA”. On the other end of the table set up a tent card that says “CONSTRAINTS”. Ask the group to sort the cards based on their thinking about what these terms mean in the context of an engineering design challenge. Encourage the group to express their ideas aloud. Remain silent as the discussion ensues!
- For virtual trainings, use Jamboard: https://jamboard.google.com/d/1rJ-KXVwLBDwF7HHzfSDsPvZeF0T6BrYVHySGTlLUGTI/edit?usp=sharing
- First, Screen Share the Jamboard’s first slide to familiarize participants with the Jamboard platform. Demonstrate how to select the arrow button on the left and then click, hold and drag the “sticky notes” to the side of the “page” under the column that best identifies the statement – Criteria or Constraints.
- Next, put the link into the chat and ask participants to open the Jamboard so they can move the “sticky notes” themselves.
- Last, assign participants to one of the six “pages” by clicking arrow next to the rectangles at the top of the page and selecting their page.
- Participants can work silently and see what a fellow participant is thinking by how they are moving the “sticky notes”
- For large groups, use Breakout Groups so participants can discuss their thinking.
- When done, facilitate a discussion to explore any conflicting ideas about the terms and debrief how their ideas may have merit. Then define the terms.
  - CRITERIA are things that are allowed or necessary in the design. They are things the engineer CAN or MUST DO, the “YES” actions or expectations.
  - CONSTRAINTS are things that are limitations or restrictions to the design or how it needs to function. They are things the engineer CANNOT or MUST NOT DO, the “NO” actions or expectations.
- Consider how the wording in the challenge can determine if it is a criteria or constraint.
  - Criteria: *The ball must roll at least 3 feet.*
  - Constraint: *The ball must not roll off the table.*
  - Criteria: *Your car design must carry an egg “passenger” down the ramp.*
  - Constraint: *Your design cannot total more than $15.*

- **The Juice Box Analogy:** Hold up an actual juice box or show an image on a PPT screen.
  - Review the concept of a “trade off” – when one benefit of an engineering design can result in a negative consequence. See information here about the juice box invention: https://en.wikipedia.org/wiki/Juicebox_(container)

- Essentially, the juice box added convenience for on-the-go juice consumption and immense space saving and therefore cost savings for its rectangular shape for shipping. However, it is nearly impossible to recycle with multiple layers of materials that cannot be separated. (This design is being improved by some companies who have heard feedback from consumers.)
- A trade-off can happen when there is not balance in the criteria and constraints. Something has to give. The goal then, is to minimize the effect of *nearly* meeting the demands of the criteria while staying within the boundaries as best as possible with the limitations, the constraints, of the task.

The Device: Designing with Criteria and Constraints in Balance

- **Introduce the Storyline:** Share with the group that you have a first aid kit with essential medicines that needs to be sent to the other side of a raging river. There is a family who became isolated by the flood while camping on a mid-river island. You will need to quickly design a prototype of a device to launch the kit.
- Share that you will be modeling a simple version of the Engineering Design Process (Appendix C) developed by the Museum of Science, Boston's Engineering is Elementary© curriculum as you engage in the engineering task:
- **ASK!** *What do you need to know to solve this problem?* Capture all participants questions first on a virtual whiteboard or newsprint. *Do not answer them yet.* Once their questions have been exhausted, go back and then answer each one. This will typically generate the engineering challenge's criteria and constraints. For example, the initial list of questions might include:
  - *How far is the distance from the shore to the island?*
  - *How heavy is the first aid kit?*
  - *Is it a windy day?*
  - *What materials do we have to build with?*
  - *How much time do we have?*
- After the questions, you can "step out of the story" go back and answer their questions one at a time **generating the criteria and constraints** (in bold below) on newsprint or virtual white board.
  - *How far is the distance from the shore to the island?* **Your device must launch the package 8 feet.**
  - *How heavy is the first aid kit package?* **The package is represented by a ball of foil wrapped around a marble or metal nut. The "package" would be about the size and weight of a superball.** *(Note: For fun, consider a different "package" such as a Koosh ball, Beanie Baby, or other toy!)*
  - *Is it a windy day?* **No. However, you must not get the package wet, so the island will be represented by this target** (trash can, bucket or a tape square on the floor). **You must launch from a starting point (river's edge) and try to hit the target.**

  - *What materials do we have to make the catapult?* **Uncover a supplies table with the available materials. You are limited to four rubber bands in your design.**
  - *How much time do we have?* **~20 minutes** (this might vary for each group)
  - *An additional constraint:* **You cannot use muscle power (no throwing or kicking) only the force of your design can launch the package.**
- **Imagine!** Reveal the materials on the supply table. Point out the limitation on the rubber bands. Pass around the rubber bands so participants can explore their properties – how stretchy are they? Show them the launching point and target. Ask the group to *silently* sketch their ideas on paper.
- **Plan!** Share their sketches with others at their table. Work in pairs on a design the two people can agree on.
- **Create and Test!** Let the action begin as participants create and test their designs. Keep track of the time and give a warning when there is only 5 minutes left. Do one final test demonstration of their catapults.
- **Improve!** First, create a culture of respect for everyone's efforts – cheer and celebrate! Then ask: *What might you do to improve your design? If you could have one new material to add to the supplies, what would you want?*
- **Debrief Questions:**
  - *How well did your design balance the criteria and constraints of the challenge?*
  - *What adjustments did you make along the way to meet the goal?*
  - *Which criteria or constraint was the hardest to fulfill?*
  - *In real life, what might be examples of "non-negotiable criteria and constraints" in an engineering problem?* (Safety, budget, time, capacity of a structure, etc.)

Exploring Further: Fanning the Flames: *https://www.youtube.com/watch?v=SmDn6QnD7z4*

- Provide context to the video including the age group, content and the goal of the challenge being presented.
- Ask the group to jot down moments in the video when the criteria and constraints are being revealed and any clarity about how they must be balanced in the final design.
- Discuss observations of the video and common threads in the discussion.

Closure and Resources

- Ask the group to consider how they might create their own engineering challenge from scratch.
  - *What problems exist in their program/building that could be solved through engineering?*
  - *How would you engage youth in a story to illustrate the problem to solve?*

- *How would you design manageable criteria and constraints that are realistic for youth to balance in order to design a solution?*
- *How would you test it?*
- *What would be the evidence that a workable solution was found?*

"Don't give a child something to learn, give him something to do and the learning will follow." - John Dewey

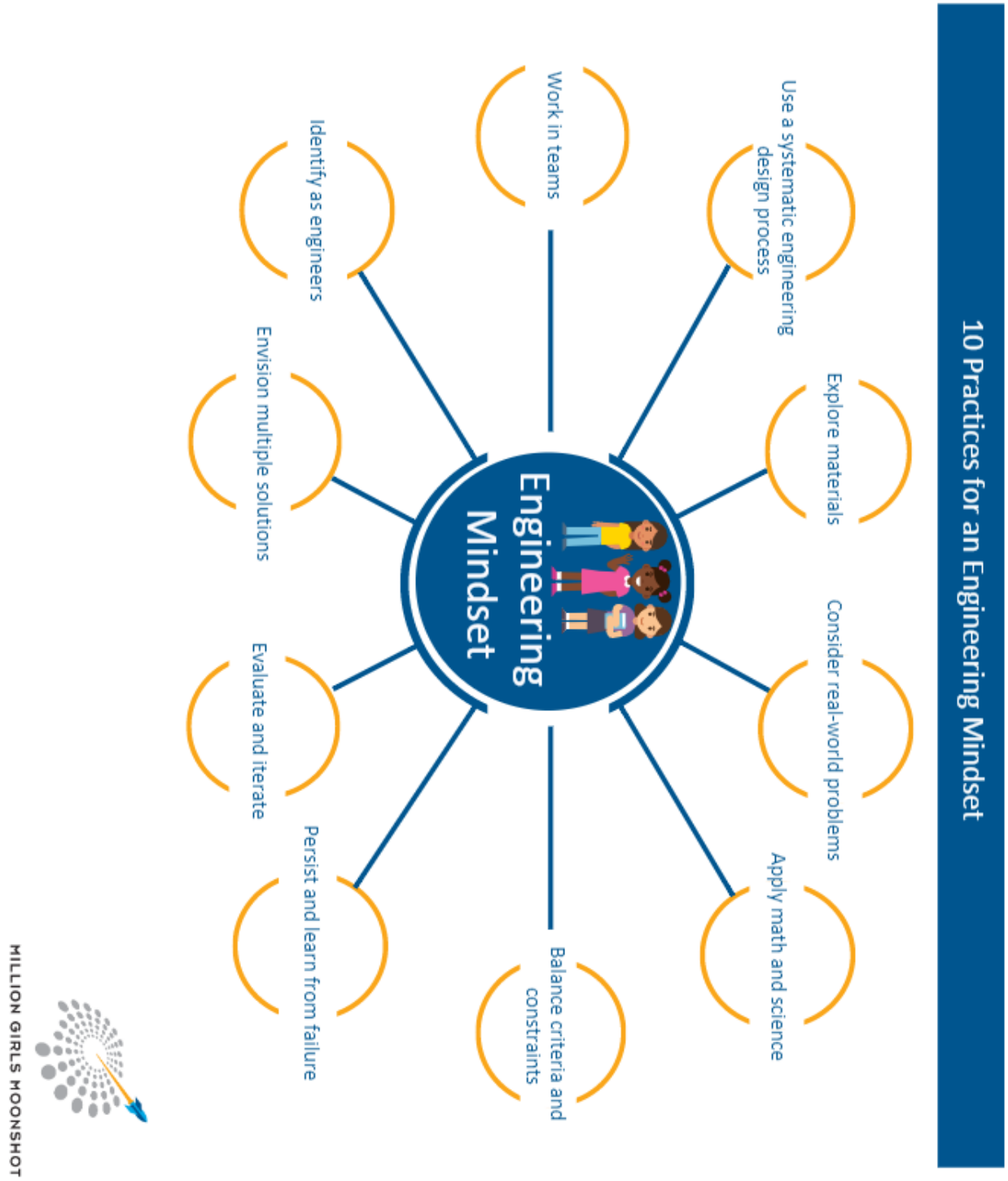
After the Session

Email the participants:

> *Thank you for your participation in the recent Click2Engineering training. I hope you found it useful and applicable to your practice. I am including handouts we used. Consider sharing your thoughts with a co-worker, supervisor, or friend. Additionally, you can reach me at ____.*

Attach handouts and other resources shared during the training.

APPENDIX A


10 Practices for an Engineering Mindset
Engineering Mindset
Use a systematic engineering design process
Explore materials
Consider real-world problems
Apply math and science
Balance criteria and constraints
Persist and learn from failure
Evaluate and iterate
Envision multiple solutions
Identify as engineers
Work in teams
MILLION GIRLS MOONSHOT

APPENDIX B

The tower should be at least 10 inches tall.

The ruler is a tool and cannot be included as part of the design.

The filter should produce between 1/3 and ½ cup of clean water.

The prototype of the prosthetic hand must lift a 3oz cup of water.

The budget for each design is up to four popsicle sticks.

You have 20 minutes to design your egg drop container.

The structure must be freestanding and not be taped to the table.

The bridge must support the toy car AND fit the little boat underneath.

APPENDIX B

The ball must roll uphill twice before landing in the cup.

No more than 5 rubber bands can be in the design of your cup rocket.

The final mixture needs to include two liquids and one solid substance.

You will have a half hour to improve your car safety designs.

The right-of-way in the new path must consider the speed of bicycles, pedestrians, and segues.

The circuit must not use more than two AA batteries.

The team must negotiate design features and agree to the final design.

Your bear chair must be durable enough to stay intact when dropped from knee height.

APPENDIX B

CRITERIA

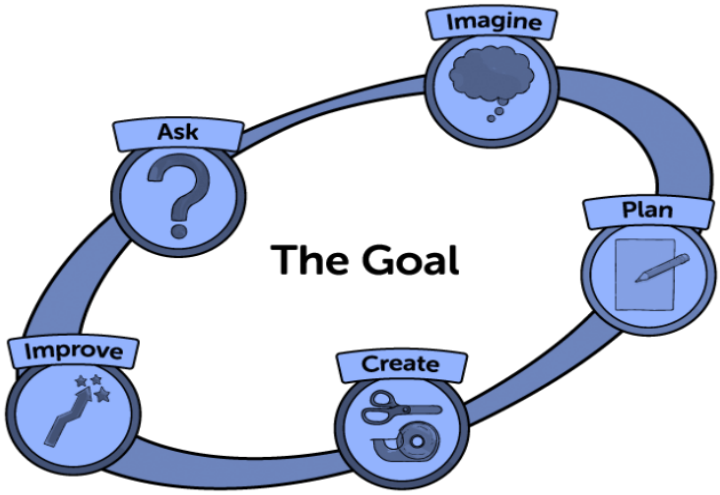
CONSTRAINT

Link to Jamboard version of the Criteria and Constraints Jamboard:

https://jamboard.google.com/d/1rJ-KXVwLBDwF7HHzfSDsPvZeF0T6BrYVHySGTlLUGTI/edit?usp=sharing

APPENDIX C

THE ENGINEERING DESIGN PROCESS



Engineering is Elementary
Developed by the Museum of Science, Boston

TIPS FOR ENGAGING YOUTH IN THE ENGINEERING DESIGN PROCESS

GOAL – Specify the goal without any parameters. For example: "You will need to make a tower to support this bird's nest"

ASK – Make a list of youths' questions, then go back and answer each, one at a time, to create the Criteria and Constraints

IMAGINE – A solo activity, think independently, sketch, list, manipulate materials

PLAN – Share aloud the ideas of the group equitably – don't allow dominance or omission – if in teams, agree on the plan and make the materials list, sketch or steps

CREATE – Go ahead and make the prototype (adhering to the criteria and constraints), test it, and collect data on the design's performance

IMPROVE – Consider the weak points, trade-offs, and desired changes to the design