The Tech's Core Engineering Education Principles

The Tech has over 30 years of experience engaging youth in engineering problems through our Design Challenge Learning model. Through years of facilitating, observing and refining our model with The Tech Challenge, in our museum field trip labs, on the floor and with our Tech Academy Engineering Education Leaders (EELs), we have developed some key principles that form the foundation of our learning model.

- **Principle I: Engineering can be integrated with any subject**

  There are authentic problems to be solved in any subject area and we believe that engineering can and should be integrated with any subject when these real-life problems arise in the curriculum. This is powerful, as it helps young people apply skills and concepts and see their relevance as youth develop critical skills for 21st century careers. As one of our Engineering Education Leaders (EEL) reflected, "Social Studies is the history of how people solve problems; English is researching or talking about solving problems." We would add that engineering is applied science and requires math skills for data collection and analysis. We've even worked with PE teachers who have found ways to integrate the engineering design process into their instruction by engaging youth in the design of a new sport using equipment in a different way.

- **Principle II: Call it engineering!**

  If youth don't know that problem solving through prototyping, testing and iterating is engineering, then they won't know that they like engineering and think of themselves as engineers. We notice that the youth that participate in our field trip labs sit a little taller when we call them engineers and that populations traditionally under-represented in STEM careers share that they might like to be engineers.

- **Principle III: The real-life problem/hook matters**

  The engineering problem and how it's presented can make all the difference in how hard youth persevere to solve the problem and how engaged they are with the problem. We have observed our EELs use a number of strategies for effectively introducing a problem: showing videos, reading stories or even Skyping in an industry professional to provide the context of a problem.

  We have never seen youth persevere as much as 3rd and 4th graders at our Alum Rock Boys and Girls Clubhouse Tech Academy, when one of our EELs used part of the trailer from the movie "The Martian" to introduce a challenge. These youth were tasked with finding a way to get food to Mark on Mars, and as their solutions fell short of Mars, they expressed real concern for Mark's survival as they continued to iterate.

- **Principle IV: The best challenges aren't necessarily solved in a day**

  We notice that a lot of adults believe it's critical for youth to solve a problem in one museum visit or class period. We believe the opposite is true. We notice that youth enjoy persevering and working on interesting problems for days, weeks or even months!

  When The Tech Challenge solution of one team of 6th grade engineers from our Britton Middle School Tech Academy wasn't completely successful, the team was undeterred and begged their teacher to let them keep working on the challenge back at school. This kind of perseverance is critical, as the real-world problems that we need our youth help to solve will not be solved in an hour. These problems will take years to solve!

- **Principle V: Youth are generally ok with failure, if adults are**

  Failure is critical to success in engineering as it typically takes many (sometimes even thousands) of iterations to achieve the optimal solution. Fostering an environment where it's safe to fail is also important to encouraging the kind of risk-taking necessary in coming up with innovative solutions.
  We notice that youth that demonstrate the most creativity and fun at The Tech Challenge — designed to be our most challenging problems — are those who have adult advisers who allow youth to try and fail, focus on learning from failure, celebrate youth progress and refrain from pressuring youth "to win." We know that these youth are learning to love engineering and will be effective problem solvers.

  Unfortunately, some youth who have learned to fear failure will require more support in making this shift. One strategy The Tech's lab instructors use prior to testing designs, is to start with the strengths they notice in each design, invite students to share their design process and ask them what they hope to learn from the test.

- **Principle VI: Innovator mindsets must be intentionally taught**

  Engineering problem solving provides authentic situations where youth can apply and develop critical skills such as perseverance, collaboration, empathy, risk-taking, creativity and other 21st century skills. However, these skills must be intentionally modeled, taught and practiced just like any other concept or skill.

  We make it a practice in formal classrooms to intentionally model, practice and reflect on one of these skills as part of every engineering challenge. We also make a point of positively reinforcing when we notice students practicing a skill that real engineers practice in their work and companies look for when hiring.

- **Principle VII: There should be multiple solutions**

  One of the joys of engineering and using an engineering mindset in problem-solving is that it allows for flexibility, change, and diversity in answers. This is a step away from simplified knowledge based understandings where there is one answer and toward creativity and flexibility in designing solutions in a rapidly changing technological world. Furthermore, engineering answers do not stay the same. Solutions adapt with new information, criteria, and constraints. The bridge we build today might be repaired, but it might also be replaced as other needs are identified or materials are developed.

Flexible Structure (for formal educators)
The following principles address a tension between allowing for flexibility with a non-linear problem-solving process while providing some structure important in more formal learning environments. These principles aim to help facilitators find the right balance.

- **Principle VIII: Allow flexibility in facilitating the design process**
  Creative problem solving doesn't happen in a fixed sequence of events, and different individuals might approach the same problem in different ways. Some might start by tinkering with the materials to see what they can do. Others might brainstorm and sketch. Still others might build a quick prototype and test it. We've noticed that informal learning environments like the museum allow individuals and groups to drive their own process organically which fosters creativity, ownership and engagement. This can be challenging to formal educators and administrators as they learn to be comfortable with a messy process, not having all the answers and guiding youth through questioning.

- **Principle IX: The role of the facilitator is to ask good questions when needed**

  When youth struggle with a problem but ultimately figure it out for themselves, the learning is more powerful and sustained, as youth construct their own learning and feel proud of their accomplishment. Facilitators can foster this powerful learning experience by asking open-ended questions at strategic times that guide students thinking rather than driving students toward a particular solution. The facilitator does not need to know the answers to these questions; in fact, sometimes it's better when they don't have a particular answer in mind. The purpose of asking these questions is to guide youth in their thinking and to help them to find their own solutions to the problem.

  Timing of these questions is most effective when asked during group share-outs when all students can learn from each other, to help a group get started, or after students have struggled some already and can benefit from a little help in identifying why a particular design isn't working. Questions with no right or wrong answer help youth to come to their own conclusions and are less intimidating to youth.

  We acknowledge that this can be a big shift for educators used to feeling like they must know all the answers. As one of our Tech Academy teachers said to us "I googled an answer to one of your earthquake related questions about representing earthquake waves, and instead of accepting my answer that 'I'd cheated, you countered that I was using my resources. Paradigm shifted. Amazing."

- **Principle X: Allow access to materials during brainstorming**

  While allowing youth time to reflect, brainstorm and sketch before building is a great way to consider many different ideas, denying access to materials until a sketch is complete can actually limit idea generation and creativity. Material exploration can serve to generate more ideas as engineers test and tinker with materials to get a sense of the attributes and limitations of different materials.

  We've noticed many creative ideas emerge when materials are a part of the brainstorming process. For example, one of our Tech Academy EELs had each student select a different material and share one idea for how that material could be helpful for a particular solution.

- **Principle XI: Whenever possible, allow access to testing during building**

  To encourage many iterations of a solution and foster an environment where failure is critical to success, youth need easy access to a means of testing their design throughout their process. We notice some youth examining the parameters of a test very carefully when designing their solution, even testing materials in isolation to see how they behave when dropped for an egg drop challenge, for example. Furthermore, we notice that when youth invest a lot of time on one design and their first test of that design is in a one-time public share-out, failure can be more difficult to accept and they aren't as likely to iterate multiple times to improve their solution.

- **Principle XII: Assess students on learning rather than on the success of their solution**

  To foster a growth mindset and an environment where it's safe to fail as youth iterate their solutions, its critical for student assessment to focus on learning of standards-based concepts and skills rather than on the success of their solution. Students can demonstrate their learning of standards by communicating verbally or in writing how their solution demonstrates standards-based concepts or how their process demonstrates important engineering processes.

  Ultimately our goal is to foster creative problem solving in everyone and to help each person find the problem they are most passionate about solving.