Professional Development of Student Engineers Using Design Thinking

INCOSE IS 2018

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75 Los Alamos NATIONAL LABORATORY EST. 1943

NNSA National Nuclear Security Administration

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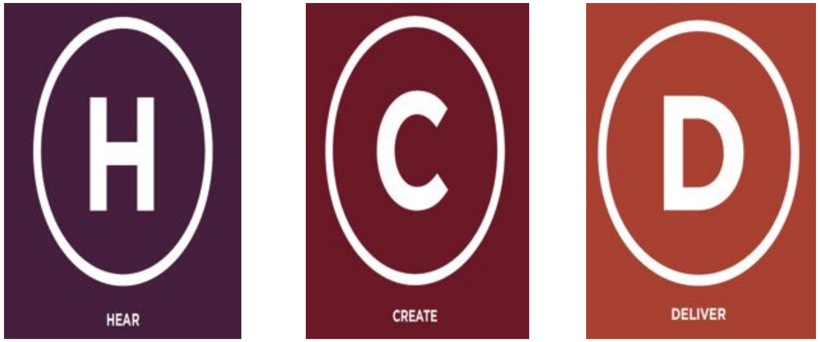
The FFLIE program's professional development activities focus on skills that enable successful application of students' technical capabilities in the LANL work environment.

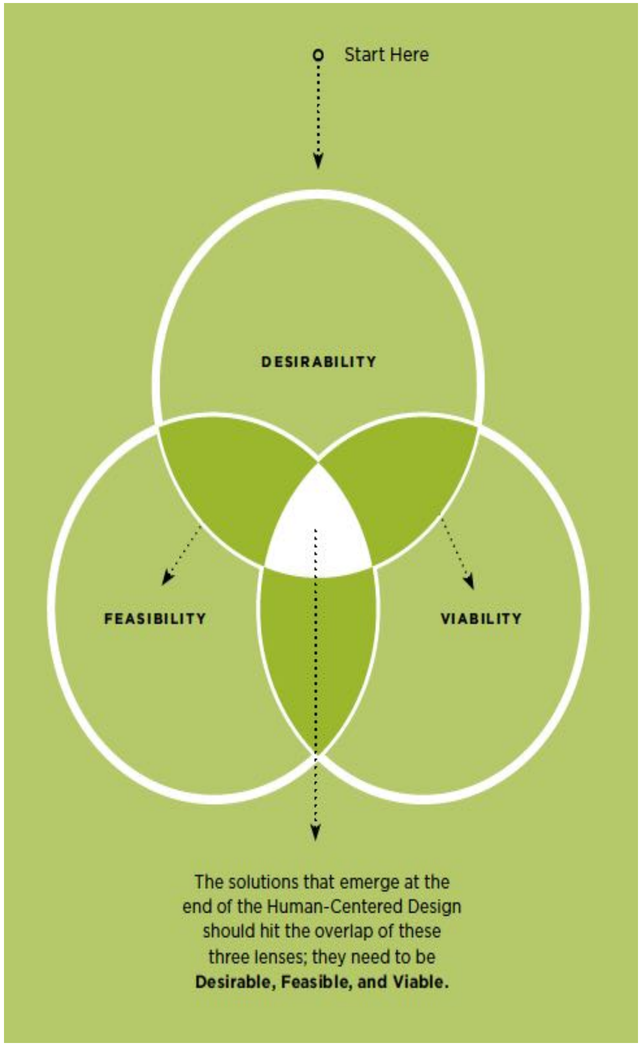
- **First year enrichment activities revolve around the LANL R&D Engineering Primer**
  - Navigating the R&D Engineering Enterprise @ LANL
  - Mission Assurance Framework
    - Integrated application of systems engineering (SE), project management (PM), and engineering quality and rigor (QA)
    - Focus is on activities and artifacts more than theory
    - Includes hands-on practice on a demonstration project
  - Technical writing and presentation skills
- **Second year enrichment activities involve a Design Thinking project and ongoing honing of technical writing and presentation skills**

Design Thinking evolved from Human-Centered Design.

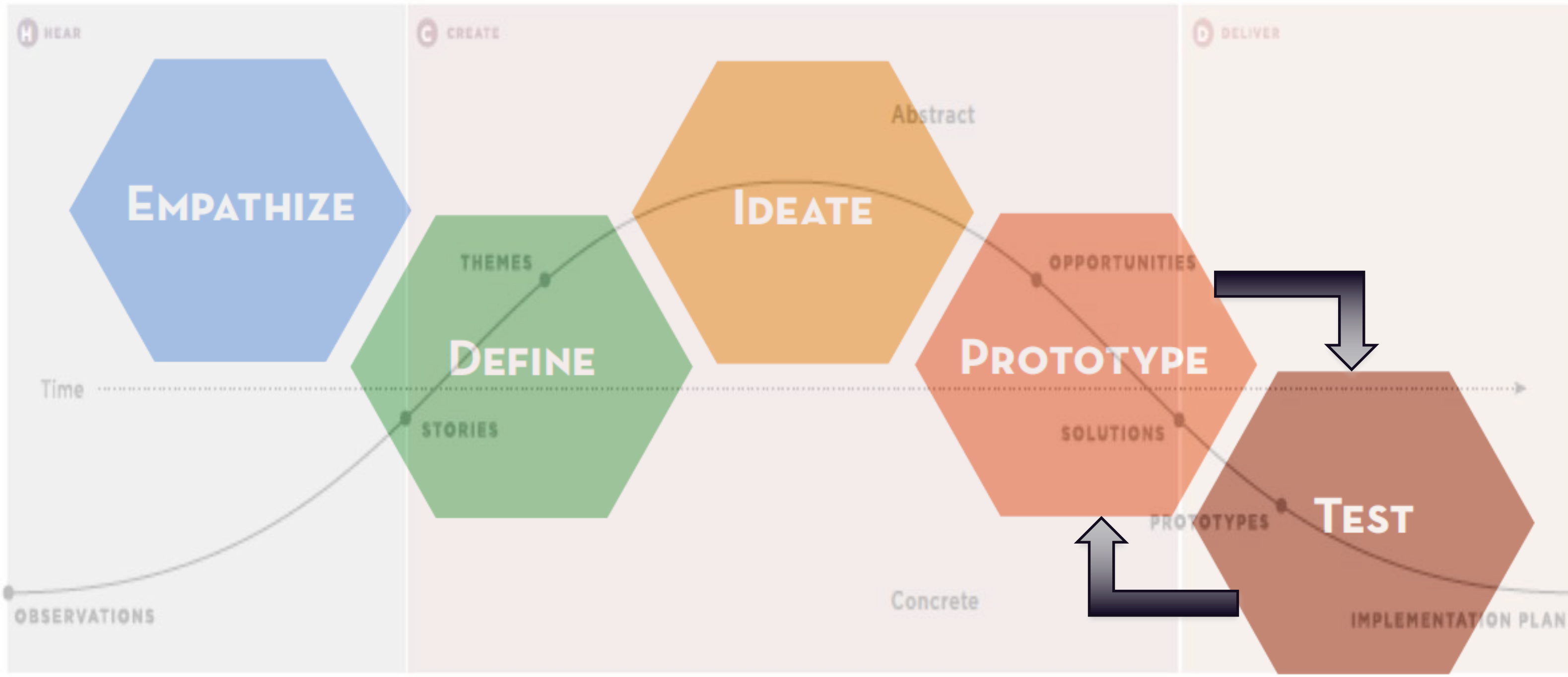
- **Process and a set of techniques used to create new solutions for the world**
  - Solutions include products, services, environments, organizations, and modes of interaction
- **Starts with the people we are designing for…**



Human Centered Design Toolkit (http://www.designkit.org/resources/1/)



The Design Thinking process is an “overlay” to the HCD process.



Human Centered Design Toolkit (http://www.designkit.org/resources/1/)

Image from: d.mindsets

Design Thinking helps develop the soft skills and systems perspectives needed to be a technical leader in engineering.

- Considers the full system life cycle
- Uses critical thinking to evaluate potential solutions
- Expands beyond the quantitative and incorporates qualitative approaches throughout the design process
- Hones professional competencies in ethics, communication, negotiation, and interdisciplinary team dynamics

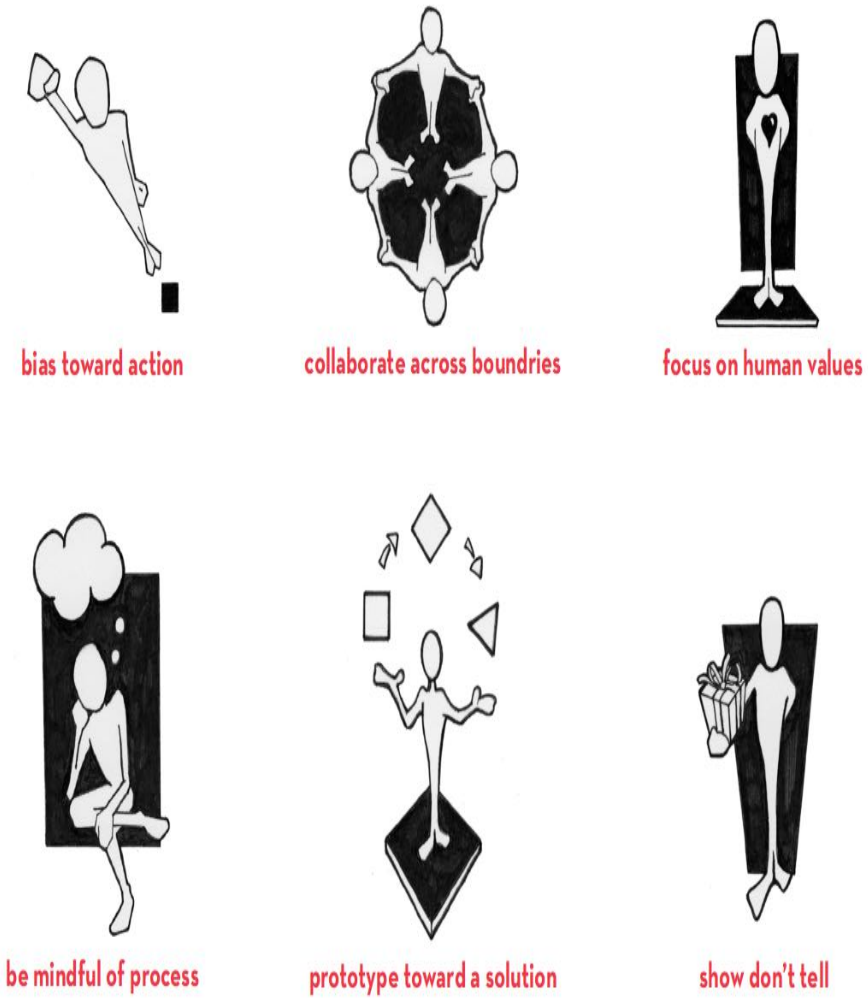


Image from: d.mindsets

Design Thinking as practiced at Stanford d.school stems from Guilford's four-factor theory of creativity.

- **Building is a new way of thinking**
- **Framing the problem domain creatively**
- **Generating a wide array of innovative solutions**
- **Using rapid prototyping and an iterative approach to solve complex problems**
- **Questioning larger implications**

- **Four factors of creativity**
  - *Problem sensitivity*
  - *Fluency*
  - *Flexibility*
  - *Originality*

YOU ARE HERE STANFORD DESIGN PROGRAM

http://designprogram.stanford.edu/projects.php

Students learned Design Thinking by doing it!

Structure of the FFLIE DT Project:

- **Overview of Design Thinking and Research Ethics in the context of Human Centered Design**
- **Students spent a half day in each of 8 weeks on instruction on and practice with DT**
  - Instruction on DT step, example from a prior project, students execute the step
- **Worked on a real project for a real customer**

The FFLIE students' project was undertaken for the Bradbury Science Museum.

- **Bradbury Science Museum (BSM) mission: To stimulate interest in and enthusiasm for science, technology, engineering and mathematics (STEM) and promote public understanding and appreciation of Los Alamos National Laboratory**
- **Three primary ways of delivering mission:**
  - Exhibits interpreting and explaining the Lab's science and history
  - In-museum educational programs led by BSM educators and Lab Science Ambassadors
  - Educational outreach to NM schools

The BSM was looking for different ways to meet its educational outreach mission.

- **Educational outreach to NM schools mission fulfilled by BSM educators via Science on Wheels (http://www.lanl.gov/museum/teachers/we-visit-you.php)**
- **Issues with delivery model:**
  - –Limited ability to meet demand for services
  - –Long-term sustainability questionable due to staffing, budget issues

How can we help BSM meet its educational outreach mission using a delivery method other than Science on Wheels?

Design Thinking Process Phase 1: Gather, organize information with empathy.

- **Identified stakeholders**
- **Conducted document reviews (BSM internal and external web pages), interviewed stakeholders, and observed museum patrons**
  - Interviews conducted *in situ* wherever possible
  - While interviewing, observed body language and surroundings for contextual clues
- **Coded interview notes, documents, and observations**
- **Distilled themes and points of view into vision statements for each stakeholder**

EMPATHIZE

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STAKEHOLDER KEY THEMES

- ***Students*** **want hands-on activities that are memorable**
- ***Teachers*** **want hands-on activities that promote retention and engagement despite differences in educational environments**
- ***Museum Educators*** **want a hands-on quick start program for grade-school students that focuses on physical sciences and is both easy to transport and easy for teachers to use**
- **The** ***BSM Senior Staffer*** **wants a physical deliverable for small groups that "changes" participants, that has been thoroughly tested, and that is easy to fabricate and ship**

VISION STATEMENTS

- Each of the stakeholder interviews were condensed into a vision statement that summarized the items of critical importance.
- An overall vision statement was then developed
  - The stakeholders want a hands-on and flexible outreach program that is robust and transportable that will engage, retain, and change the visitor.

Design Thinking Process Phase 2: Define the issues.

- Created empathy maps for each type of stakeholder
- Analyzed maps to identify *needs* (human emotional or physical necessities) and *insights* (remarkable realizations that could be leveraged to better respond to a design challenge)
- Translated insight statements into design opportunities by reframing them as "How Might We" questions and generating answers (in the Ideate phase)

DEFINE

Photo courtesy of Leticia Britos Cavagnaro, Stanford University Action Lab

HOW MIGHT WE…

- **How might we make it hands-on?**
  - **Crafts – combine science and art**
- **How might we make it indestructible?**
  - **Materials, boxes, use existing equipment**
- **How might we make it flexible?**
  - **Video instructions, adaptable levels of detail**
- **How might we make it engaging/interesting?**
  - **Building catapults, local theme, competition, Skype visitor**
- **How might we make it portable?**
  - **Drones, Amazon, driving to school, shipping**

Design Thinking Process Phase 3: Ideate

- Checked the framing of the problem and adjusted it to include the "why"
- Brainstormed multiple solutions
- Identified alternatives already in existence and added them to the mix
- Evaluated how well each solution might solve the problem

IDEATE

BSM Educators need a way to fulfill their educational outreach function without leaving the BSM because the future viability of the Science on Wheels program is questionable.

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BRAINSTORMING

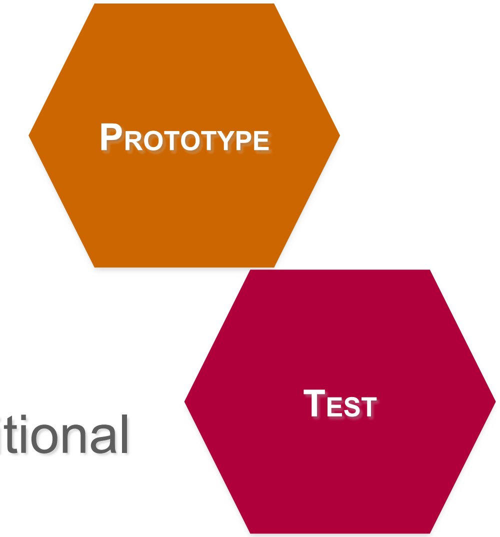
- Solution Concepts
  - Virtual Reality Simulator
  - Mystery Box
  - Scavenger Hunt
  - Physical Exhibit or Demonstration
  - Museum Visit
  - Museum Partnership
  - Visitors
  - Lesson in a Box (Boxes with Student Instructions)
  - Teacher with Instructions

SELECTED DESIGN: MYSTERY BOXES

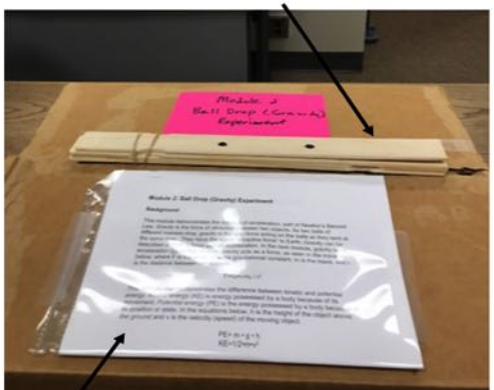
- 2 hours
- Teacher introduction about Newton's laws
- Students assigned a module for discussion
- 15-20 minutes per station
    - Friction and Force: cloths and weights
    - Gravity: two-ball drop
    - Inertia, Weight, and Mass (F = ma): trucks
    - Action/Reaction Forces: ball catch on wheels
- Discussion
- Catapult

Design Thinking Process Phases 4 and 5: Prototype and Test

- Built low resolution prototypes of the selected design and subjected them to rapid prototype-test iterations
  - Provided complete prototypes for two of the lesson modules and the catapult
- Final presentation to museum staff resulted in additional feedback



Prototype ball drop apparatus (apparatus would be packed inside the box)



Prototype teacher instructions

Prototype student instructions

Prototype data logs

Trucks w/ hex nuts & cords inside

BALL DROP MODULE

<u>Prototype</u>

Goal:

- We want students to perform simple math and understand basic concepts
- We want to demonstrate potential and kinetic energy
- We want consistency

<u>Testing</u>

- Objective: Verify the ball drop apparatus does not introduce bias
- Method: Test with two balls of unequal mass and diameter
- Results: Balls landed simultaneously; hypothesis supported

<u>Conclusion</u>: This module still involves human error, but is definitely successful in showing how gravity works

CATAPULT

Prototype

Goal:

- **We want students to learn that building designs is fun (and will hopefully encourage them to become engineers!)**
- **We want students to finalize their learning experience with a fun competition**

Testing

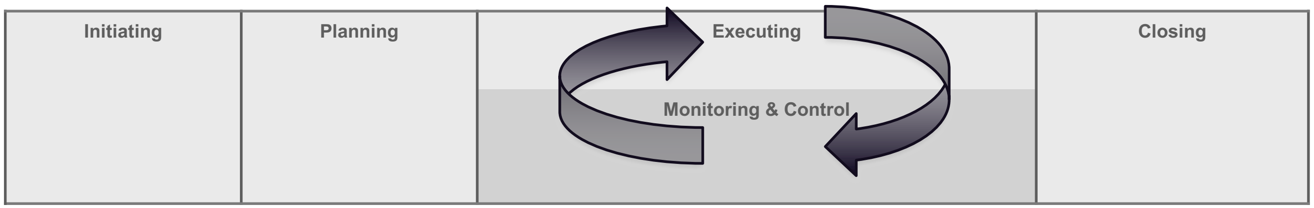
- **Objective: Verify that an operational catapult can be constructed quickly**
- **Method: Follow instructions with provided materials. Test with marshmallows as projectiles**
- **Result: Catapult constructed in under 5 minutes; marshmallow followed expected kinematics**

Conclusion: The catapult is not perfect in design, as it does not aim correctly; however, the prototype still shows how fun it is to shoot marshmallows all over the room

CONCLUSION

- How we met the requirements
  - Affordable
  - Easy shipment
  - Does not require personnel hired by the lab
  - Easy-to-follow instructions allow teachers without prior knowledge or experience to run the show
- What we learned
  - How to effectively brainstorm, communicate with others, gather needed information through interviews, analyze the found information, and work as a team to finalize our ideas
- We have shown through prototyping and testing that this work is feasible and, most importantly, should help students in middle school gain an interest in STEM

They also began to understand Design Thinking and SE as complementary.



Initiating
- Formulate/ Receive Design Challenge
- Develop Stakeholder List

Planning
- Develop Research Plan (Methods & Schedule)
- Conduct Qualitative Research
- Write Vision Statements
- Develop Empathy Map (Identify Needs & Insights) & "How Might We" Statements
- Reframe the Problem

Executing / Monitoring & Control
- Brainstorm & Evaluate Solutions (Ideate & Iterate)
- Prototype & Test
- Incorporate Prototyping Feedback & Iterate to Final Solution
- Turn Over to Production

Closing
- Deliver/Deploy Product/Service/ Process
- Document Lessons Learned

Conceive	Design	Implement	Operate	Retire

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