Designing the Future: How Engineering Builds Creative Critical Thinking

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ProjectEngin™

Educating for the Future

Every young person needs to understand the “designed world”; systems-thinking and ethical approaches needed

Future of work – “machines” can do highly technical, algorithmic work; human factor and “power” skills will be valued

Engineering will be critical in meeting global challenges; creative problem-solvers needed

Innovation: From the Imagination of Science to the Creativity of Engineering

Science Engineering Designed World

"Imagination is the ability to bring to mind things that aren't present to our senses. Creativity is putting your imagination to work. It is applied imagination. Innovation is putting new ideas into practice." *Sir Ken Robinson, "Creative Schools", p. 118.*

Leaks in a Porous Pipeline

WHO WE NEED	WHY WE LOSE THEM
Creative thinkers	Science, math = BORING
Diverse backgrounds/ talents	Lack of role models and mentors; self-limit identities
Team players; collaborators	School values the individual
Lifelong learners/agile, adaptable	No time for reflection; meta-cognition
Systems thinkers	Siloed/sequential education; no time for failure; lack of mental model building
Empathetic and ethical	Spatial reasoning; technical jargon

How People Learn

School	Real life (everyday settings)
Individual work	Collaborative effort
“Mental” work to solve problems	Use of tools to develop solutions
Abstract reasoning	Contextualized reasoning

“School should be less about preparation for life and more like life itself.”

John Dewey

Engineering + PBL = Creative Learning

Goal	Engage innovators while they are young; keep creativity and resilience of young children; avoid “siloed” learning and labelling of abilities
EDP	The Engineering Design Process gives learners a problem-solving approach that stresses critical thinking, creativity and divergent thinking, systems, and connections
PBL	Project-based learning supports “learning by application” versus “learning by acquisition”; experience collaboration and synergy that result from diverse talents and viewpoints.
Result	Young people who are informed about the development and potential of the designed world; provide optimism for the future due to focus on inclusive solution-finding

Engineering Design as an Integrative Tool

The engineering design process, which synthesizes humanistic, social, creative, and analytical skills, is one avenue for meaningful integration of a range of disciplinary methods and values in courses. Frameworks for the engineering design process use varying nomenclature to describe the same essential elements: need finding (or empathy), problem definition and framing, creative idea generation, prototyping, and testing and analysis. The process is iterative, and communication with multiple stakeholders is critical throughout the process. While this is an engineering methodology, it shares with the arts an emphasis on creativity, and with the humanities and social sciences a comfort with the ambiguity of nonunique, context-specific solutions.

National Academies of Sciences, Engineering, and Medicine 2018. *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*. Washington, DC: The National Academies Press.

Learning about concepts, ideas, and information

How do concepts, constraints, criteria connect?

Know your problem

- Define challenge
- Identify constraints
- Develop criteria

Know your options

- Research
- Brainstorm

Develop a solution

- Prototype
- Test
- Modify/optimize

What do I need to know?

Applying concepts, ideas and information to engineer a solution

Using the Engineering Design Process

Project-based Learning

Increase expert thinking through application

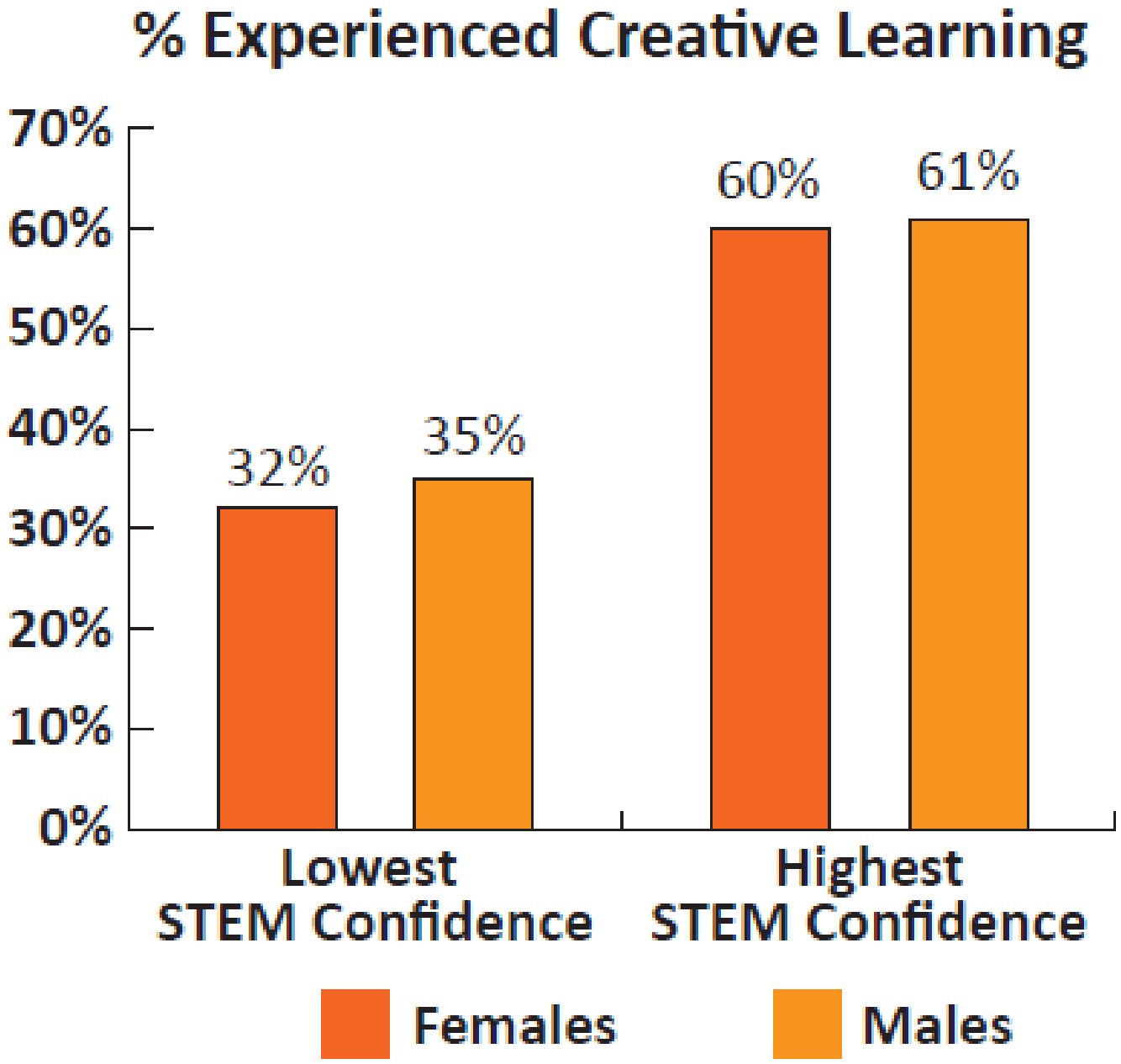
Makes learning authentic via connections to real-world challenges

Foster interdisciplinary thinking; blurs boundaries

Provides context for true collaboration (Johnson and Johnson, 2009)

Excellent way to teach project management skills; problem-solving method that transcends disciplinary boundaries

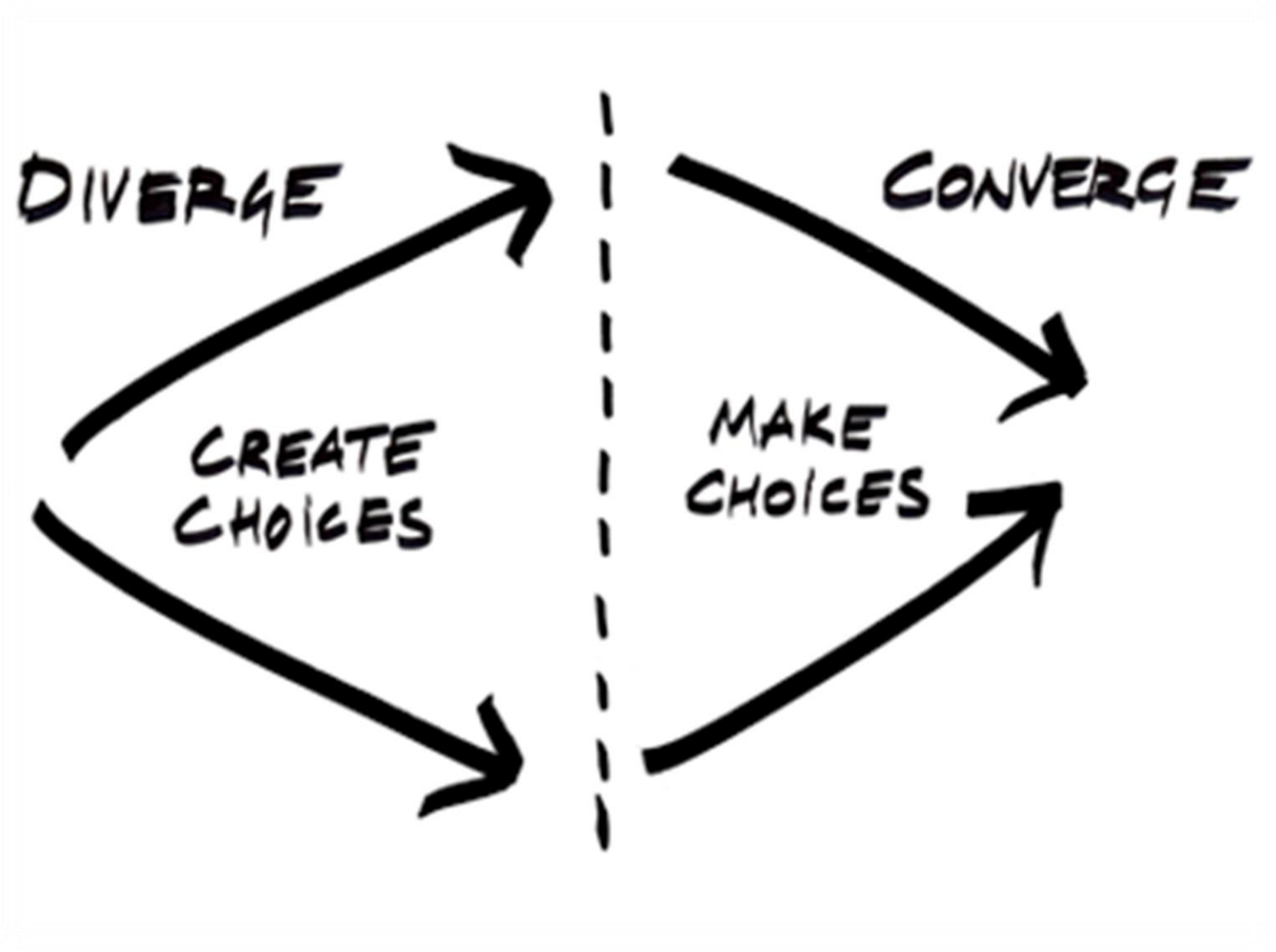
Through college level, PBL found to increase student confidence in STEM courses and in their capacity to solve complex problems (Vaz and Quinn, FIE 2014)



Students highly confident of STEM abilities report frequently experiencing creative learning in STEM classes.

Study by Destination Imagination, National Girls Collaborative, Educational Research Center of America, and NAPE

Problem



Solution

Finding the A in STEAM

Who are you designing for? End user and culture (*Interviews and research)*

What are you designing? Aesthetics and appeal in design

How can you communicate your results? Picture, graph, or video can equal 1000 words

Finding the A in STEAM

Visual – good design

Visual – spatial reasoning

Verbal – communicate with team; outside of team

Social/cultural – technology needs to work for people

Gender Gaps in Spatial Reasoning

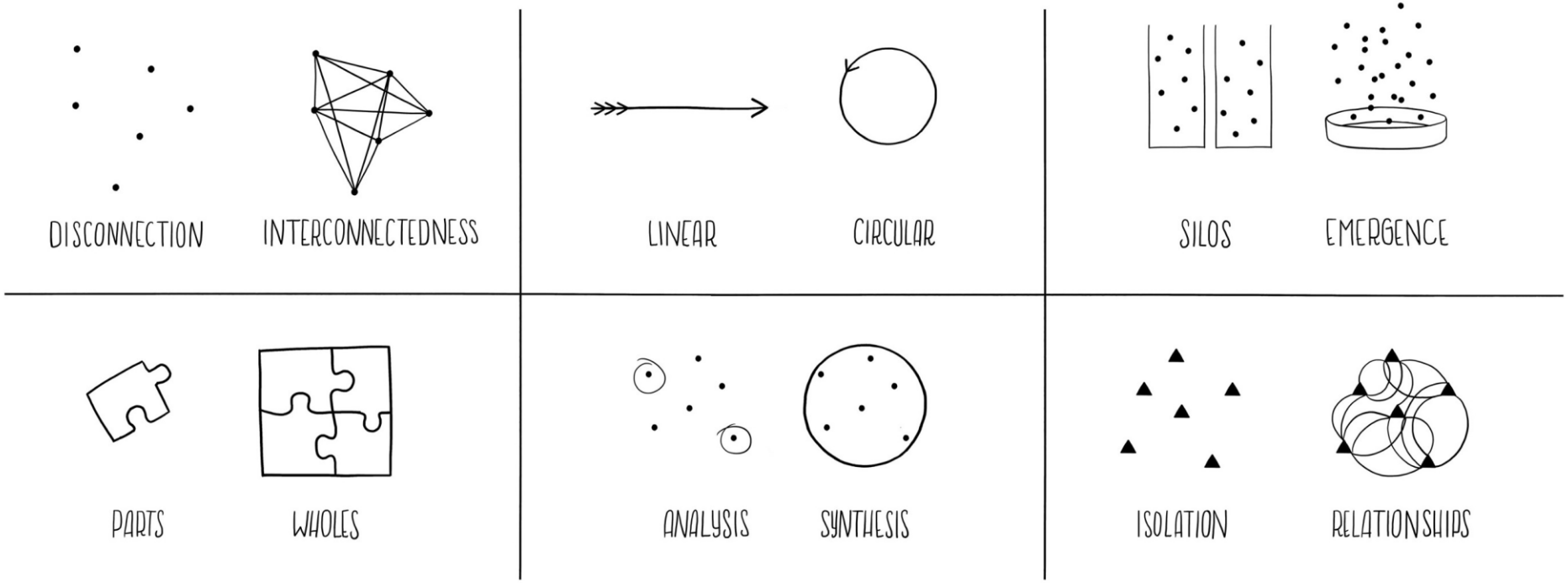
Presents challenge in both art and STEM fields. Artists and scientists often need to visualize things that cannot be seen

Typical Engineering approach is an orthographic (orthogonal) projection for 2D and isometric view for 3D

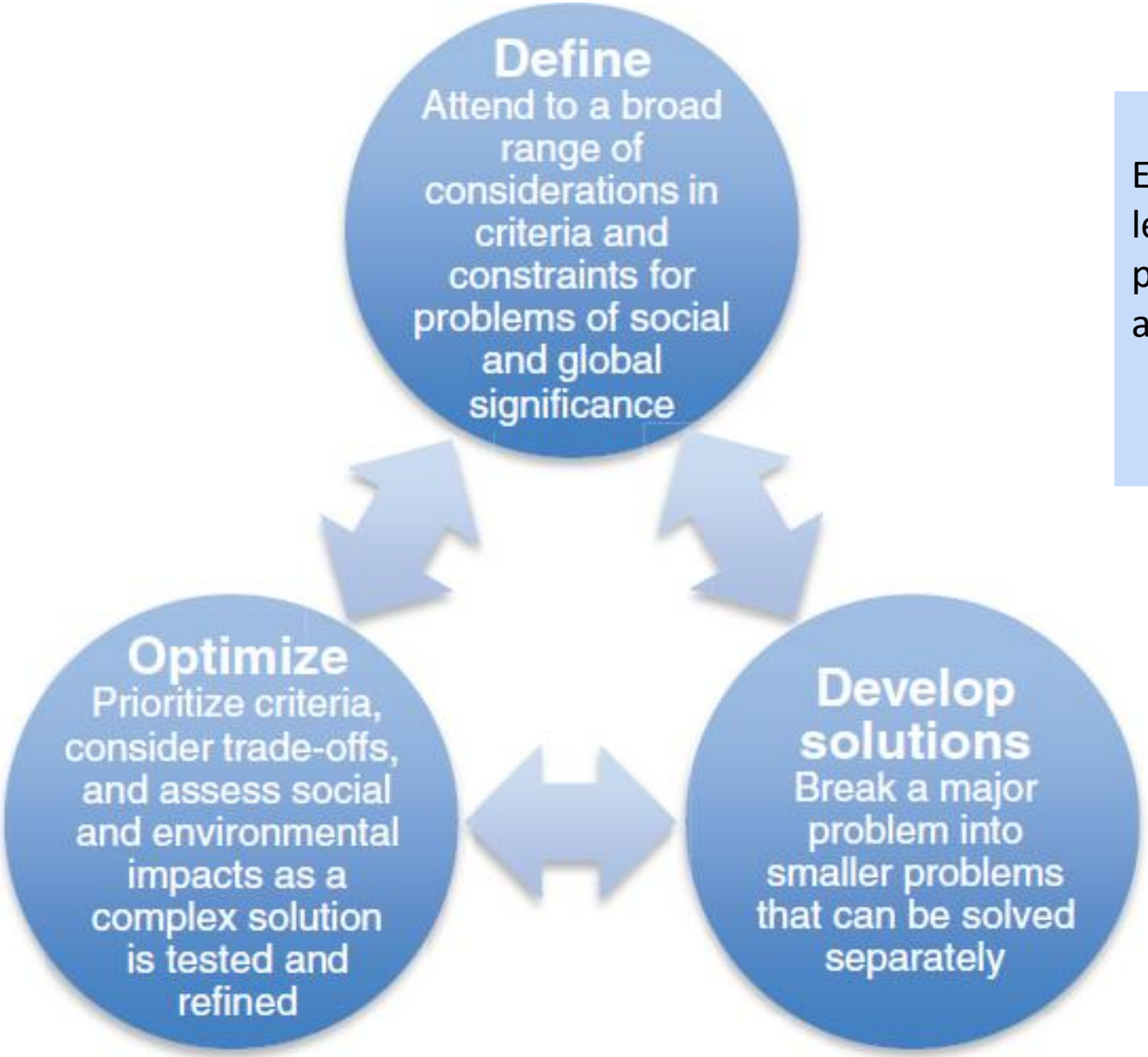
Can it be improved? Exposure to blocks, exercises in perspective and rotation and folding.

"The 15-hour program—which uses blocks, sketching, software, and workbooks full of practice exercises—brought the women who took it even with the baseline for men on basic spatial cognition tests and helped boost retention rates for female engineering students by 20 to 30 percent." *Sheryl Sorby Ohio State University*

TOOLS OF A SYSTEM THINKER



DISRUPT DESIGN



Engineering design at the high school level engages students in complex problems that include issues of social and global significance.

Next Generation Science Standards, p. 440

Ethics, Empathy, Engagement

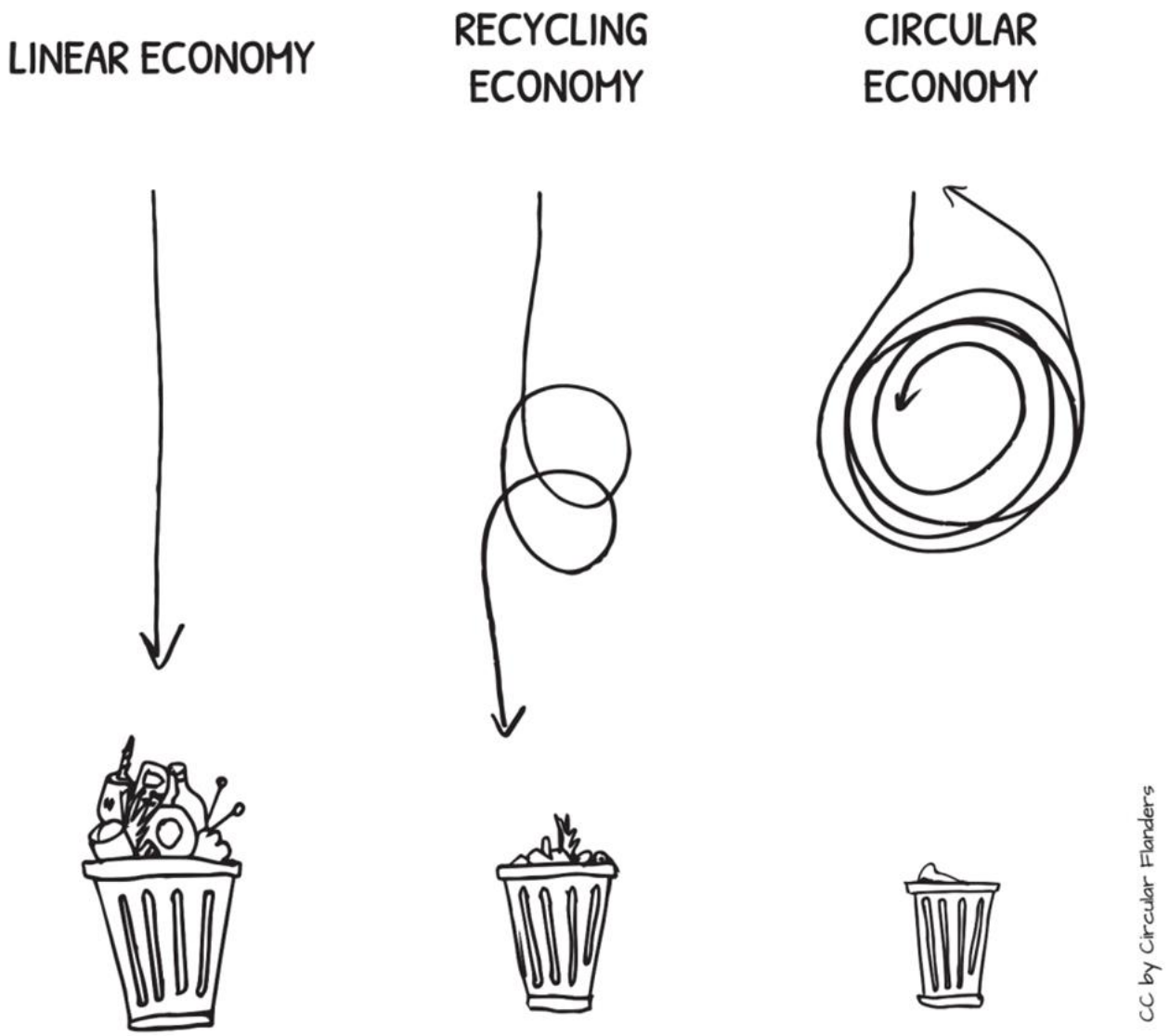
- Technology needs to work for people
- Design “with” people versus “for”
- Diverse groups of students are drawn to the idea that can improve lives; meet challenges
- Unintended consequences; future impacts
- Respect for the planet

Figure 6.5: Appropriate Technology Checklist

How appropriate is your technology?

Check all those that apply. Ensure your design includes at least five of the following.

- ☐ **Compatible** with local culture
- ☐ **Small scale** so the community should not have to rely on heavy industry or corporate wealth
- ☐ **Local tools and practices** can be used
- ☐ **Local materials and resources are** used as much as possible
- ☐ **Local energy** sources are used
- ☐ **Environmentally friendly**
- ☐ Can be **repaired locally**
- ☐ **Easily maintained**
- ☐ Values **local creativity and design**
- ☐ **Easy to understand and use**
- ☐ **Low cost**
- ☐ Creates **local industry and businesses**
- ☐ **Flexible** for use in many different situations

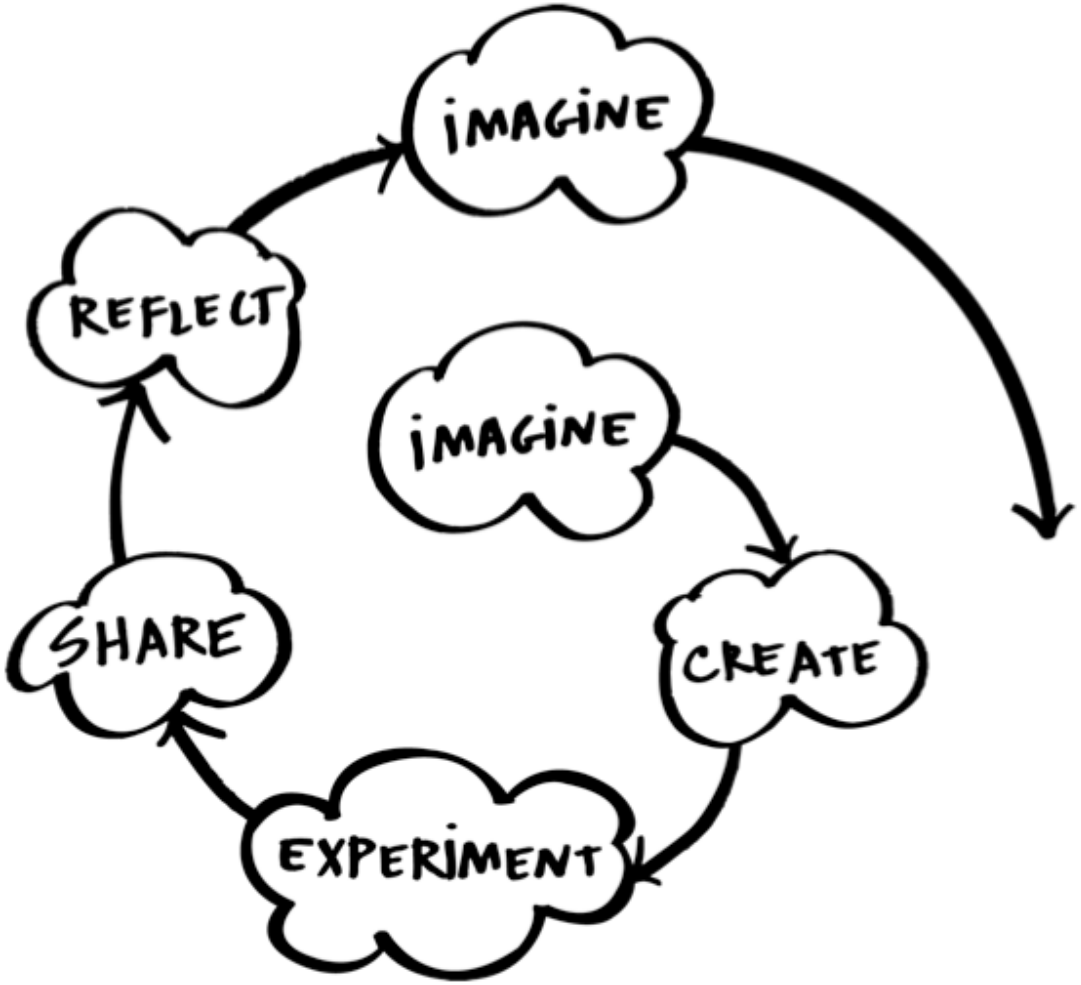

LINEAR ECONOMY
RECYCLING ECONOMY
CIRCULAR ECONOMY
CC by Circular Flanders

Research areas

- Most of PE research is action research in conjunction with classroom teachers. Data triangulated; results generally qualitative

- Current/past focus:
  - Enhanced mastery of science/math concepts
  - Better awareness of what “engineering” is
  - Value of collaboration; project planning

- Several research projects are on hold currently due to COVID
  - Assessment of 6th grade game design project; technical writing and spatial reasoning
  - Assessment of primary grade projects - better understanding of key science concepts. Spatial reasoning, second grade project
  - 4 high schools assessing increased interest in engineering fields due to Engineering Design electives



Lifelong Kindergarten Group, MIT Media Lab

Innovating to Educate

- Innovation happens at the edges
- Ability to see the “next steps” and the possibilities
- Resilience to learn from failure
- Creativity and joy of “lifelong kindergarten”

"My favorite part of this experience was you and your group members are building a product that can solve a problem that is destroying the world. I also like that the ideas for solutions are endless."

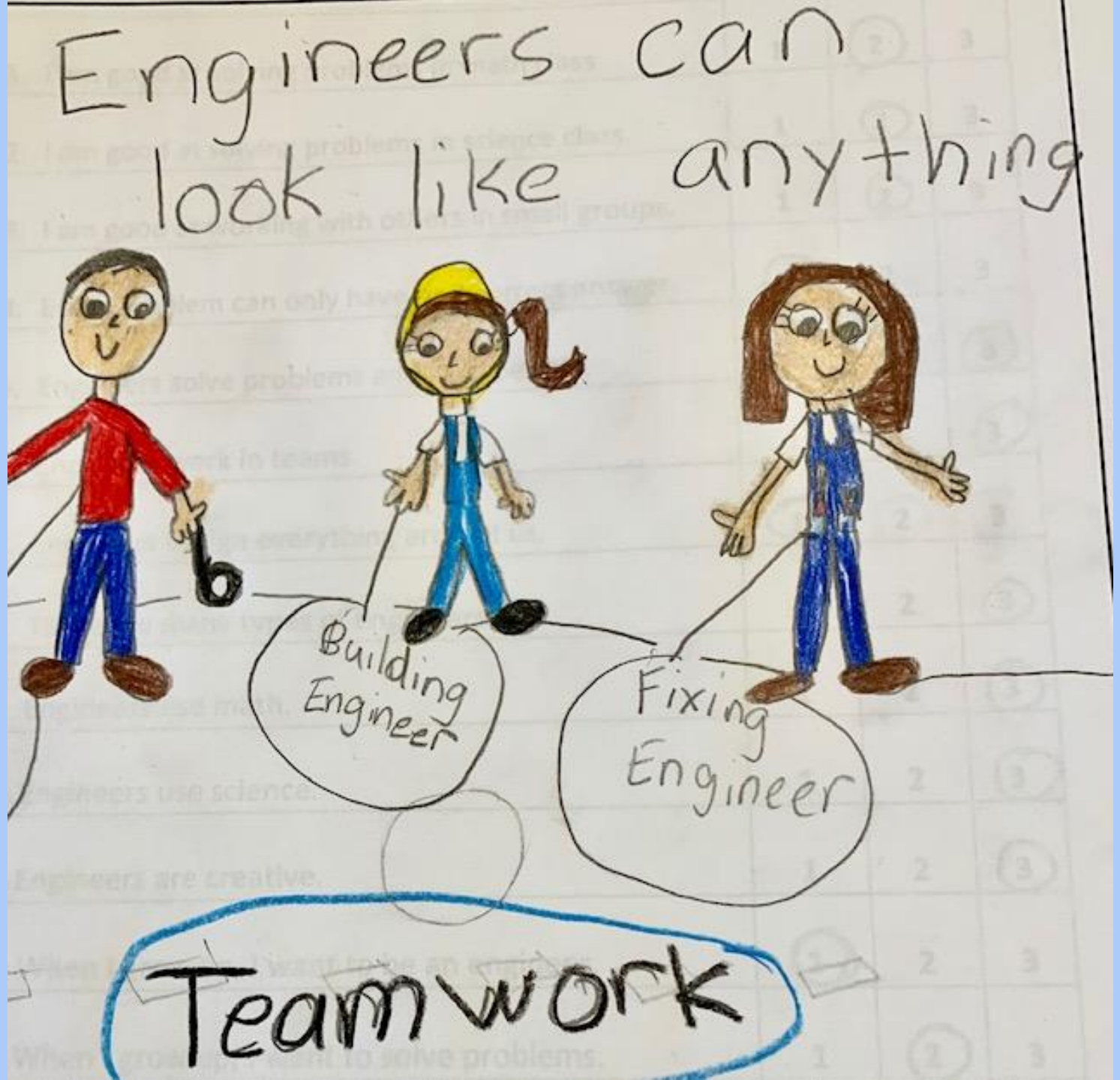
5th Grade Student

"We are providing them with a framework that can be applied to any challenge, interest, or subject they encounter. Students learn to develop empathy for their user and see the importance of really understanding the problem before coming up with solutions. They reflect on their failures and use that knowledge to make iterations and turn them into successes. Students also see the value in sharing their products or plans with an authentic audience… one student said, "If you don't share what you learned or created, what's the point?"

Middle School Science Teacher

"The latest project we have completed is a toy for special needs children. This project was important to me because we were designing it for someone I know personally. Making a toy for him, that he would like and enjoy was really important to me going into this project."

High school Senior


Engineers can look like anything
Building Engineer
Fixing Engineer
Teamwork

ProjectEngin™

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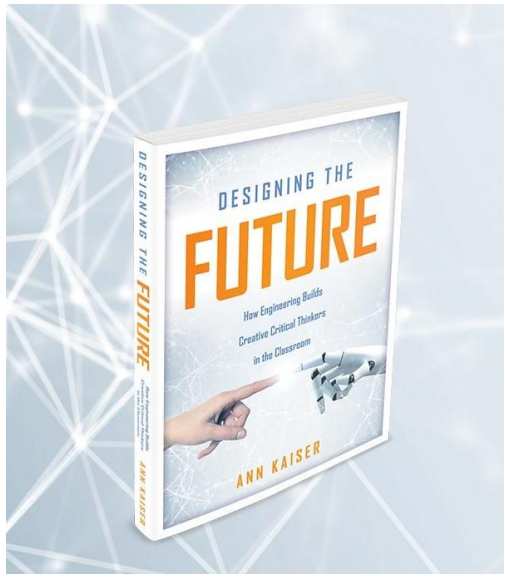

Thank You!

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