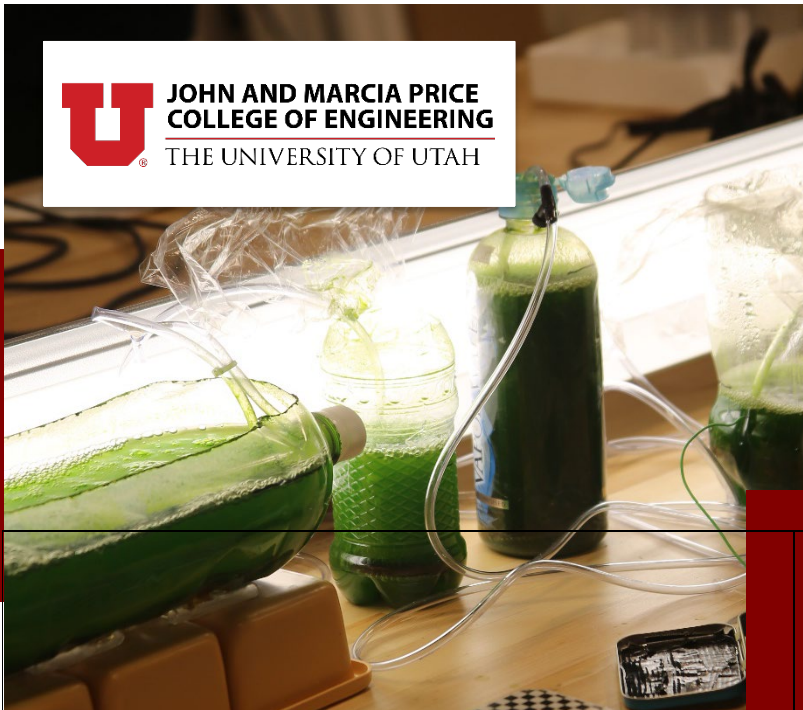
Is this a good engineering activity? Helping K-12 teachers implement quality activities in their classrooms

Dr. Stacy K. Firth

Stacy K. Firth is an Assistant Professor (Lecturer) in the Department of Chemical Engineering at the University of Utah. In her role, she focuses on Engineering education in grades K-12 and undergraduate education. She has developed an inclusive curriculum for a year-long Engineering exploration and projects course that is now taught in 57 Utah high schools. She also developed and provides professional development workshops for Elementary and Secondary science educators to support their teaching of Engineering within K-12 classrooms. She has developed and implemented a senior-level projects laboratory course in the Chemical Engineering curriculum at the University of Utah, giving students hands-on experience with the concepts she is teaching in their Process Control theory course. Stacy received a BS and MS in Chemical Engineering from the University of Utah. She then earned a PhD in Chemical Engineering at the University of Texas at Austin. Her research was focused on algorithms used in the processing of semiconductor wafers and resulted in two patents.



Is This a Good Engineering Activity? (Resource Exchange)

Helping K-12 Educators Implement Quality Activities in Their Classroom

Stacy K. Firth, stacy.firth@utah.edu

The Problem

With a growing number of hands-on activities available for K-12 educators, choosing ones that accurately reflect the practice of engineering without proper engineering training can be difficult, potentially miscommunicating engineering concepts to students. Expensive third-party kits or "fun" activities like Rube-Goldberg machines can limit budgets and prioritize complexity over efficiency, diluting the meaningful nature of engineering problem-solving.

The Approach

The framework of 5 criteria becomes a system by which K-12 educators can evaluate the quality of an engineering activity. Educators are introduced to and trained in using the framework during a professional development workshop. They work through quality engineering activities and then rate other activities that fit their subject or grade level curriculum standards. The framework and rating system can be adapted to grade level and subject area.

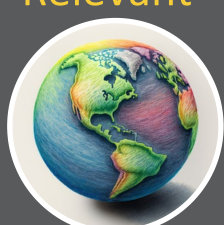
The Framework

Based on educational research and engineering practice, the following 5 criteria were chosen to motivate students and portray a more complete picture of what it means to engineer.

Connected

Connected to governing concepts

Relevant



Relevant to real problems

Creative

Opportunity to make design choices

Analytical

Quantitative measurements and analysis

Iterative

Opportunity to iterate on design

The Rationale	
1. Connected – Governing science concepts and mathematical equations inform the design phase.	Students should understand that engineering is fundamentally design under constraints, the most basic of which are physical laws. [1], [2]
2. Relevant – The activity is connected to a real-world need or addresses a significant issue.	Student engagement increases when they can see a connection between what they are learning and a problem affecting them or their community. [3]
3. Creative – Students use creativity to make decisions that impact design outcomes. Some uncertainty and complexity exist.	Engineering is an inherently creative endeavor. Students who are given choices show greater intrinsic motivation. [4] Uncertainty can set the stage for students to initiate and sustain inquiry. [5]
4. Analytical – Measurements are taken and data are analyzed to evaluate if design criteria have been meet.	Students should understand that engineers measure and use mathematics to analyze if a design has met the need and the design criteria. [2]
5. Iterative – Students have the opportunity to improve on original design. Focus is on what was learned from the design experience.	Engineering is also an iterative process. Through reflection on the activity, students make meaning from what they did and better integrate their learning. [6]

Scoring					
0	Activity does not address this criterion.	1	Some attempt is made to meet this criterion	2	Activity fully meets this criterion.

Examples	Passive Solar Design		Water Rocket Launch – As executed in a 6th grade class	
	Students construct a model home to maximize heating in winter and minimize heating in summer.		Students construct a rocket made from a soda bottle and launch it using water and an air pump.	
Connected	2	Concepts of Radiative, Conductive, and Convective heat transfer, as well as solar angle changes with the seasons, are used.	0	Concepts of forces, Newton's laws could have been used but were not discussed.
Relevant	2	Reduction of heating and cooling energy needs connects to a broader need for energy conservation.	1	Some students may connect to rocketry, but it may be outside the interest or experience of others.
Creative	2	Students choose materials, shapes, and sizes for the design of their model.	0	Templates are used for rocket fin cut-outs; students are given materials and instructions for attachment to the rocket body.
Analytical	2	Students measure material, use amounts to calculate a project cost. Students	0	No attempt is made to measure the amount of water used or the height the rocket flew.
Iterative	2 or 1	As time allows, students iterate on their design, or recommend future improvements. Students reflect on what worked well and what did not through observation of own and peer models.	0	No opportunity is given to redesign and no reflection on the activity is performed.
Total Score	**8 or 7**		**1**	

[1] B. Moulding *et al.*, *Science and Engineering for grades 6-12 : investigation and design at the center*, 2019.
[2] National Academy of Engineering. Committee on Standards for K-12 Engineering Education., *Standards for K-12 engineering education?* National Academies Press, 2010.
[3] S. Järvelä and K. A. Renninger, "Designing for learning: Interest, motivation, and engagement," in *The Cambridge Handbook of the Learning Sciences, Second Edition*, Cambridge University Press, 2014, pp. 668–685. doi: 10.1017/CBO9781139519526.040.
[4] E. A. Patall, H. Cooper, and S. R. Wynn, "The Effectiveness and Relative Importance of Choice in the Classroom," *J Educ Psychol*, vol. 102, no. 4, pp. 896–915, Nov. 2010, doi: 10.1037/A0019545.
[5] J. Watkins, D. Hammer, J. Radoff, L. Z. Jaber, and A. M. Phillips, "Positioning as not-understanding: The value of showing uncertainty for engaging in science," *J Res Sci Teach*, vol. 55, no. 4, pp. 573–599, Apr. 2018, doi: 10.1002/TEA.21431.
[6] J. Turns, B. Sattler, K. Yasuhara, J. Borgford-Parnell, and C. J. Atman, "Integrating Reflection into Engineering Education Integrating Reflection on Experience into Engineering Education," *ASEE Annual Conference Proceedings*, 2014.