Usable STEM Knowledge for Tomorrow’s STEM Problems

COP27, the Conference of the 197 nations following the United Nations conventions on Climate Change (https://cop27.eg/#/), has resulted in multinational cooperative agreements on how to address climate-fueled disasters, phase out fossil fuels, and transition to renewable energy. To realize results, these agreements rely on interdisciplinary solutions with foundations in science, technology, engineering, and mathematics (STEM). Whether individual communities or governments need to design a water filtration system to increase the availability of potable water or a modification of a vaccine to challenge a virus variant, we need STEM education programs in formal and informal settings that guide learners in applying STEM learning to the creation of solutions. As outlined in a recent policy document, “Science is an essential tool for solving the greatest problems of our time and understanding the world around us. Scientific thinking and understanding are essential for all people navigating the world, not just for scientists and other STEM professionals. They enable people to address complex challenges in local communities and at a global scale, more readily access economic opportunity, and rein in life-threatening problems such as those wrought by a global pandemic.” (NRC, 2021a). To emphasize the need even further, a recent President of the National Academy of Sciences stated, "Today, unless we can spread both scientific thinking and these critical scientific values much more broadly throughout society, I fear for humanity's survival." (Alberts, 2022).

This urgency needs to be reflected in the priority placed on science education in formal educational settings. A recent study found that the average time devoted to teaching science in US elementary schools is 20 minutes per day, a few days a week (NRC, 2021b). When science instruction exists, it often does not provide opportunities for learners to practice epistemic agency, i.e., the ability of students to shape the knowledge and practices of their learning within their classroom (Miller et al., 2018). Pre-university STEM Education programs must support students in harnessing their intellectual and creative resources. These programs might start with asking questions and engaging in scientific investigations, but they do not end there. Content learning is extended through cooperative problem definition, brainstorming problem solutions, and the enactment and testing of solutions.

To explore these ideas, we designed a learning approach, Solutioning, that guides youth to deepen their learning of science content through the practices of both science and engineering. Next, we created a six-week curricular program that manifested the learning approach and provided opportunities for students to study their local ecosystem and use engineering design to create and provide feedback on a trap design that would attract a local invasive insect that was harmful to their community.

The five phases of the Solutioning Instructional Model

Solutioning Instructional Model	
Phase	
Engage	Students **ask questions** associated with an introductory activity that engages their curiosity and provides a purpose for why they are studying local issues (often local environmental issues).
Explore	Students **collect data** to **use as evidence** to understand a local issue.

Explain	Students **analyze their data** and **use their data as evidence** to construct arguments to address their scientific questions.
Engineer	Students extend their understanding through **brainstorming, designing, and building a solution** that meets specific design criteria and constraints. Students **test their solutions** through feedback and data collection to determine if their solution is optimal for addressing the problem.
Educate	Students synthesize key ideas from their designs to inform and **educate** local stakeholders about possible implementation in their area.

Student trap designs took into account what phase of the life cycle of the invasive insect the students were interested in attracting, what kinds of pheromones or lures might attract the selected insect, where and when the traps should be placed, and how to create a trap that was both cost-effective and could be maintained over a period of time. Some traps were designed to look similar to their natural environment, such as a young tree, while others emphasized particular oils, fruit, or other attractants known to attract their insect.

Two Traps Designed to Mitigate Local Invasive Insects

We also conducted research studies to provide empirical evidence on student STEM learning and their ability to define science and engineering. Research results indicate that even elementary-age students demonstrate significant improvement in their understanding of STEM arguments as evaluated with a pre-post assessment provided before and after the implementation of a six-week solutioning curricular program (e.g., Songer and Ibarrola Recalde, 2021).

Understanding adolescents' perceptions of science and engineering is a necessary part of fostering holistic conceptions of science and the application of scientific knowledge through engineering design. New research explores the quality and characteristics of students' solutions and their ability to define and provide articulate examples of science and engineering before and after the curricular program. Throughout our continued investigations, we will categorize students' understanding of science, engineering, and the relationship between the two.

Science and Engineering Definitions Coding Rubic

	1 **Attitudinal**	2 **Weak**	3 **Developing**	4 **Sophisticated**
Define SCIENCE	Purely attitudinal	One or more specific scientific fields or concepts	Simplistic processes or umbrella terms	Thorough explanation of practices or concepts OR purpose of science
	"Science is fun."	"chemistry"	"how things work"	"A study of different things to have a better understanding of the world we live in."
Define ENGINEERING	Purely attitudinal	Limited to examples of items that were engineered or are parts of engineering	Includes a problem OR a simplistic process or solution approach	Articulate explanation mentioning a purpose or phases of engineering design
	"Engineering is hard"	"cars"	"fixing stuff?"	"Coming up with ideas of different things and making it."

Additionally, we are examining students' motivation to learn science and engineering and quantitatively analyzing any potential changes in interest or understanding throughout the curricular program. In these ways, we have begun to develop empirical information on the value of solutioning programs. As we have only begun this conversation, we welcome collaborators who wish to help us all to understand and foster pre-university students' scientific thinking and critical scientific values toward thinkers well-prepared to solve tomorrow's interdisciplinary problems.

References

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This work is funded in part by the National Science Foundation Grant 2125844.