Training a new generation of problem solvers

Innovation in STEM education

Humankind faces unprecedented environmental, social, and economic challenges. There is a critical need for STEM education to foster both science learning and the application of learning to problem solving. At the University of Utah, Professor Nancy Butler Songer and her collaborators have developed a suite of interdisciplinary instructional and field-based data collection resources offering elementary and secondary students the chance to create solutions for local, urban environmental issues. Tested in an economically disadvantaged neighbourhood with limited resources, students achieved significant learning gains after involvement in the eco-solutioning programme. A particular success was the increased awareness of local issues and students' increasingly seeing themselves as scientists.

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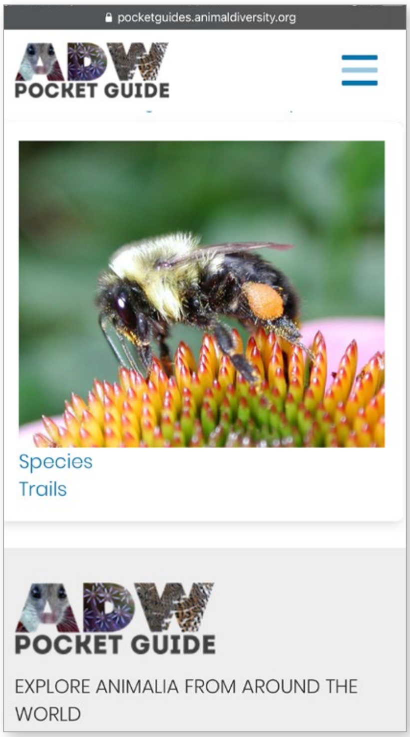
Humankind faces unprecedented environmental, social, and economic challenges that are typified by escalating climate change and the global COVID-19 pandemic. Students engaging in STEM (Science, Technology, Engineering, and Mathematics) education today are those who will be tasked with finding the solutions of the future. As such, there is a critical need for STEM education to foster both science learning and the application of that learning to practical youth problem solving. However, in reality, few pre-college instructional programmes prepare students to apply classroom learning to the engineering design of solutions.

Socio-Scientific Issues (SSI) is the term used to describe science education focused on problem solving. Programmes that emphasise SSI are increasingly championed around the world, and range from those aimed at school-aged children, to citizen science initiatives aimed at harnessing



the power of population to address scientific questions.

At the University of Utah, Professor Nancy Butler Songer and her collaborators (including Dr Prasad Ram, Dr Kirby Whittington, Dr Tanya Dewey, Dr Michelle Newstadt, Dr Tamara Gayolan, Dr Guillermo D. Ibarralo Recalde, and Roger Espinosa) use design, delivery, and evaluation of a suite of interdisciplinary pre-college instructional and field-based data collection resources focused on STEM education and the development of environmental solutions. Under this programme, elementary and secondary

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The programme instilled a desire to assist the local community through positive action.

school students are offered the chance to create solutions for increasing biodiversity in their local, mostly urban neighbourhoods. With funding from the United States National Science Foundation, the instructional materials are delivered through Gooru's Learning Navigator, a data backbone system that organises curricular activities, assessments, and teacher materials into one interactive system that provides customised real and near-time data for students, teachers, and researchers.

LEARNING APPROACHES

SSI programmes tend to have four main features: (1) personal relevance (ie, the use of problems that are relevant to the target student cohort); (2) socially important and non-trivial (ie, a focus on socially important topics towards which there are multiple positions, fostering discussion and debate); (3) moral reasoning (choosing topics that have ethical considerations and facilitate evidence-based reasoning); and (4) personal development (ie, facilitating character building and social/environmental awareness).

In general, developing programmes that are culturally and practically relevant to the student cohort requires a focus on local issues. As such, teachers can and should move away from textbook-based teaching, and instead foster first-hand exploration followed by discussion and reflection. A critical component is three-dimensional science learning; that is, knowledge of science and engineering practices, disciplinary core ideas, and concepts that cross-cut them all.

The approach developed by Professor Songer and her colleagues, *eco-solutioning*, focuses on environmental issues for students, and emphasises a sequence of activities that deepen students' understanding of life science content through the engineered design of local solutions. Based on the eco-solutioning concept, materials have been designed for students and teachers in a range of culturally, racially, and linguistically diverse schools in the United States, including Philadelphia, in Pennsylvania, and Salt Lake City, in Utah.

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How does eco-solutioning differ from more traditional teaching models? Where a traditional approach aims to help students understand a topic, eco-solutioning asks those students to *ask questions* about a project. Where a traditional approach uses existing information to inform students, *eco-solutioning* tasks students with *original data collection* and the *interrogation of self-generated evidence*. Where a traditional approach encourages conceptual understanding, *eco-solutioning* promotes *discussion* and asks students to *construct arguments*. Where a traditional approach may aim to provide broader understanding of an issue, *eco-solutioning* requires that students *design their own solutions* to complex socio-ecological issues.

ECO-SOLUTIONING: THE NUTS AND BOLTS

The design of the eco-solutioning approach, which was developed based on both qualitative and quantitative research into the application of SSI teaching, can be summarised in six main steps corresponding to a six-week curricular unit for elementary school students (aged 8–11 years old).

(1) Identify a small number of 3D science and engineering learning objectives to form the foundation of the curriculum; the number chosen should consider the age of the students and complexity of the objectives.
(2) Together with (1), or shortly thereafter, identify local issues that exemplify the chosen learning outcomes. For example, learning outcomes focused on urban biodiversity could be illustrated by planting projects in local municipal parks that aim to increase the number of pollinators.
(3) Develop a series of smaller learning goals, that together build towards the overarching learning objectives.

Eco-solutioning encourages students to ask questions about the project at hand.

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A focus on urban biodiversity could encourage planting projects in local parks.

(4) Design classroom activities that work towards the learning goals and objectives; these activities should facilitate discussion among students. There should be no easy answers.
(5) Using the classroom activities identified in (4), develop the necessary lesson plans that culminate in student design and presentation of their solutions to local policymakers and other community members.
(6) Develop means of assessment and pathways to allow for feedback. Multiple assessment pathways should be chosen to cater to different thematic areas and to obtain a holistic measure of student performance.

Using this workflow, Professor Songer and her colleagues put their programme design through a three-stage testing process, updating and improving the approach after each cycle. A critical pedological shift of recent years has been the move away from viewing education as an individual cognitive process, and instead recognising that knowledge and the process of gaining knowledge cannot be viewed independently of the cultural and social context. The *eco-solutioning* approach was tested within a 'Promise Zone', urban areas identified in 2014 by the Obama administration as facing the challenges of pervasive poverty, limited resources, and a lack of opportunity; in such neighbourhoods, students often fall short in terms of standardised educational testing. The 94 students in the trial, and their teachers, were from three culturally, racially, and linguistically diverse schools.

Data from various assessment pathways show that these students achieved significant learning gains after involvement in the eco-solutioning programme. In particular, students benefited from interacting with local scientists and from visiting local sites. For example, on trips to a local urban farm, students learned about local biodiversity and sustainability, and the issues of living in a local 'food desert'.

A particular success of the programme was the increased awareness of local issues and a new-found wish to serve the local community through positive action. Moreover, students increasingly saw themselves as scientists, despite most having no previous experience with professional scientists or even with the concept of a 'scientist'. In short, the programme was aspirational, perhaps the mightiest of all pedological goals.

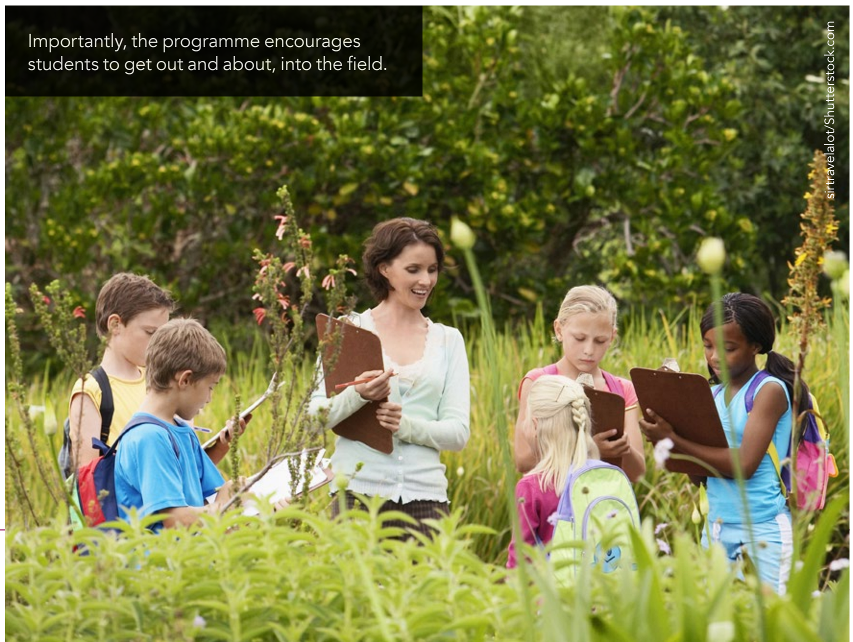
GETTING OUT AND ABOUT

Among the materials developed was a field-based data collection tool called the Animal Diversity Web Pocket Guide. This guide is a web-based tool with content customised to help students identify the most commonly encountered local insect faunas within USA cities. In particular, the tool includes species accounts and information on higher taxa (above the species level) to help students navigate content (eg, find butterflies [*Lepidoptera*] and then navigate to butterfly species that they observed). The resource also provides students with a traditional scientific tool known as a dichotomous key which presents users with two options

Eco-solutioning requires that students design their own solutions to complex socio-ecological issues.

From this knowledge, students were encouraged to develop solutions to mitigate non-native insects and encourage native pollinator species. Learning was very much hands-on, with the students helping to harvest, clean, and transport produce to market. Informal settings for feedback were also provided, including interviews, open-ended surveys, and discussions.

to describe a series of characteristics. By moving through the options, the user can identify a particular species to make species identifications with visible features (ie, in the field) in a fun and easily navigable way on a digital device. Professor Songer and her team believe the dichotomous key is the only such tool for this student audience, and that its format represents a novel use of the technology.



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Importantly, the programme encourages students to get out and about, into the field.

Behind the Research

Professor Nancy Songer

E: nancy.songer@utah.edu **T:** 1 801 581-8221 (office phone)
W: https://education.utah.edu/about/dean-bio.php **W:** https://lrhe.utah.edu

Research Objectives

Professor Nancy Butler Songer researches the design, delivery, and evaluation of a suite of interdisciplinary pre-college instructional and field-based data collection resources focused on STEM education and the development of environmental solutions.

Detail

Address
Nancy Butler Songer
Dean, College of Education, University of Utah
1721 Campus Center Drive, Room 3202
Salt Lake City, UT 84112

Bio
Nancy Butler Songer is Dean of the College of Education at the University of Utah. Songer and her team create instructional systems that emphasise pre-college students' engineered solutions to address local environmental challenges. Recognition includes a Presidential Faculty Fellowship from the President of the United States, and two Fulbright awards.

Funding
United States National Science Foundation

Collaborators
Dr Prasad Ram, Dr Kirby Whittington, Dr Tanya Dewey, Dr Michelle Newstadt, Dr Tamara Gayolan, Dr Guillermo D. Ibarralo Recalde, Roger Espinosa

THE UNIVERSITY OF UTAH
College of Education

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Personal Response

What is the next stage in development? Will you expand testing of the eco-solutioning approach to different geographical areas (and different sociocultural settings) and/or will you expand it to different levels of education (eg, high school and even undergraduate teaching)?

" We believe that as educators we have a societal duty to empower pre-college students to ask questions, engage in investigation, and work cooperatively with others to generate solutions to present and future interdisciplinary problems. To realise this goal, students and teachers need instructional resources that organise students' learning, field-based data collection, solution generation, and evaluation. Our next step is to extend from our work with younger audiences to design and evaluate eco-solutioning instructional materials for secondary students' engagement and environmental problem-solving, including solutions that mitigate the effects of local invasive species. "

Your work is at the forefront of pedagogical STEM research, but how do you present these ideas outside of the academic realm? That is, how do teachers learn about these ideas, and how long does it take for new approaches to become part of mainstream teaching?

" To find out more about eco-solutioning and our instructional materials, a good starting place is our project website, https://lrhe.utah.edu. This webpage has sample instructional lessons, a research paper written for teachers, and a contact email for follow-up inquiries. While our eco-solutioning approach is not yet mainstream teaching, several STEM initiatives in various countries emphasise pre-college STEM curricular programmes and problem-solving like our work to address local environmental challenges. An exemplar project is the USAID-funded STEM Schools project to develop secondary schools in Egypt where all student learning is applied to solving Egypt's Grand Challenges (https://www.21pstem.org/videos). "