Problem Scoping in Designing Biomimetic Robots

Fayette Shaw, Tufts University, fay.shaw@tufts.edu
Kristen Wendell, Tufts University, kristen.wendell@tufts.edu
Gillian Puttick, TERC, gilly_puttick@terc.edu
Debra Bernstein, TERC, debra_bernstein@terc.edu
Ethan Danahy, Tufts University, ethan.danahy@tufts.edu

Abstract: We examine problem scoping in our interdisciplinary curriculum where students build biomimetic robots. Biomimicry is a context for learning biology, computational thinking, and engineering design. In the *solution space,* students narrow the scope of their robot designs, informed by animal structure-function relationships. In the *challenge space*, they narrow the scope of real-world disasters by modeling them in the classroom. This dual problem scoping enables students to be active participants shaping the content of their learning.

Keywords: problem scoping, interdisciplinary curriculum design, design-based research

Introduction

Robotics design over the past two decades has drawn heavily from the study of biological systems (Cho & Wood, 2016), and biomimetics is beginning to make its way into K-12 classrooms (e.g., Gardner, 2012; glbiomimicry.org; teachengineering.org). Biomimetics provides an ideal context for both fostering and investigating interdisciplinary STEM learning, as it invites the study of biological structures, functions, and processes to inform engineered solutions to problems. In our work, middle school students build biomimetic robots from available classroom materials to solve a search and rescue challenge. This poster focuses on an early stage of a multi-year project and explores the research question: *How do middle school students engage with problem scoping in the development of a biomimetic robotics design challenge*?

Theoretical and methodological approach

Participatory learning spaces emphasize the intellectual resources of students as knowledge producers (Tucker-Raymond et al., 2012), draw on the values, practices, and histories of learners and their communities (Bell et al., 2009), value distributed expertise, and flatten traditional knowledge structures (Jenkins, 2009). Our project's *participatory* approach allows young people to shape content, collaboratively solve problems, and develop self-efficacy as learners and technology creators (Jenkins, 2009; Tucker-Raymond et al., 2012). The study uses a design-based research (DBR) approach, driven by our design conjectures about the tools, task structures, participant structures, and discursive practices that support learning in a classroom environment. The DBR framework allows us to contribute to theory about participatory pedagogy as a strategy for improving learning and efficacy in STEM, and contribute design principles for effective interdisciplinary learning environments that integrate science, engineering, and computing. Here, we report on our investigation of problem scoping in three middle school classrooms that implement the pilot version of our biomimetic robotics curriculum.

Problem scoping

We focus on problem scoping because it is an engineering practice aligned with participatory pedagogy. We define problem scoping as determining the boundaries of a complex problem space (Watkins et al., 2014). Much of the research on problem scoping has been done at the university level (Atman et al., 2008); we build on the work that has been done with young learners (Watkins et al., 2014). As we have designed the curriculum and explored scaffolding needed, we have observed that problem scoping both narrows the *challenge space* of search and rescue (Figure 1, left, green), and the *solution space* of biomimetic robot design (Figure 1, right, orange). Students employ *reflective decision-making* (Wendell et al., 2017) as they decide how to represent real-world disaster scenarios and robotic solutions. Throughout the curriculum, students examine structure-function relationships from an organism to design a human-created system.

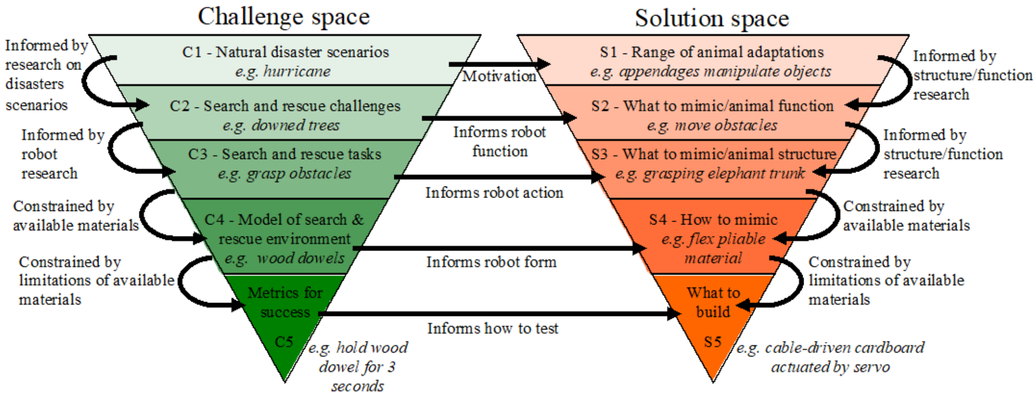

Figure 1. Problem scoping in the challenge space (left, green) and solution space (right, orange). We highlight a hurricane disaster example in italics.

We first examine the challenge space to include a wide range of natural disaster scenarios (C1). In these scenarios, the terrain may be impassable by wheeled vehicles, making animal adaptions applicable. Animals are able to burrow under, jump over, cut through, and manipulate obstacles (S1). In this example, we describe a hurricane scenario (C1) where large obstacles are downed trees (C2). Students study animals that can manipulate objects (S1) and move them out of the way (S2). They then examine potential robot tasks and they choose to grasp objects (C3) as inspired by an elephant trunk (S3). The students model their environment and wood dowels can represent downed trees (C4). Mimicking an elephant's trunk, students design a pliable robot to pick up a dowel (S4) and hold it for 3 seconds (C5). One solution is to construct a cable-driven mechanism actuated by a servo (S5). Biomimicry provides a rich context for students to develop a wide variety of solutions to problems they identify, define. Students do repeated reflective decision-making as they narrow scope to build a representation of a disaster scenario and a robot that can negotiate it. The students are empowered as active learners as they define their own criteria for success.

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