# Navigating Dual Goals of Team Collaboration and Design Concept Development in a Middle School Bio-Inspired Robotics Unit

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**Abstract:** We present a microgenetic case study of a sixth-grade student who succeeded in achieving the dual goals of collaborative design teamwork and prototyping a biomimetic robot. She combined a consensus-building stance with a strategy of repeated multimodal explanation to achieve the uptake of her complex robot design concept as the shared team design plan.

## Introduction

Engineering is a collaborative social decision-making process and this reality is mirrored in the participation structure typically set up in classrooms during engineering design projects: students are grouped into design teams and asked to collaborate. Two rationales for this participation structure are often given by teachers as well as the engineering education literature: (1) it is essential to practice collaborating both because it is an aspect of engineering and because it is part of preparing to participate meaningfully in society, and (2) collaboration will improve the outcomes of students' engineering work; that is, they will be more likely to design a successful solution if they have peers to help prototype and refine ideas (Jordan & McDaniel, 2014). However, collaborating with peers to produce a single tangible artifact that successfully carries out a function is difficult socio-cognitive work (Bucciarelli, 1994). It requires capacities to explain ideas, to produce knowledge objects, to represent them in multiple modes, and to navigate social relationships and disciplinary uncertainty. In this paper, we present a microgenetic case study that emerged from the enactment of an interdisciplinary robotics curriculum in a sixth-grade science classroom. This case study was guided by the research question, *how does a sixth-grade student achieve the often competing goals of productive team collaboration and individual design concept development throughout a multi-day biomimetic robotics engineering project?*

## Frameworks and methods

Overall, in developing the curriculum and building theory from its enactment, we follow a design-based implementation research methodology (Fishman, Penuel, Allen, Cheng, & Sabelli, 2012). In this case study, we take the sociocultural perspective that learning engineering involves becoming a more proficient participant in its disciplinary practices (Lave & Wenger, 1991). We are also informed by prior work on how students achieve conceptual convergence when working in groups (Roschelle, 1992) and on design conceptualization specifically in engineering (Daly, Yilmaz, Christian, Seifert, & Gonzalez, 2012).

This study is part of a larger design-based research project aimed at developing and studying interdisciplinary learning experiences that integrate engineering, life science, and computational thinking at the middle school level. In the Designing Biomimetic Robots curriculum, Week 1 introduces a digging robot design challenge along with structure/function analysis of digging animals; Week 2 introduces robot hardware and programming, ending with a design sketch; Week 3 involves building and testing a robot prototype; and Week 4 involves reflection, revising the prototype, and reporting.

We develop a descriptive case study (Merriam, 1998) of a sixth-grade design team comprised of a white female and two white male students in a public school in New England. We focus on their first five days of robot design and building in Weeks 2 and 3. Data sources included video data, photos of constructed artifacts, and students' written work. Data analysis aimed to pose and evaluate claims about the strategies and stances that the female student Meg (a pseudonym) employed to achieve conceptual convergence with her teammates.

## Findings

We trace Meg's design idea by highlighting explanatory and consensus-building talk through the two days of robot sketching followed by three days of robot building. Her team is mimicking how a pangolin digs and Meg develops a concept that uses a cable drive mechanism to mimic its digging action. This was complicated because the students examined a building guide for the cable drive mechanism, but had no physical models to understand it. Meg's talk and representations established both explanatory and consensus-building stances toward collaborative robot design (Table 1), and the interaction of those stances contributed to her teammates' eventual uptake of her design concept.

Table 1: Examples of Meg's talk indicating her consensus-building and explanatory stances

| | Consensus-Building | Explanatory |
|---|---|---|
| Sketching Days | So, what are we sketching… are we gonna sketch the motor with it? … Yeah… yeah what do we want it to look like? | Umm, what I did [on my sketch], the cable drive, umm, to me is the most similar to like the claw and we could connect the string to the rotation motor umm if we rotate it back the claw would go up and everything… yeah. |
| Building Days | Umm… Are we going to have a string going up the... To move it and everything? | So what I was thinking was like the string we'd be using to this [arm made from three craft sticks joined by brads] so that you could umm pull the string and then it's like connected to the top and if you like pull the string then it'd go like… fall. |

We found that over the course of a multi-day biomimetic robotics project, sixth-grade student Meg achieved the competing goals of productive team collaboration and individual design concept development by combining a consensus-building stance with a strategy of repeated multimodal explanation of her own thinking about the robot design. During the five days of designing and building, Meg set out to advance her cable drive design concept while frequently messaging to her teammates that she was also taking their ideas into account. She had a clear idea of what she wanted to build and successfully convinced her teammates to build what she envisions. Often when young students face this task, they attempt to persuade by appealing to social status, team votes, or turn-taking routines (Wendell, Wright, & Paugh, 2017). However, Meg achieved the uptake of her design concept by establishing a stance of consensus-building and then patiently and repeatedly describing her thinking through sketches, spoken explanations, gestures, and manipulations of the artifact.

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