Fostering Computational Thinking Through Neural Engineering Activities in High School Biology Classes

UCONN NEAG SCHOOL OF EDUCATION · Duke UNIVERSITY

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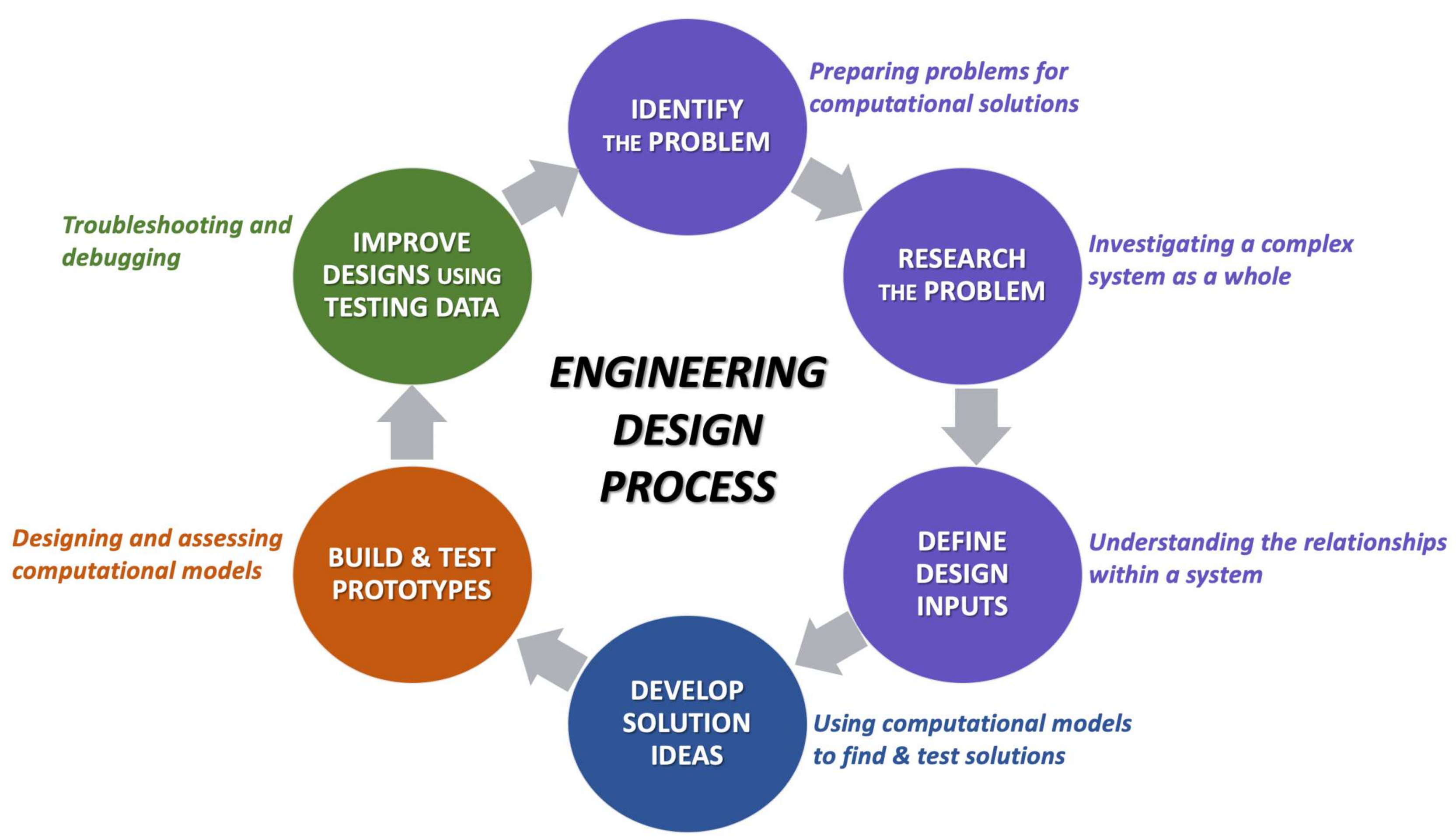
Introduction

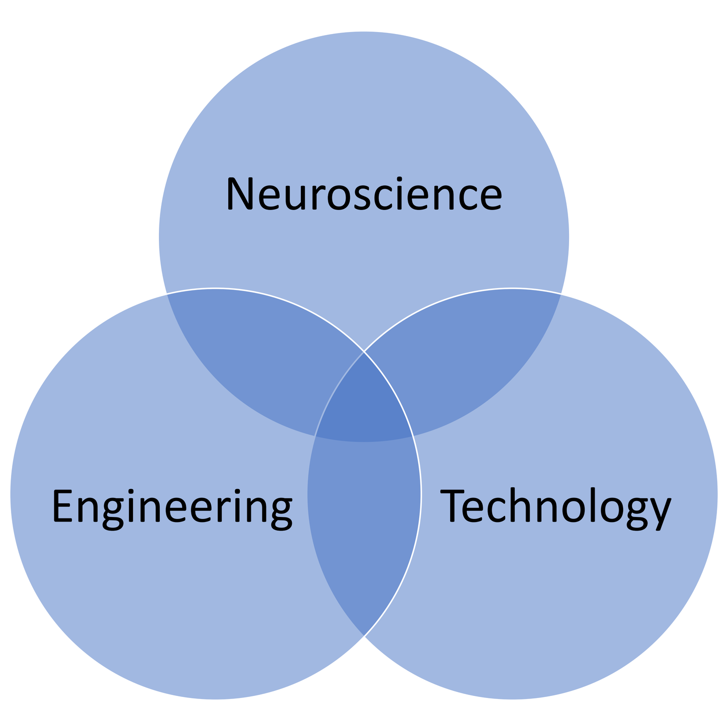
Computational thinking (CT) practices, such as abstraction, pattern recognition, and problem decomposition, are embedded in virtually every STEM discipline. Yet, most existing K-12 CT education efforts focus on computer science courses, which are only taken by a fraction of students (Computer Science Teachers Association, 2019). Therefore, there is a critical need to integrate computing and CT into one or more of the other STEM disciplines to demonstrate the inter-disciplinary, fundamental nature of CT and to broaden access (NGSS Lead States, 2013). **The current project aims to incorporate CT within two STEM disciplines: engineering and biology.**

Engineering design offers an appealing context for fostering CT



The engineering design process has many conceptual and practical commonalities with CT practices, such as those outlined by Weintrop et al. (2016).

Developing CT through Neural Engineering



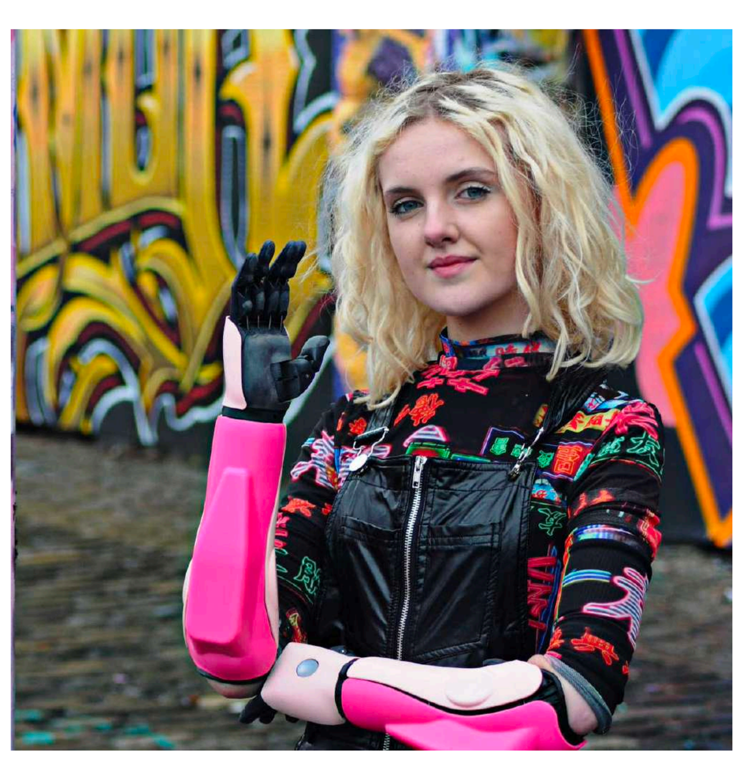


Image credit: openbionics.com

Neural engineering, the application of engineering design principles toward solving problems related to the nervous system, provides a novel, interdisciplinary, and real-world context for high school students to develop their CT.

Project Goals

- Develop and field-test a neural engineering unit to support CT in high school students.
- Adapt a node-based programming software to support engineering design activities.
- Investigate how student CT skills and attitudes towards STEM change as they participate in engineering design activities.

Module 1: Motor Control

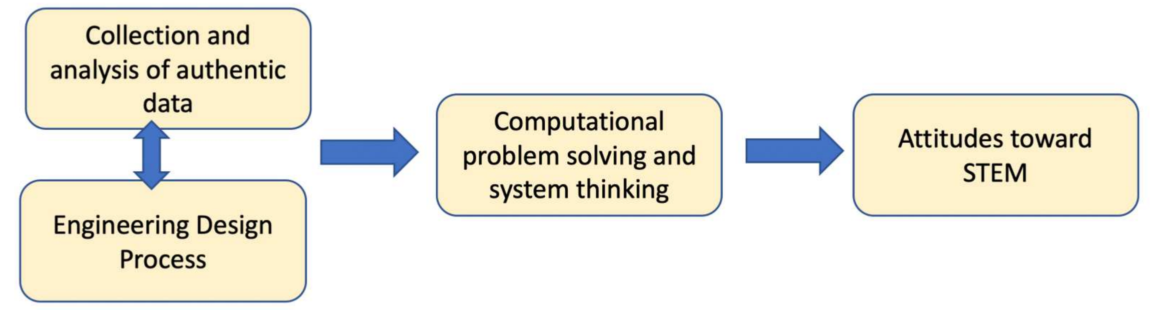
Lesson	Driving questions	Key activities
1.1	What is a bionic arm?	• Introduction of the anchoring phenomenon • Creating an initial model of how bionic arms work
1.2	What controls our movement?	• Reaction time measurement • Constructing a model of body systems that are involved in voluntary movement
1.3	How does nerve injury affect movement?	• Investigating how neurological conditions could impact limb movement • Creating a computerized model of limb movement
1.4	How do muscles work?	• Exploration of muscle electrical activity (EMG)
1.5	How do you control a robotic gripper?	• Design challenge #1: A muscle-controlled gripper

Module 2: Tactile Feedback

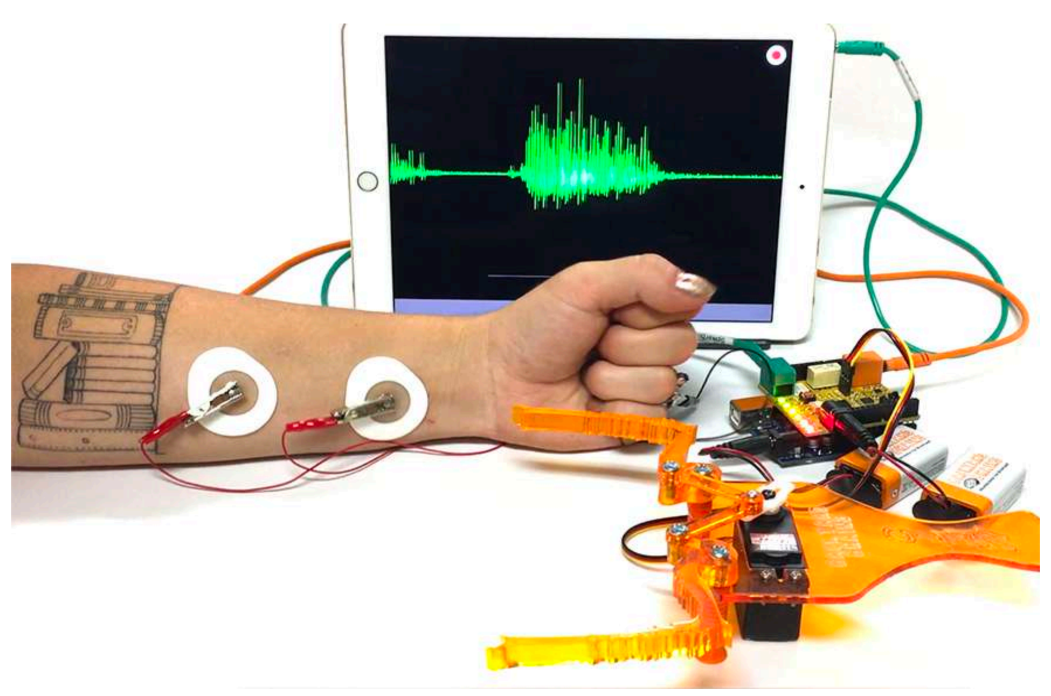
Lesson	Driving questions	Key activities
2.1	How does touch impact movement?	• Measuring reaction time with and without gloves
2.2	How do we perceive touch?	• Homunculus mapping • Constructing a model of body systems that are involved in touch perception
2.3	Can robots sense objects?	• Design challenge #2: Can you grab an egg without cracking it?
2.4	Putting it all together	• Case studies

Research Questions

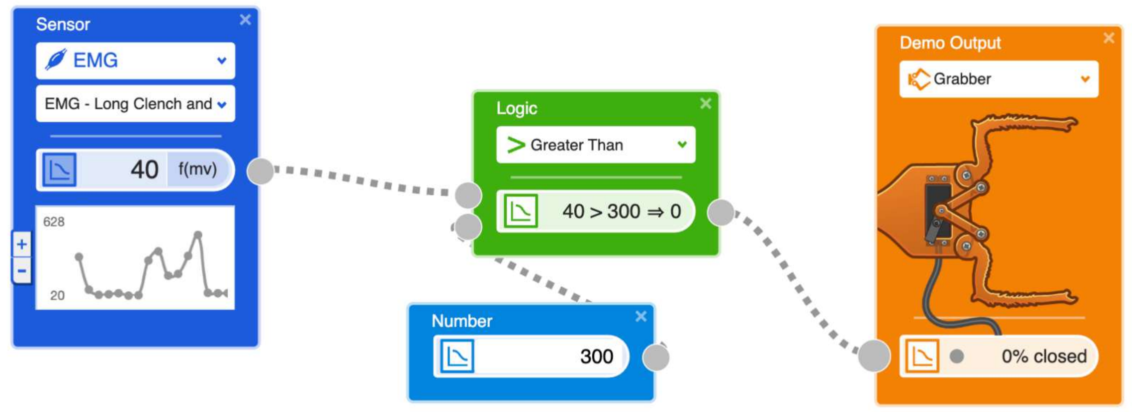
- How does the process of collecting and analyzing data relate to students' CT?
- How do students' attitudes towards STEM change over the course of their participation in a CT-intensive biology unit?
- How can we help teachers foster CT in their students via engineering design?



Technology Tools



A prefabricated EMG-controlled gripper used by students throughout the unit



Students design computer programs in "DataFlow," a node-based programming environment, which has been developed by the *Concord Consortium* (Bondaryk, Hsi, & Van Doren, 2021).

Preliminary Findings

- Students appreciated the authentic nature and real-world value of engineering and technology.
- The experience of measuring one's own muscle activity and the use of this data to control the movement of a robotic gripper was engaging and helped students make meaningful connections between the unit and their day-to-day lives.
- In some cases, students' understanding of the underlying biological phenomenon (e.g., interaction of body systems and muscle contraction) was limited.
- Teachers needed additional support to effectively integrate technology and programming in their instruction.

For additional information, see Aldemir et al., 2022

Aldemir, T., Davidesco, I., Kelly, S. M., Glaser, N., Kyle, A. M., Montrosse-Moorhead, B., & Lane, K. (2022). Investigating Students' Learning Experiences in a Neural Engineering Integrated STEM High School Curriculum. *Education Sciences*, 12(10), 705.

Bondaryk, L. G., Hsi, S., & Van Doren, S. (2021). Probeware for the modern era: IoT dataflow system design for secondary classrooms. *IEEE Transactions on Learning Technologies*, *14*(2), 226-237.

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Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, 25(1), 127–147.

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