The Computer Science and Computational Thinking of STEM

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Outline of the Presentation

- Define terms related to computational thinking
- Examine research surrounding computational thinking and STEM
- Examples of coding and STEM integration

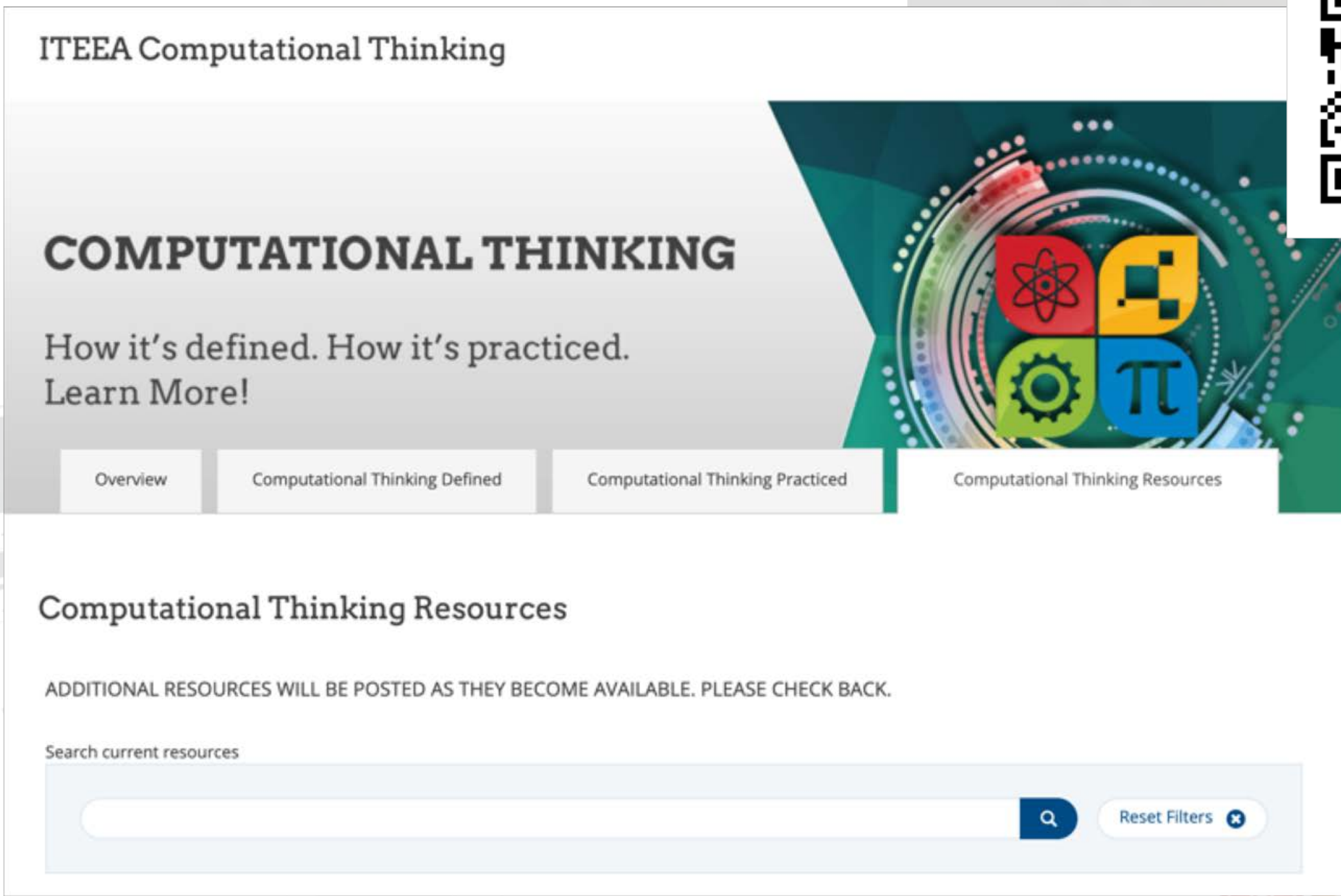
Defining Computational Thinking

What is Computational Thinking?

- A problem solving process of organizing information and thinking to allow a computer to generate solutions (identifies patterns and generates algorithms to predict future patterns).

How does this differ from the definitions of coding, programming, computer science?

https://www.iteea.org/Resources1507/ComputationalThinking.aspx



Defining Integrative STEM Education

" the application of technological/engineering design based pedagogical approaches to *intentionally* teach content and practices of science and mathematics education through the content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (Wells & Ernst, 2012/2015).
(as adapted from Wells/Sanders program documents 2006-10).

The Status of Computer Science in U.S. Schools as of 2019

- Many Governors have supported the CS in every school initiative
- NJ and MD include Computational Thinking in their T&E Standards
- At least 35 states allow CS courses to count toward HS graduation
- Maryland is currently the only state allowing CS courses to replace T&E Education courses for graduation
- Multiple studies have shown vast differences among CS and T&E curricula and standards
- There is a need for curricula that apply computational thinking as a tool to teach T&E content through hands-on, design-based approaches
  - **Often referred to as "Physical Computing"**

Tech Ed/Computer Science Graduation Requirement in Maryland

MSDE Preapproved Courses for Technology Education Graduation Credit	
Engineering Design-Based Courses	**Computer Science-Based Courses**
• ITEEA's Foundations of Technology • Project Lead the Way Introduction to Engineering Design* • Project Lead the Way Principles of Engineering*	• Exploring Computer Science • Foundations of Computer Science* • Advanced Placement Computer Science Principles

http://www.marylandpublicschools.org/programs/Documents/CTE/TE/TEGradCreditOptions.pdf

How Similar are Computer Science and Technology Education Standards?

Love, T. S., & Strimel, G. (2017). Computer science and technology and engineering education: A content analysis of standards and curricular resources. *The Journal of Technology Studies, 42*(2), 76-88. Retrieved from https://scholar.lib.vt.edu/ejournals/JOTS/v42/v42n2/pdf/love.pdf

Curricular Resource	*Description*	*STL Designed World Components*
Precision Farming	The FarmBot is an example of an open-source CNC system operating from Arduino and Raspberry Pi coding that makes precision farming possible (Lentz, 2016). Teachers can work with students to create a track structure (structural and manufacturing technologies) and program (information and communication systems) for more efficient crop growth (agricultural and biotechnology).	
Microcomputers and Sensors (e.g., Raspberry Pi)	Love, Tomlinson, and Dunn (2016) provided a wealth of instructional resources for utilizing programming to control various sensors and solve authentic engineering design challenges such as a smart house.	
Scientific and Technical Visualization I & II	These standards-based curricula by ITEEA (p. 7) are focused on using complex graphic and visualization tools such as graphics and animation software to illustrate, explain, and present technical, mathematical, and scientific concepts. Ernst and Clark (2007) demonstrated learning gains related to the various designed world components as a result of these curricula.	
Game Art and Design	This standards-based curricula by ITEEA (p.7) teaches students about the basics of game theory and strategic thinking to create a working prototype of a board game. In this curricula, students learn basic knowledge and skills that relate to fundamental programming concepts associated with the industry. Lesson topics such as probability and Nash Equilibrium have proven to be important in many fields of learning including biology, computer science, politics, agriculture, and economics. Ernst and Clark (2007) found this curriculum to be very engaging while addressing many technology and science standards.	

Cyber Security	This unit from ITEEA's Advanced Technological Applications (ATA) curriculum was developed in collaboration with the U.S. Naval Academy and addresses an array of science, technology, engineering, and mathematics (STEM) standards. Current research efforts (NSF, 2015) are examining the learning of cyber security through representational fluency, which is a powerful tool to teach complex concepts in science and mathematics.	I
Advanced Manufacturing	Loveland (2012) demonstrated how learning basic G & M code promotes higher order technology and mathematics thinking. Students must apply advanced math and technological problem solving skills to operate computer numerical control (CNC) lathes, milling machines, and routers. Even if schools do not have these advanced manufacturing machines, students can still simulate the manufacturing process through Computer Aided Manufacturing (CAM) software.	I, Ma
Robotics	There are various robotics curricula available that can be beneficial to student learning, for example, as Berenguel et al. (2015) demonstrated. Those that go beyond kits, and require students to design and construct their own robotic systems apply many STEM skills. Additionally, they integrate programming with engineering design to solve problems related to many of the designed world components.	C, E, I, Ma, T

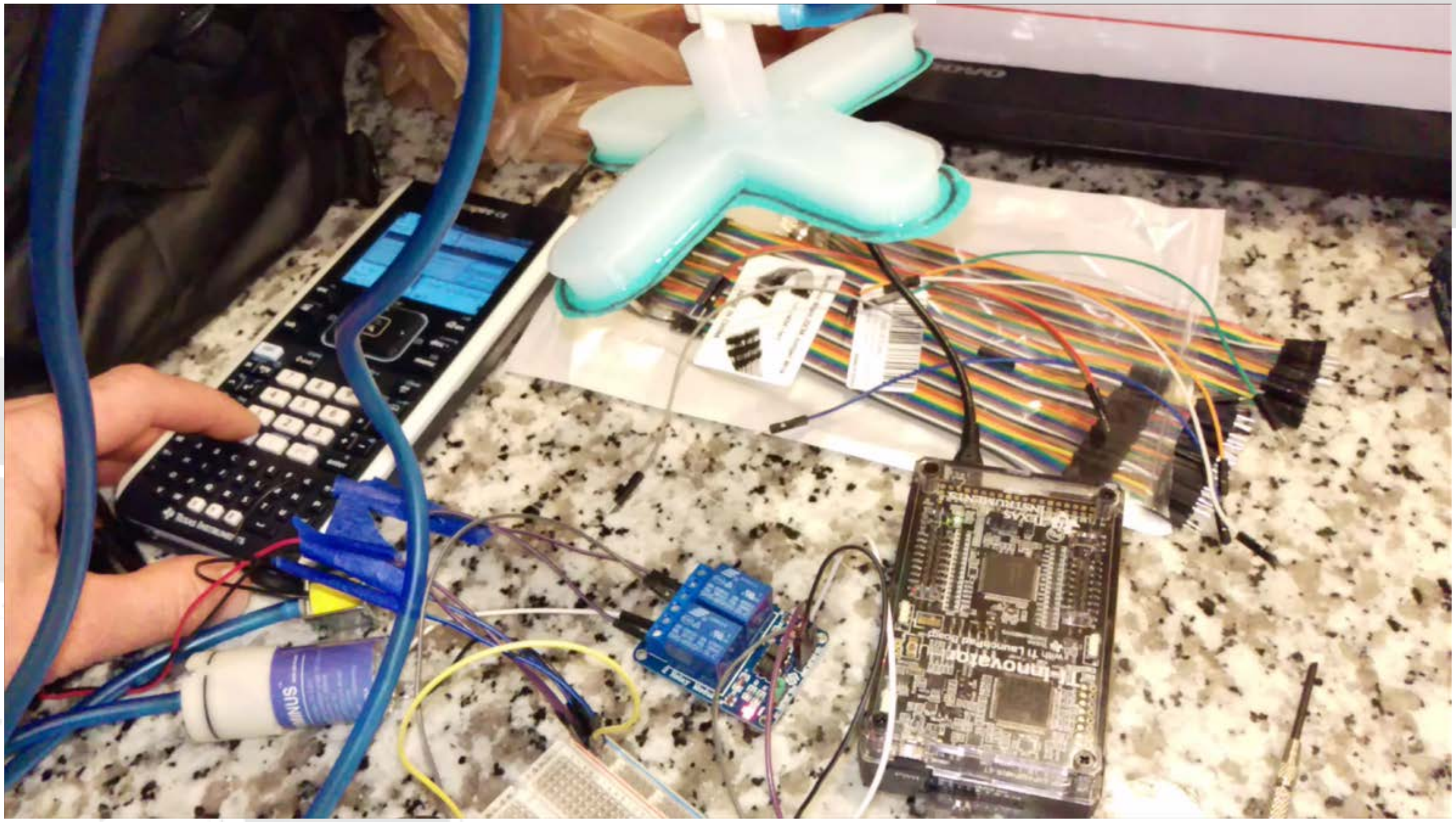
How Similar are Computer Science and Technology Education Courses?

- Buckler, C., Koperski, K., & Loveland, T. R. (2017). Is computer science compatible with technological literacy? *Technology and Engineering Teacher*, *77*(4), 15-20.

Physical Computing: Integrating Computer Science and *Hands-On* STEM

- What is Physical Computing?
- "Teaches students about computer science and computational thinking through physical tools and hands-on activities."
- Genota, L. (2019, January 23). 'Physical computing' connects computer science with hands-on learning. *Education Week*. Retrieved from https://www.edweek.org/ew/articles/2019/01/23/physical-computing-connects-computer-science-with-hands-on.html

What Integrative STEM and Physical Computing looks like: Soft Robotics for EbD™ with Purdue University



eTextiles with Elementary Students at Purdue University

Laser tag vest using micro:bit

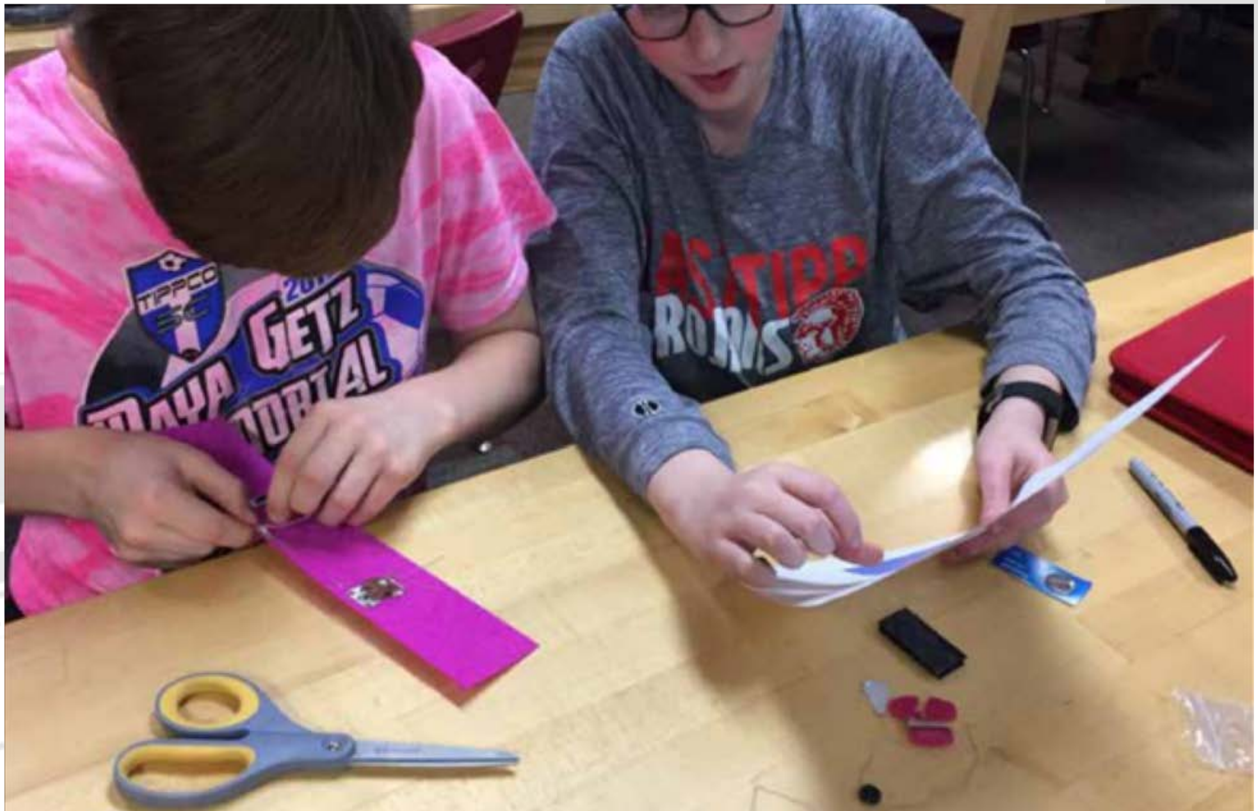
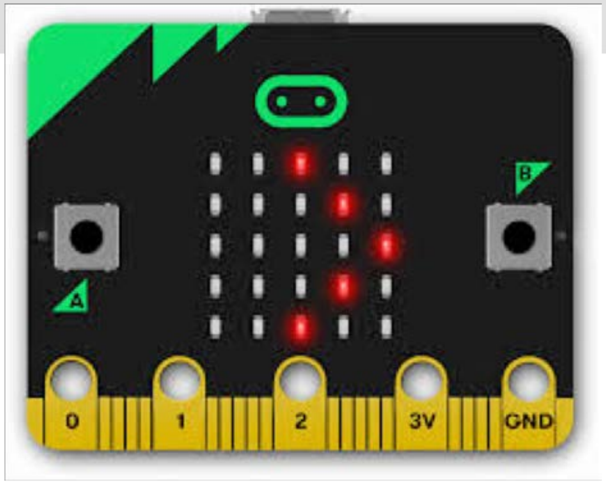
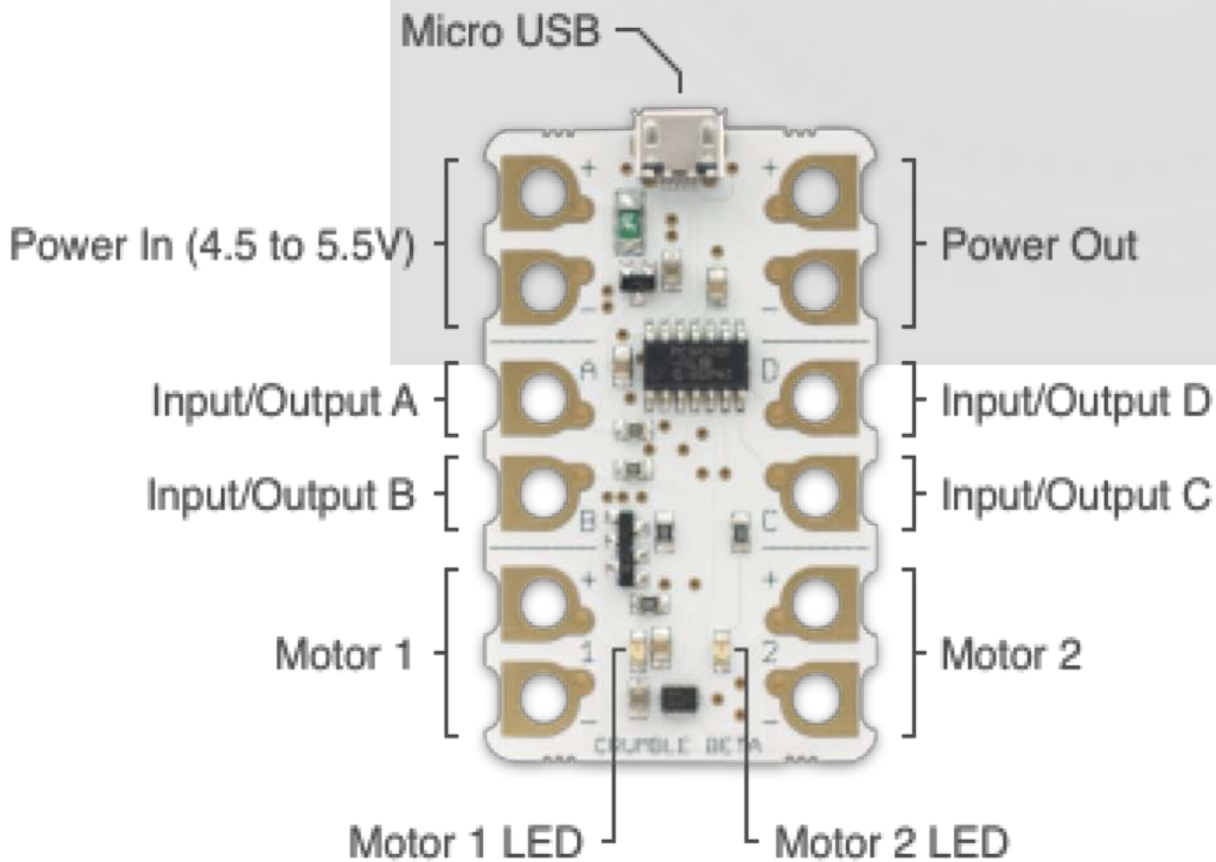


Figure 1. Student sewing an electrical circuit for a wearable device using conductive thread and E-textiles.



The Crumble: What is it?

- https://vimeo.com/94097687
- An **inexpensive**, easy to use, robust controller that can be programmed using free drag and drop **block coding** software. Connects to many **external sensors** via alligator clips and has been used with multiple **open-ended design challenges** (Love & Bhatty, in press).



The Crumble: Where Can You Find It?

- In the U.S. – TeacherGeek
  https://teachergeek.com/collections/crumble

- Redfern Electronics (manufacturer) - https://redfernelectronics.co.uk/crumble/

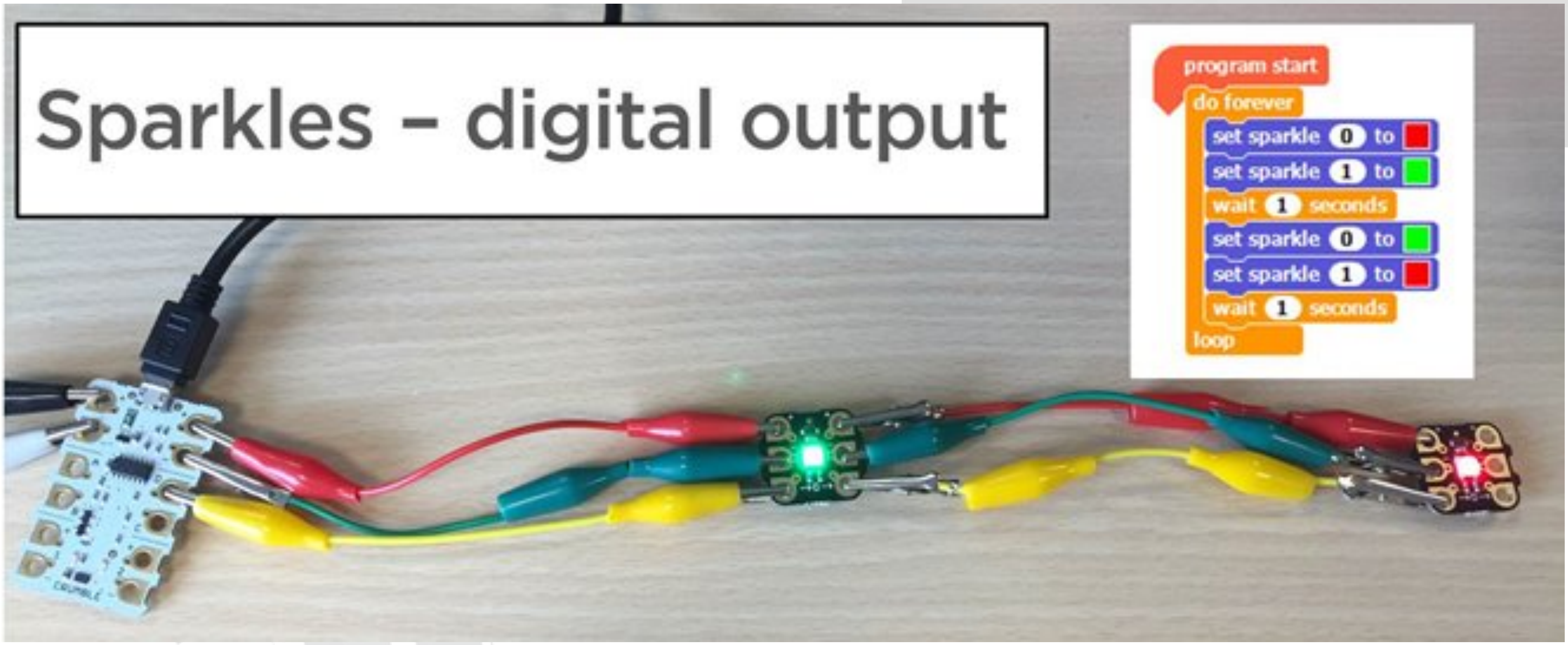
- **FREE** downloadable software from Redfern Website

- Works on Mac, Windows, and Google Chromebooks (requires a USB port)

- *Can be used with TeacherGeek fabrication materials or other common materials

Crumble Demonstration Using Sparkles: VERY User Friendly!

https://redfernelectronics.co.uk/getting-started/guide-to-using-crumbs/



The Collision Avoidance Design Challenge

- Developed to apply coding skills for designing a solution to an authentic challenge, while reinforcing various integrated STEM concepts

- **Context**: Distracted driving is a major safety concern in the U.S. Many sensors and electronic components in cars help improve safety. IIHS estimated that 11% of distracted driving accidents in the U.S. could have been avoided with sensors like a collision avoidance system.

- **Challenge**: Your task is to create a small-scale, affordable collision avoidance system that can fit into a model car. You must devise a way that the Crumble and sensors help to slow the vehicle, display brake lights, and stop the vehicle completely (if necessary) to avoid a collision.

*Love, T. S., & Bhatty, A. (2019). The crumble: Integrating computer science through engineering design. *The Technology and Engineering Teacher, 79*(2).

The Collision Avoidance Design Challenge Continued

- **<u>Addresses various standards:</u>** NGSS, STL, K-12 CS Framework, 21ST Century Skills, Engineering Habits of Mind
- **<u>Materials:</u>** Crumble, wires with alligator clips, ultrasonic sensor, sparkles, wheels, motor, gears, axels, batteries, any fabrication materials (ex. cardboard).

- **<u>Evaluation Criteria:</u>** Students will be evaluated on a vocabulary quiz, their documentation through the engineering design process, a workable code/circuit, a workable vehicle, and the accuracy of their data collection/calculations for velocity and acceleration.

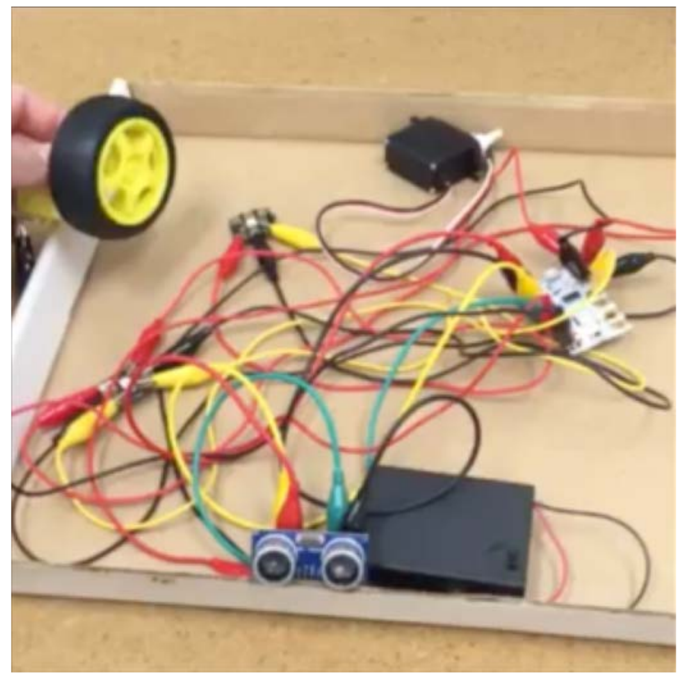
*Love, T. S., & Bhatty, A. (2019). The crumble: Integrating computer science through engineering design. *The Technology and Engineering Teacher, 79*(2).

The Collision Avoidance Design Challenge: 6E Phases - Engineer

Engineer:

- Students drew a schematic of how their circuit might appear. Needed instructor approval before obtaining fabrication materials.
- Students set up their circuit and

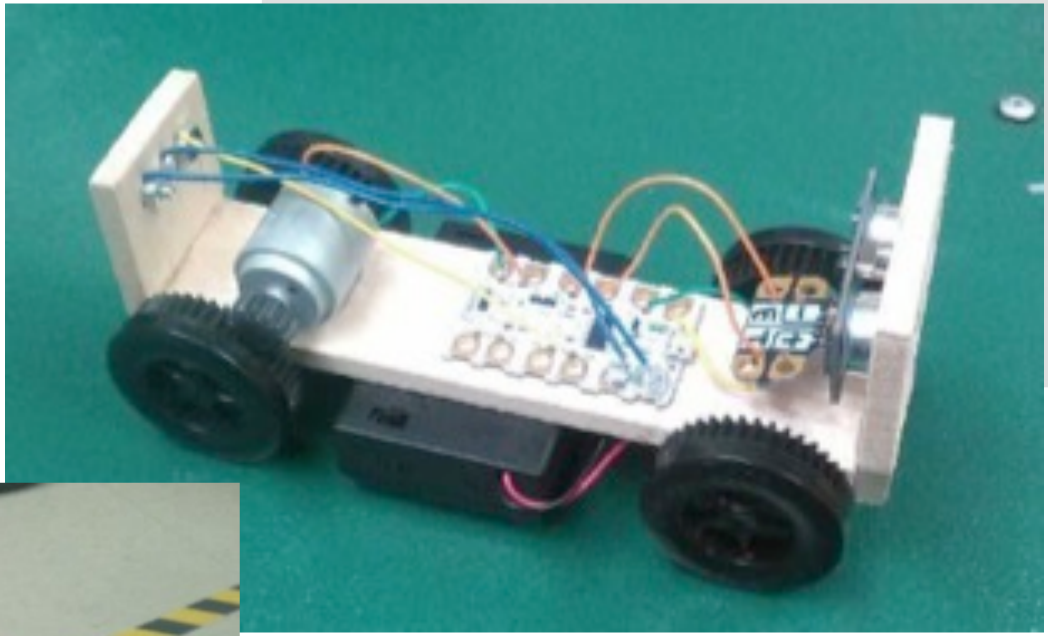
  programed it first.
- After a working circuit and program were created, then students designed their vehicle and built it.
- Straws must be straight for axels!

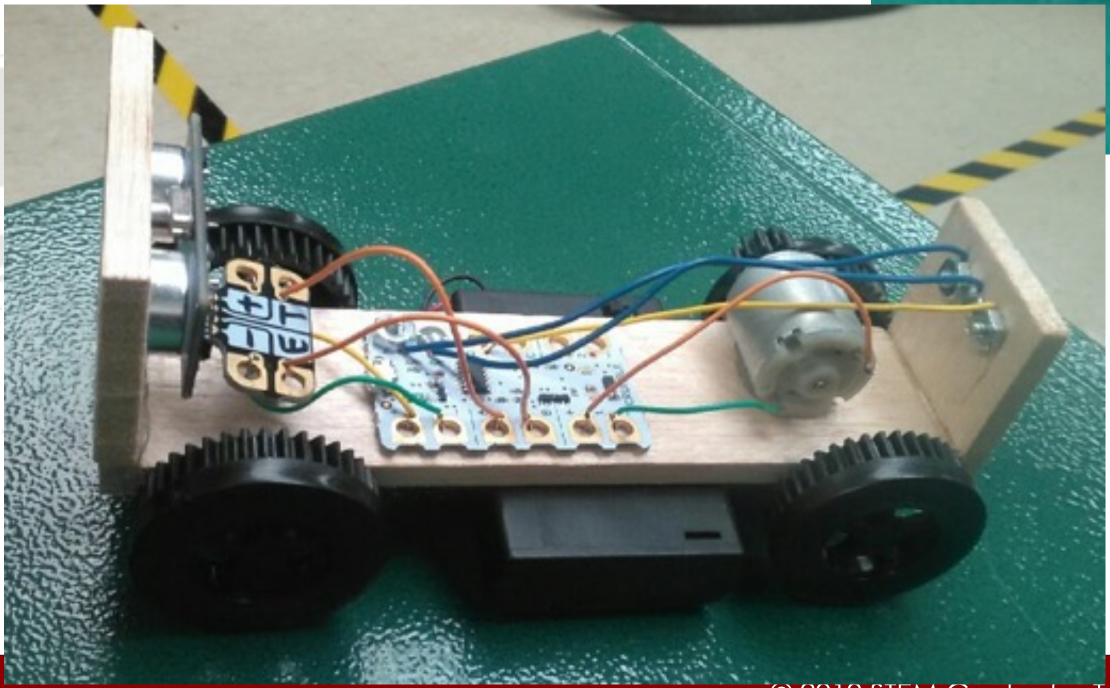


The Collision Avoidance Design Challenge: 6E Phases - Engineer

Engineer:

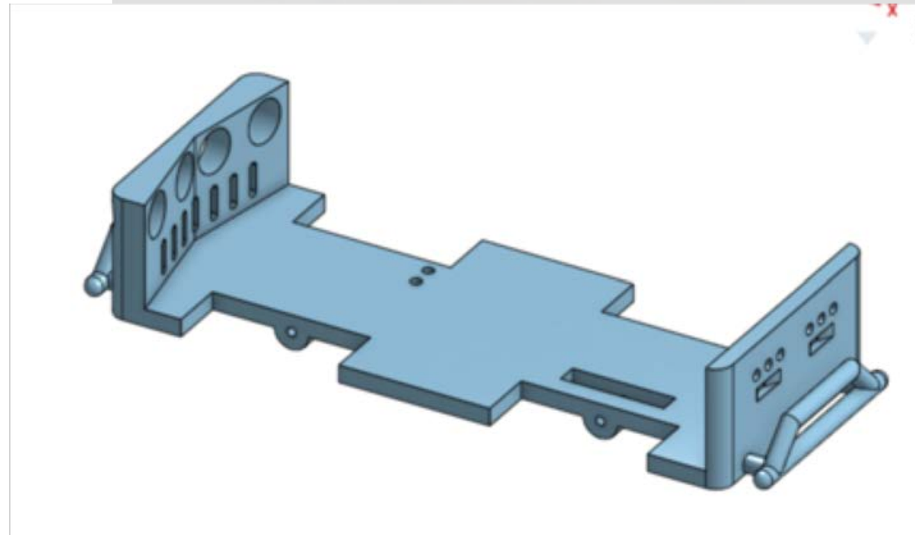
- Prototype Example

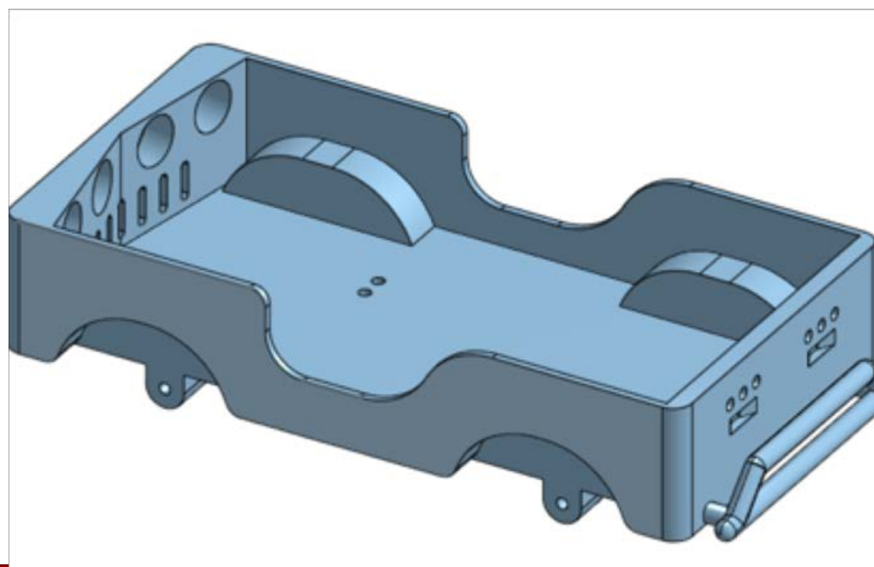




The Collision Avoidance Design Challenge: 6E Phases - Enrich

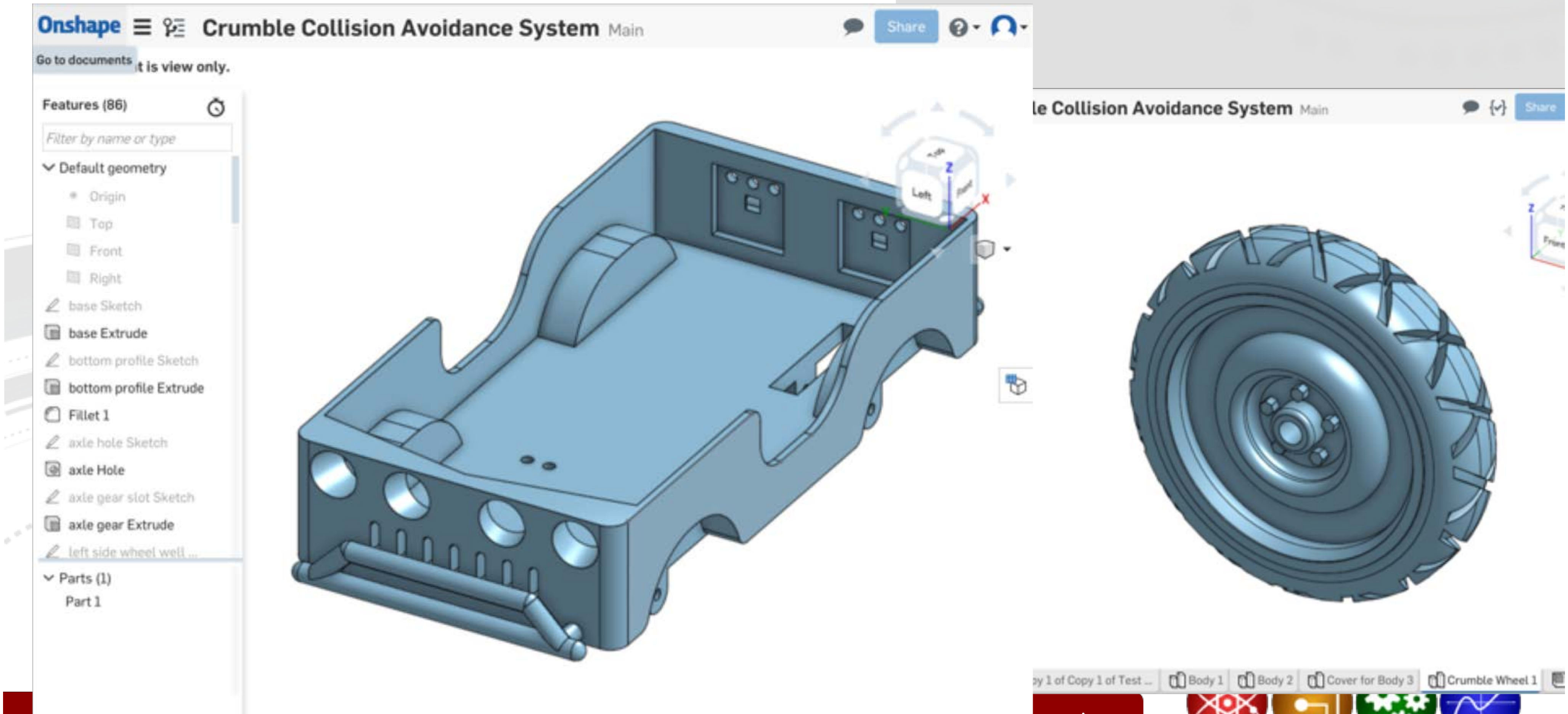
- **Enrich:**
- Students designed a more advanced prototype
  - Can use foam or other materials
  - 3D design software
  - 3D print car body
- Used OnShape – great for schools
- STL file on website in resources slide





The Collision Avoidance Design Challenge: 6E Phases - Enrich

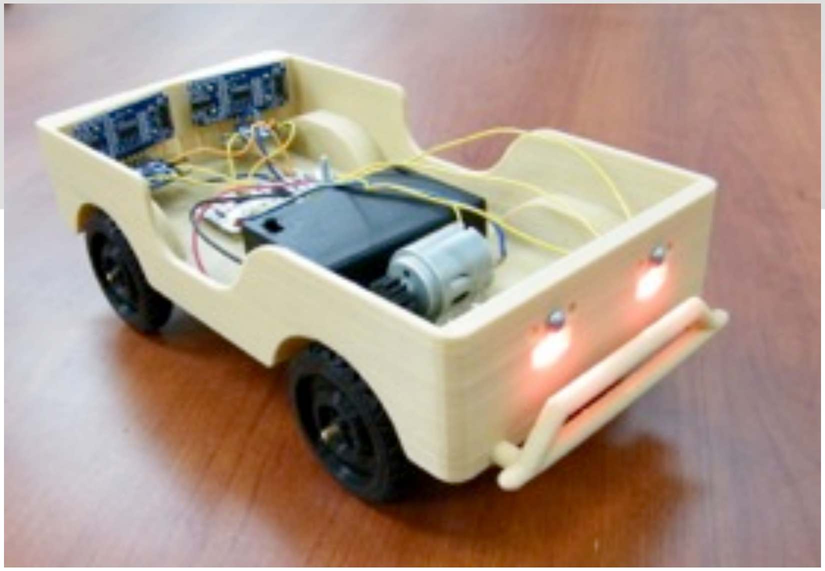
- **<u>Enrich</u>**: OnShape Examples



The Collision Avoidance Design Challenge: 6E Phases – ENRICH STEM

STEM Concepts/Data Collection:

- Physics – Calculated the deceleration when sensing an object, used to adjust the program
  - V=d x t
  - (vf-vi)/t
- Math - Graphed results and predicted
- Other topics discussed: Newton's 1st and 2nd Laws of Motion, friction, gear ratio, momentum, and horsepower



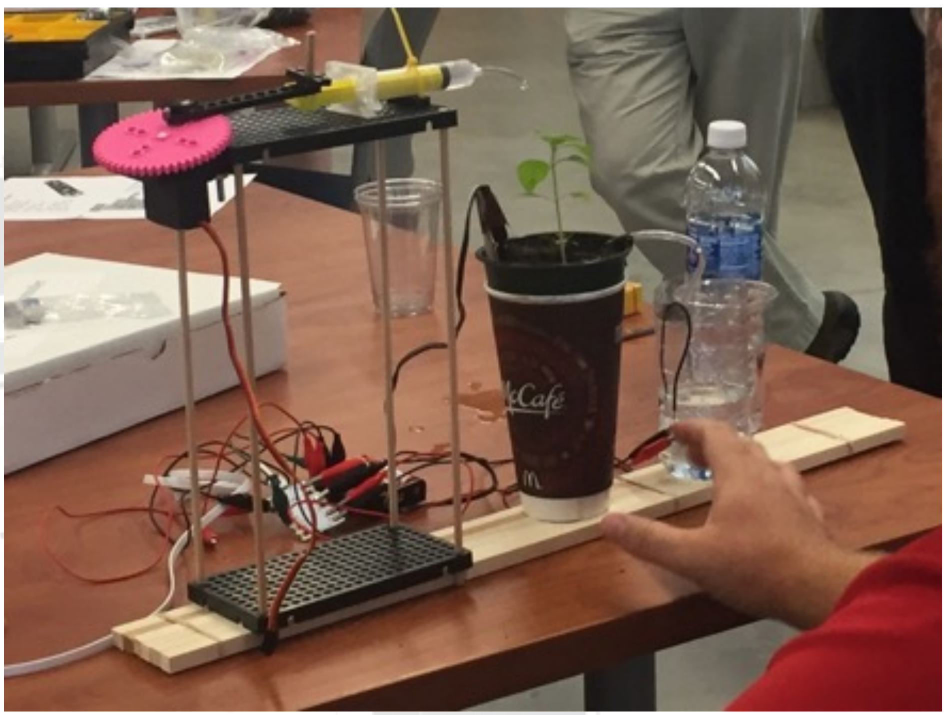
Instructional Resources for the Crumble

- https://sites.google.com/a/vt.edu/crumble/
- https://redfernelectronics.co.uk/projects/

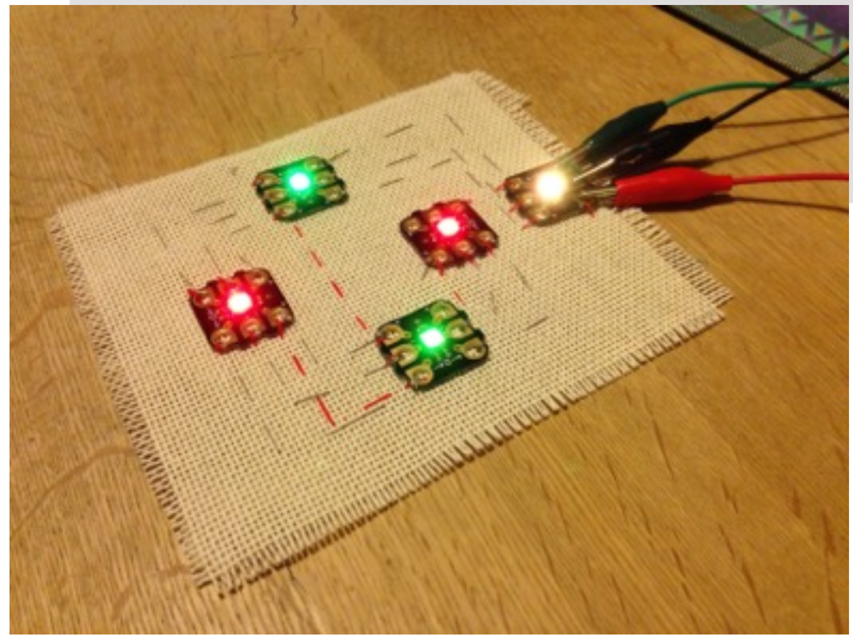
Design Challenge	Source
Parking Sensor	https://redfernelectronics.co.uk/projects/parking-sensor/
Card Buggy	https://redfernelectronics.co.uk/cardbuggy/
River Pollution Monitoring System	https://community.computingatschool.org.uk/resources/5229/single
Fairground Ride	https://community.computingatschool.org.uk/resources/4167/single
Robot Instruments/ Orchestra	https://www.manchester.ac.uk/connect/teachers/teacher-events-resources/resources/robot-orchestra-kit/

Additional Design Challenge Ideas: Sky Is The Limit!

- Moisture Sensor and Plant Watering System Challenge

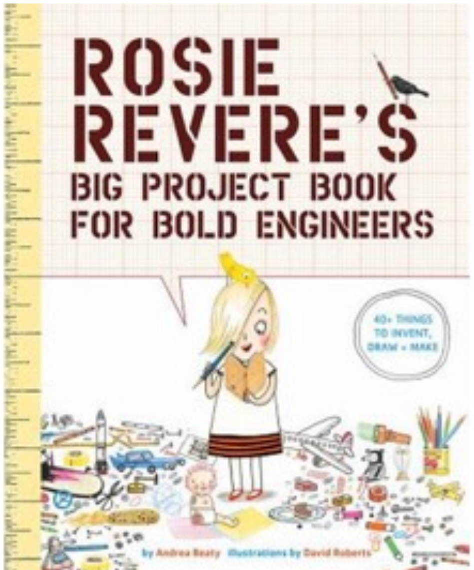


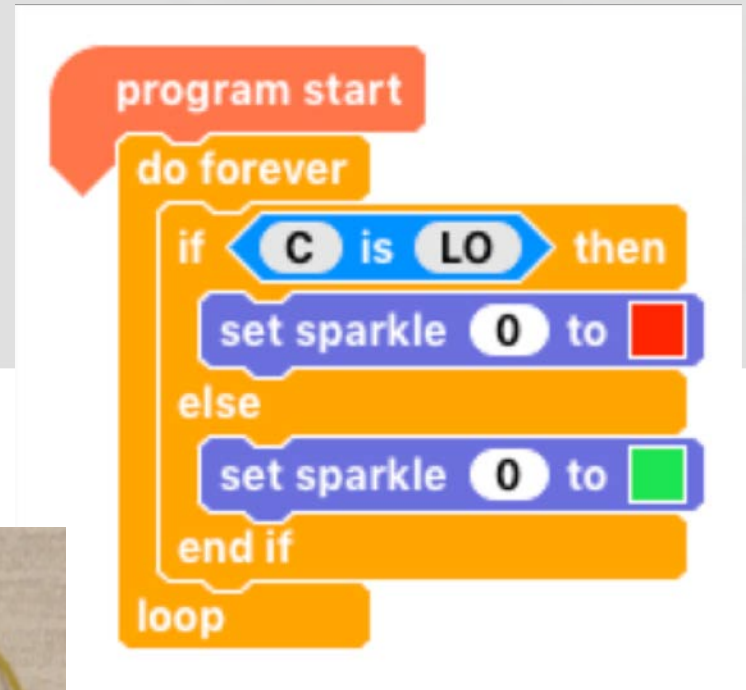
- eTextiles and Smart Clothing with conductive thread

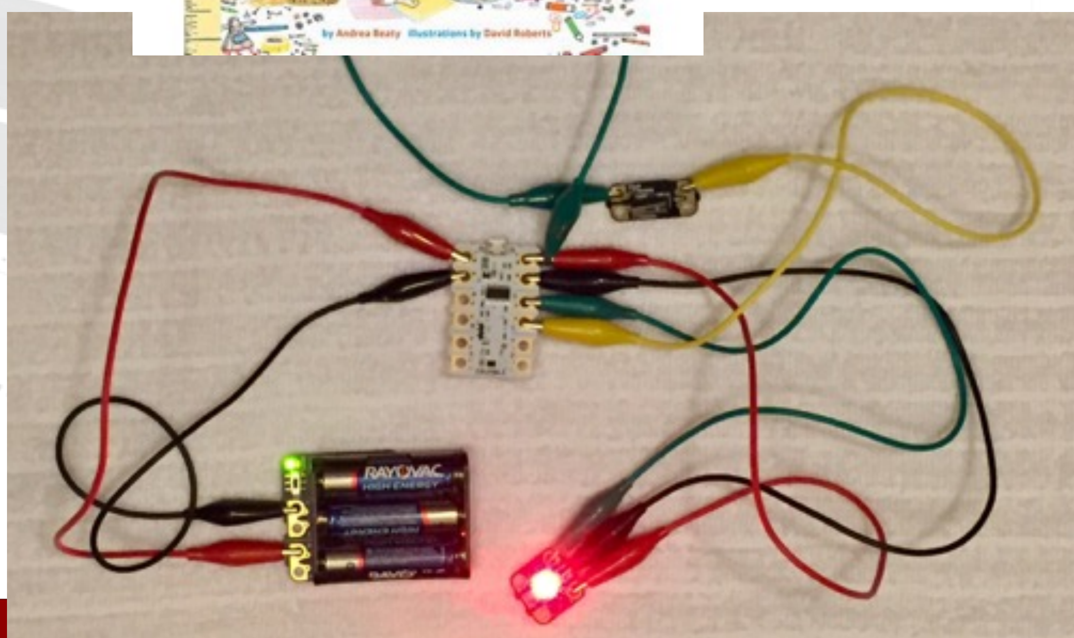


- https://en.wikibooks.org/wiki/KS3_Computing/Projects_Ideas/Creating_wearable_tech_using_a_crumble

Additional Design Challenge Ideas: Integrating Literacy







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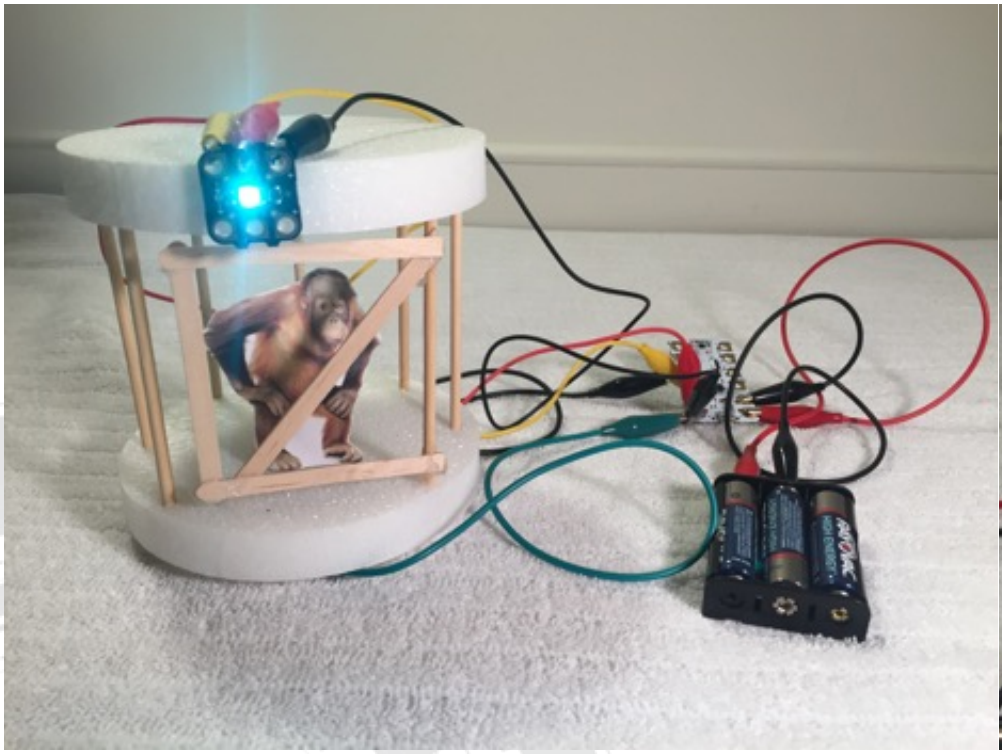
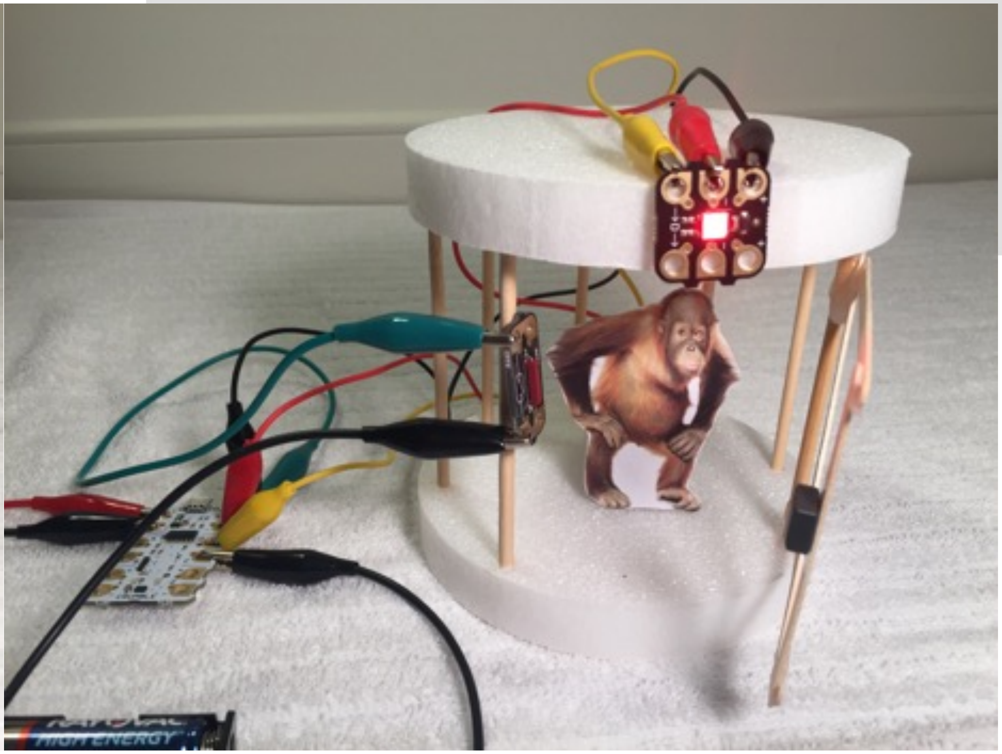
Additional Design Challenge Ideas: Integrating Literacy





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Additional Design Challenge Ideas: Sky Is The Limit!

- Silent Alarm Scanner Bot

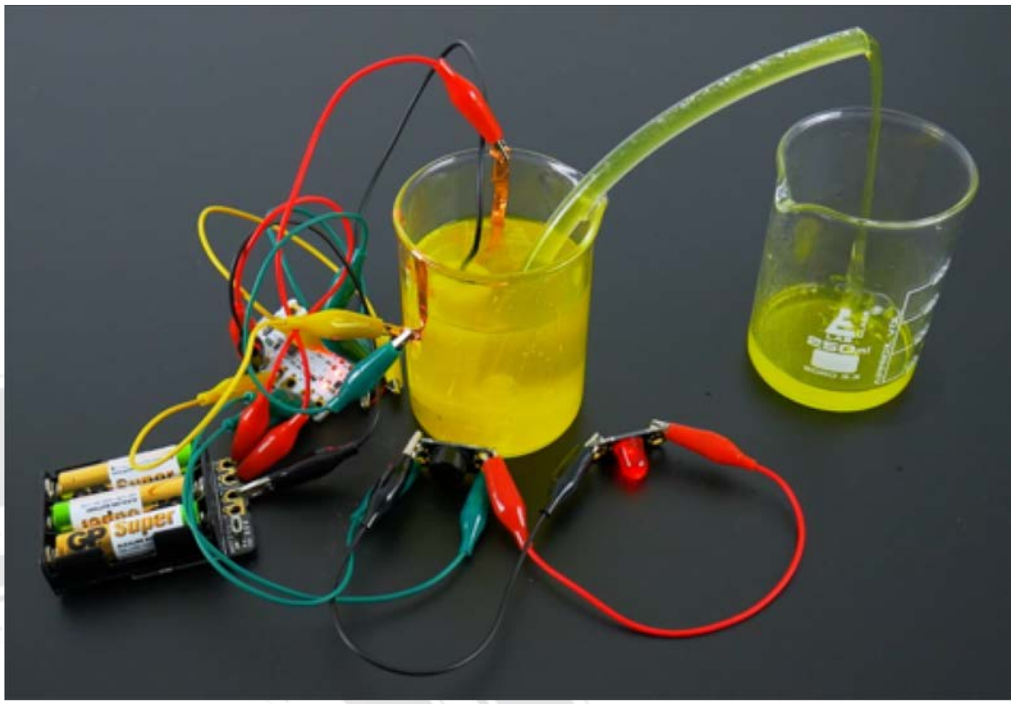
- https://rundontwalk.co.uk/2018/12/07/crumble-creations-continued/

Additional Design Challenge Ideas: Sky Is The Limit!

- Motion Activated Trash Bin

- https://redfernelectronics.co.uk/projects/creating-automation-project/

Additional Design Challenge Ideas: Sky Is The Limit!

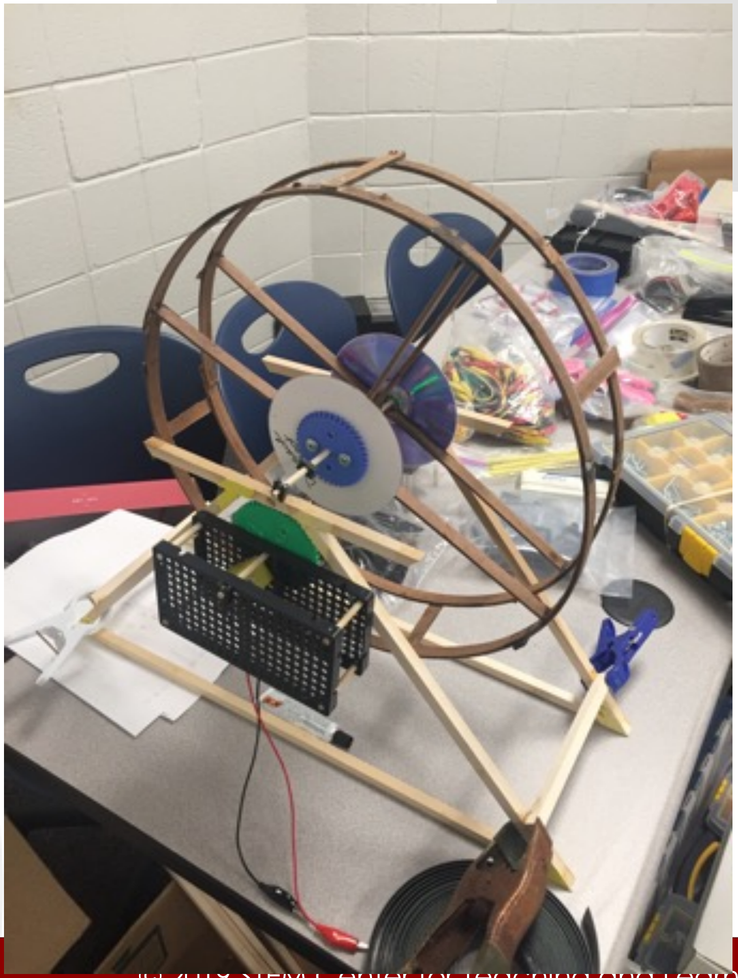


- High Water Pump (sump pump) with Alarm

- https://redfernelectronics.co.uk/projects/creating-automation-project/

Additional Design Challenge Ideas: Sky Is The Limit!

- Various amusement park ride ideas (ex. Ferris Wheel with automated stops)



ITEEA EbD Curriculum Example: Grade 6 Big Idea

Programming Devices for Energy Savings

Students are provided with an overview of programming, coding, and electronics concepts using everyday examples. Students will enhance their knowledge and apply it by creating a prototype of an automated energy saving device.

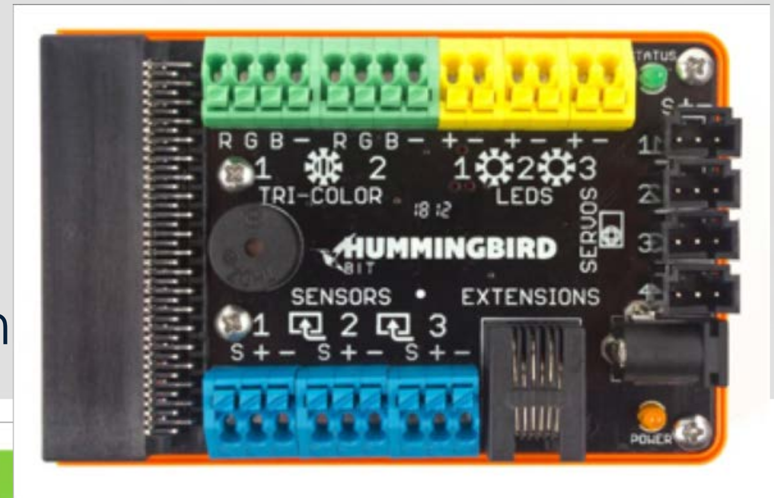
Automated Farming Example

FarmBot

FarmBot intro video - https://www.youtube.com/watch?v=uNkADHZStDE

Other Programmable Devices

- **Hummingbird**
- https://www.hummingbirdkit.com/
- Can span Elementary through High School



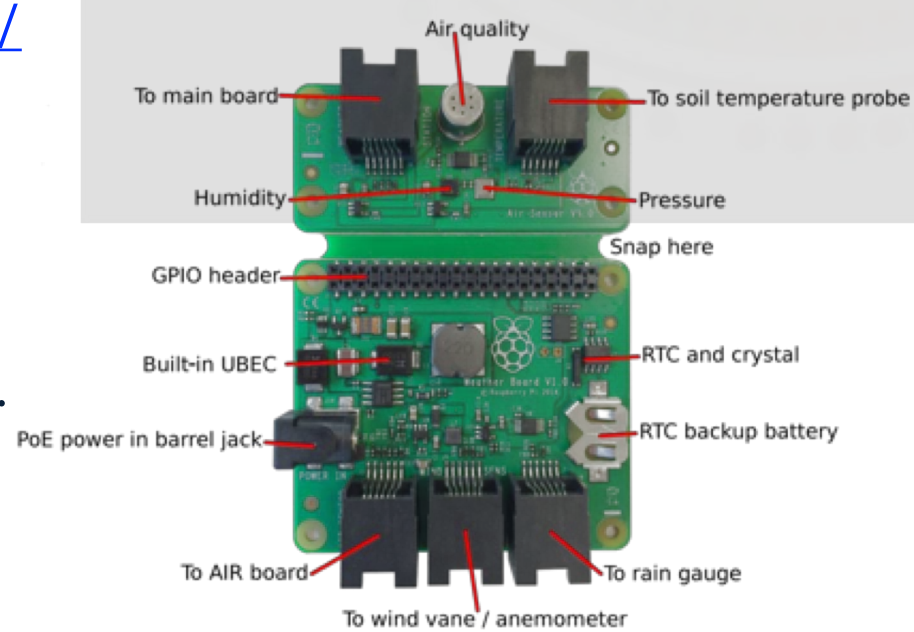
HUMMINGBIRD Recommended Software

	Elementary	Middle School	High School+	
CREATE Lab Visual Programmer	✓	✓		
Snap!	✓	✓		
Scratch	✓	✓		
BirdBlox	✓	✓		iOS
Ardublock		✓	✓	
Arduino			✓	
Python			✓	

Click on a programming language to learn more!

Microcomputers

- **Arduino or Raspberry Pi**
- https://projects.raspberrypi.org/en/
- Steeper learning curve for electronic sensors and coding language (Python)
- Love, T. S., Tomlinson, J., & Dunn, D. (2016). The orange pi: Integrating programming through electronic technology. *The Technology and Engineering Teacher, 76*(2), 24-29.



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