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Research in Mathematics Education

# STEM+C Educator Advisory Panel

## Summer 2020

RESEARCH IN MATHEMATICS

**Technical Report 20-18**

# STEM+C Educator Advisory Panel Summer 2020

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Southern Methodist University

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## Abstract

Integrating computing into science, technology, engineering, and math (STEM) education at the K-12 level is critical to creating a competitive, innovative workforce that is capable of the computational thinking needs of the future. Efforts to increase intrinsic interest in math and data science have proven difficult to apply evenly across gender, race, and socio-economic factors. The STEM+C research project will assist in creating a more stable, ethical, and inclusive data science workforce by broadening the interest in data science to a more diverse population of students. This research spans the fields of game design, human computer interaction, machine learning, curriculum design and educational assessment by integrating STEM+C based curriculum directly into "Minecraft." It advances the knowledge in game-based learning by building on techniques and experiences from commercial game design. The game and infrastructure produced through this research will serve as a vital computing resource for middle and high school educators that will be sustained beyond the current project.

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# Educator Advisory Panel Summer 2020

## Overview of the Project

The goal of the STEM+C project is to integrate STEAM curriculum and computing into the standards of computer science to engage and increase students' competency in STEAM fields. Through understanding how we grow the creation of a stable, ethical, and inclusive community that is capable of using these innovations through a developed standards-based curriculum, we enable more ways to grow engagement and interest in computer science and STEAM. The program's focus is not on programming but on enhancing computational thinking and how we use this concept as build blocks toward broadening interest in STEAM fields. Through this broadening of interest in STEM fields, there is potential to attract more diverse populations (socioeconomic, gender, race) to pursue these career avenues.

The learning management system (LMS), Canvas, will serve as a scalable and known tool for instructors and teachers to integrate directly into Minecraft, and will reduce the burden and any barriers for teachers to integrate the two systems.

## Context

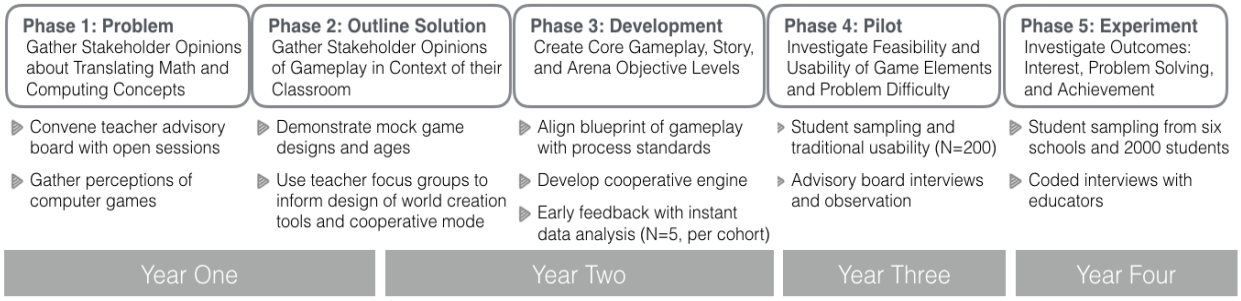
The goal of the June 2020 EAP meeting is a follow up on discussion of standards categories from the previous EAP (March 2020) to review the timeline, collect stakeholder feedback to better understand the priority content standards in students' learning and the most difficult concepts to teach in the classroom, and to ensure progress doesn't deviate from the initial goals of the project.

Multiple intents of EAP are:

- To set up the standards needed to follow when building the core gameplay blueprint,
- To communicate and discuss outcomes of each phase,
- To ensure building of gameplay can solve problems and provide solutions for teachers,
- To find the way to integrate Minecraft and Canvas most efficiently.

## Timeline and Phases

*Figure 1. Outline of each phase in the project*




The STEM+C project is a four-year plan and divided into five phases. The details of each phase is described below.

*Phase 1 Problem*

- The goal of Phase 1 is to operate as the planning year. A congregation of the teacher advisory board will allow the team to better understand the problems and seek input from stakeholders around translating math and computing concepts into the gaming platform.

*Phase 2 Outline Solution*

- The goal of Phase 2 is to develop out and mock up games for the targeted students while looking at the context in which gameplay will be implemented. The team will continue to solicit EAP's feedback throughout this process.

*Phase 3 Development*

- Develop the core of the Minecraft gameplay and integrate it within the Learning Management System (Canvas).
- Although last panel talked about building in both cooperative and competitive gameplay, researchers will focus on cooperative gameplay more.
- Develop the collaborative engine with process standards.
- Start to collect early feedback from students.

*Phase 4 Pilot*

- Test the engine out in classrooms with more of a research design
- Focus on the feasibility and usability of different game elements and also the perspectives of teachers.

- Integrate all the findings and continue to see how to implement them in the classroom.

*Phase 5 Experiment*

- Studying the use of the gameplay within a specific school system for teachers, for improving students, and for the outcomes related to students.

# Participants

## Members in Attendance

SMU Simmons School of Education:

- Dr. Leanne Ketterlin Geller, Co-PI, STEM + C Project; Director, Research in Mathematics Education; Professor, Education Policy & Leadership
- Ching-Yu Tseng, Graduate Research Assistant, Research in Mathematics Education

SMU Guildhall:

- Dr. Corey Clark, PI, STEM + C Project, Deputy Director, Research & Assistant Professor, Computer Science and Engineering; Human and Machine Intelligence (HuMIn) Game Lab
- Vinson Luo, Graduate Research Assistant, Guildhall

SMU Lyle School of Engineering

- Dr. Eric Larson, Co-PI, STEM+C Project, Associate Professor, Computer Science

Mesquite ISD:

- EAP Member 1, Instructional Technology Coach

Richardson ISD:

- EAP Member 2, Science Teacher

# Discussion EAP March 2020

## Identifying and Evaluating Content Standards

The initial panel met during phase one of this project. The main goal of the meeting was to help researchers to understand the needs of the teachers surrounding the content standards and their teaching practices.

- Identify high and low priorities in teachers' instruction?
- Identify high and low priority standards to teach?
- Which concepts are the most difficult to teach?

Based on the feedback researchers refined the idea to integrate Minecraft and its gaming world with classroom assignments or activities and how they can focus on the identified standards. Next steps for the team was to group these standards, based on the level of priority and challenge identified for teaching those standards. Researchers clustered standards by these rules:

- Which standard can be taught efficiently in the Minecraft context?
- Which standard is the most relevant to computational thinking?
- The way to elevate these standards to reach the goals that researchers and teachers emphasize?

Figure 2. Questions of previous panel and current stage

## Narrowing the Focus across Grades

At the March 2020 meeting, the grade band focus was from sixth to twelfth grade (level 2 and 3). After discussion and based on the analysis and categorization of all standards together, plus the teachers' feedback, researchers narrowed down the grade band focus to sixth to eighth grade (level 1 and level 2). Researchers will refine the proposed grade bands in subsequent EAPs to get feedback from teachers. The intent is for students to concentrate on playing Minecraft as opposed to actual programming. Students may learn some aspects of computer science, moreover, playing Minecraft may give younger students (K-5) a chance to learn about computer science in a relaxed way.

- Level 1A/B: Grades K-2 and 3-5 (identify elements of computing, breakdown problems)
- **Level 2: Grades 6-8 (solving problems, use/organize code, test/debug)**
- Level 3A/B: Grades 9-10 and 11-12 (abstractions, algorithms, hypothesis refinement, AI)

## Selection of Standards

The standards were narrowed from 23 to 11. The selected standards fit relatively well the into following four groups:

- Data and Analysis: Data and the analysis of that data.
- Problem Decomposition and Solution Design: Decompose the problem into sub-problems and solutions to each sub-problem.
- Organization and Teamwork: Organizing thoughts and code; working on a team.
- Equity and Impact: Outline and portray how equity impacts those participating in computer science.

At next meeting, some questions will be provided for teachers to think about if these solutions can satisfy their requirements or give some methods to lessen their burden of teaching.

# Discussion EAP June 2020

## Groups of Standards Selected

## Group 1: Data and Analysis

The description of Group 1 standards.

- 2-DA-07 Represent data using multiple encoding schemes
- 2-DA-08 Collect data using computational tools and transform the data to make it more useful and reliable
- 2-DA-09 Refine computational models based on the data they have generated

Questions for teachers.

- Did we capture the important and/or difficult to teach standards?
- If we integrate these standards, would this help free up some space in your curriculum OR do you already have these integrated into other activities?
- If we integrate these standards, does this solve a problem for you?

Feedback:

- Require explanation of standards 2-DA-07: It means finding different ways to represent the data, from the physical storage of bits to the arrangement of information into organized formats, such as tables. For example, if students are trying to represent the color, they can express it as binary, RGB, or a hex code.
- Teachers all agreed that researchers captured the important and difficult to teach standards, helping to free up some space, and solving a problem for them. Additional themes emerged:
    - **Time constraints to teach all content.** There is always a time constraint in classes; teachers do not have enough time to instruct students to see the data from different angles and use it in different ways, which is an important skill for them.
    - **Importance of transforming data in computational thinking.** Transforming data is a huge part of what teachers want students to do. It is essential to let students think about what the data mean, how to apply it, and if it is significant to their project or problem. It provides a chance for students actually to understand the impact of data and is necessary for teachers to teach computational thinking.

- **Value of iterative development.** Teachers thought 2-DA-09 could provide the chance for students to think about their model iteratively to understand more about how this world works and to challenge their first model. Also, they know nobody can get it right the first time, and if they want it to be perfect, repeated 'revise and review' of their model is necessary.

- **Concerns about access for all students.** If each student participates in Minecraft gameplay as part of their curriculum, there are opportunities for everyone to learn the content. If not every child participates, teachers will need to come up with alternative curriculum to make sure each student can catch up on the progress.

- **Minecraft may help students apply their knowledge in contextual ways.** The interaction of what they need to learn with the visual part of gameplay may appeal to students' gaming mentality and make learning active. So far, students can't learn by doing or apply their math knowledge in the real world. Integrating these standards into the Minecraft context can give students this valuable practice experience.

## Group 2: Problem Decomposition and Solution Design

The description of Group 2 standards.

- 2-AP-13 Decompose problems and sub-problems into parts to facilitate the design, implementation, and review of programs.

- 2-CS-03. Systematically identify and fix problems with computing devices and their components.

    - Devices are not related to the function of hardware, such as RAM or CPU, and also don't have relevance to know the interaction between hardware and software since playing Minecraft does not need to have access to the exact hardware.

    - Students may find some situations that require understanding of hardware, such as the speed of access or storing different materials in certain place, that satisfy getting a special reward in Minecraft.

- 2-AP-10 Use flowcharts to address complex problems as algorithms.

Questions for teachers.

- Did we capture the important and/or difficult to teach standards?

- If we integrate these standards, would this help free up some space in your curriculum OR do you already have these integrated into other activities?

- If we integrate these standards, does this solve a problem for you?

Feedback:

- Teachers all agreed that these standards capture the important and difficult to teach, help to free up some space in curriculum, and solve a problem for instruction. Additional themes emerged:

    - **The importance to understanding the starting point to solve a problem and the structure behind it.** It's a challenge for students to understand where to begin when solving problems. They have to learn the backbone and the structure of these standards before they can address more complicated things. These standards can help students learn the structure behind all the content and things that they're creating and building, which helps solidify and support other areas. If students can learn this skill in Minecraft before they come to a problem, it definitely can save a lot of time in the classes, because these standards can let students get prepared for continued learning.

    - **Concrete thinkers with confidence may have more motivation**. Middle schoolers are concrete thinkers. These standards can give them more confidence to begin this process of how to solve or fix a problem and how to facilitate more design and implementation of what they're trying to do. Also, it'll increase their satisfaction level because students can see how they can work through facing a problem. If gameplay can give students the background knowledge they can utilize and apply it in a new way, they will feel more successful and confident.

## Group 3: Organization and Teamwork

The description of Group 3 standards.

- 2-AP-14 Create procedures with parameters to organize code and make them easier to reuse.

- 2-AP-16 Incorporate existing code, media, and libraries into original programs, and give attribution, taking some modules that students build in Minecraft and reuse it.

- 2-AP-18 Distribute tasks and maintain a project timeline when collaboratively developing computational artifacts.

Questions for teachers.

- Did we capture the important and/or difficult to teach standards?

- If we integrate these standards, would this help free up some space in your curriculum OR do you already have these integrated into other activities?

- If we integrate these standards, does this solve a problem for you?

Feedback:

- Teachers all agreed that these standards capture the most important and difficult concepts to teach, help free up space in the curriculum, and solve a problem for instruction. Additional themes emerged:
    - **Learning by doing and teaching others can enhance metacognition**. One of the issues for students is that they don't have metacognition to recognize their processes. Creating procedures and teaching other students is an excellent way for them to understand what they have now. Students can learn that they don't need to build everything but need to review what they have available before creating. Collaboration is also another critical learning task for students. It also helps to free up space because offline activities and setting up the timeline or procedures are the primary tools teachers use to teach coding. If students can transfer what they learned in the game to other activities, these standards will save a lot of time for teachers in classes.
    - **A better way for students to learn how to replicate information and modules they have organized and used, and build into future tasks.** It's a different way to approach what we had done, but this method is better than before. These standards can free up space in the curriculum since students will learn to organize data and information to make them easy to incorporate, use, and reuse in current and future assignments. Students also can learn how to transfer what they had done in the game to other fields that they're working in. This way is much more efficient and replicable for kids.

## Group 4: Equity and Impact

The description of Group 4 standards.

- 2-IC-20 Compare tradeoffs associated with computing technologies that affect people's everyday activities and career options.
- 2-IC-21 Discuss issues of bias and accessibility in the design of existing technologies.

The discussion of possible ways to integrate equity concepts.

- There may be ways to integrate into Minecraft gameplay with storyline approaches and to be able to see cause and effect from some of these, for bias and equity.
- There is no exact game mechanic to integrate these standards. From teachers' response, it's more like a learning experience, not steps to go through.

Questions for teachers:

- Did we capture the important and/or difficult to teach standards?

- If we integrate these standards, would this help free up some space in your curriculum OR do you already have these integrated into other activities?

- If we integrate these standards, does this solve a problem for you?

Feedback:

- Both teachers agreed if these standards can be executed within Minecraft context, they capture the important and difficult concepts to teach, help to free up the space, and solve the problem. Additional themes emerged:

    - **Concrete way for students to understand their actions and how they impact others**. It will be interesting to see how the discussion about impact and equity come across, how to address, and become part of the gameplay. Understanding these standards is very important to students because they don't have enough life experience to make the proper decisions for themselves and know how their choices will affect other people. It's one of the most challenging topics to teach, because the teaching will become an abstract discussion, and will be hard to internalize for kids. It will be great if Minecraft can help students to learn how to make value-based decisions.

    - **Effective student learning within gameplay context**. It will be exciting to see students can practice making choices and watch how their decisions affect the next actions. Students learn very fast in the gameplay context; they understand what they can do and what they can't in the game. Compared with traditional instruction, learning within the Minecraft context will be more effective.

## Standards not Selected

Standards not selected may be considered for future design if augmentation of the program is developed. Standards which were not chosen were based on these rules:

- Difficult to incorporate into Minecraft context.

- Rated as lower priority in the March 2020 Educator Advisory Panel.

Following the June 2020 EAP meeting, teachers will receive a document including these standards. Teachers will be able to provide feedback about the standards that were not selected, and researchers will consider taking them back into account base on teachers' points of view.

- Hardware and Software Design, User Interface Design

- Networking and Internet

- Security and Privacy

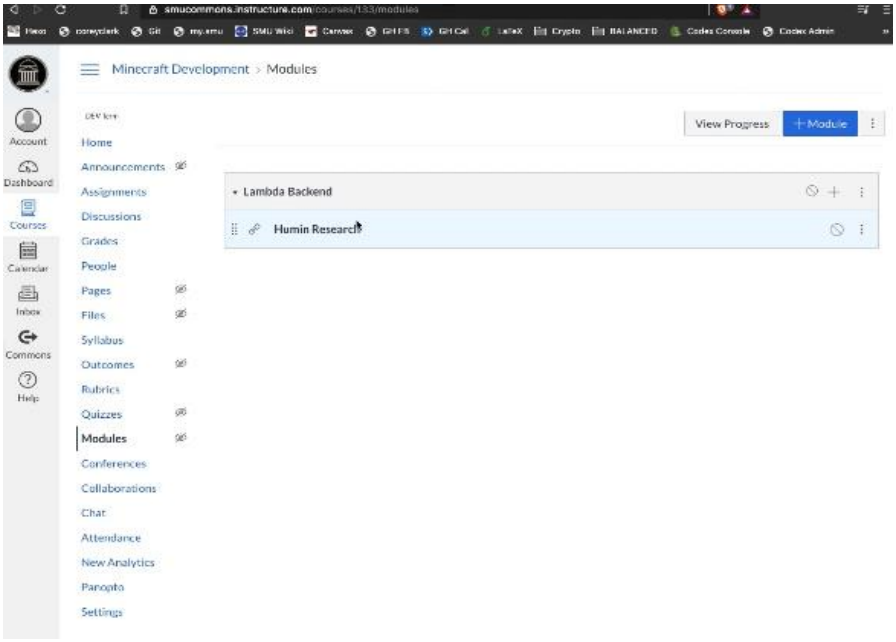
# Integration of Minecraft and Canvas

Figure 3. Integration between Canvas and Minecraft.

- Teachers can create assignments from Canvas. The workflow follows:

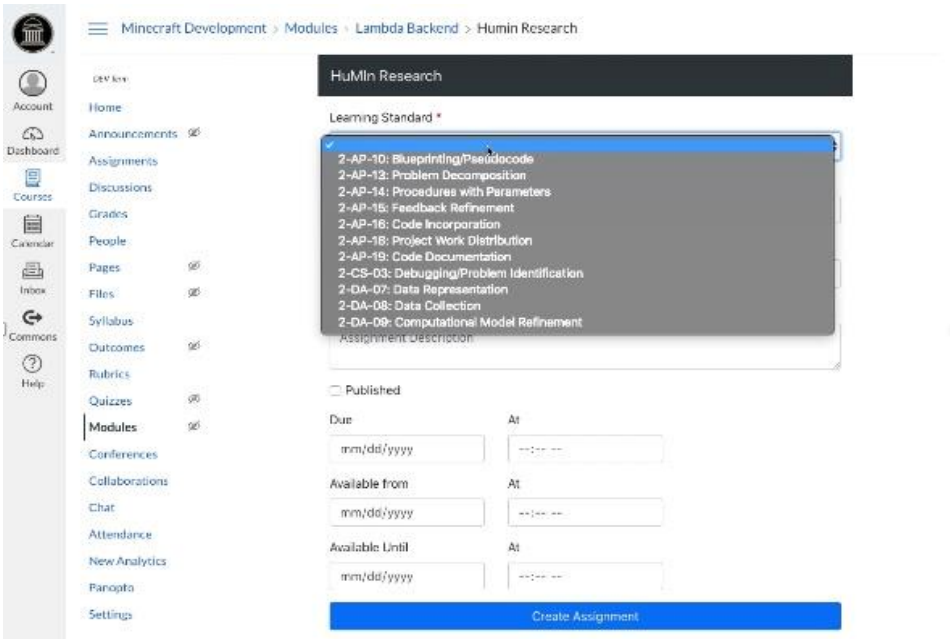
    1. Click on the build-in module.

Figure 4. Build-in module in Canvas.



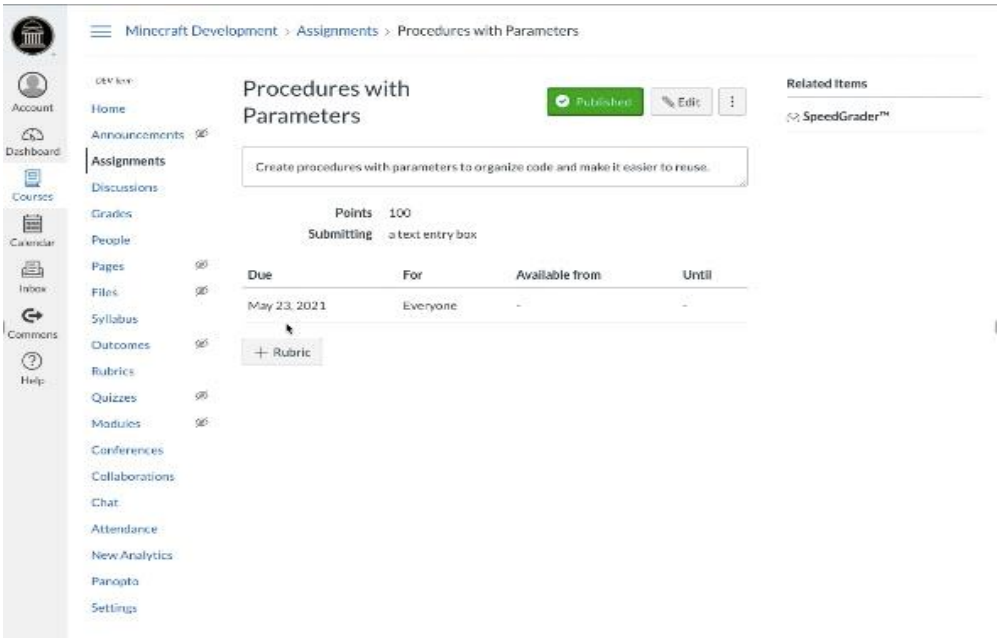

    2. There are some standards which are selected in the pull-down menu. Teachers can dropdown any of assignments they want to do, and put the necessary elements for classes in, for instance, the score.

Figure 4. Integration between Canvas and Minecraft.




3. Publish it and set the due date, then click on create the assignment.
4. The LMS system will assign the task to everyone.

Figure 5. Canvas assigns the new task to everyone.




- When the assignment is created in Canvas, you can see the item for this assignment will pop into the pre-configured Minecraft world. Every student has their area or group, which depends on how teachers design the task. The system will automatically collect data and information, such as how much water students consume and how many things they build in Minecraft, then send back to their Canvas portal after the task is over.

Figure 6. The item shows up in Minecraft after creating the task.

- Teachers can check the LMS to know the details of students' tasks and grade them. Even people who are not familiar with Minecraft still can stay in the LMS to design the assignments and observe all actions students make. This design is for some people who are not technology adopters or not confident with Minecraft can also utilize this system.

- **Impact and Equity**: Students can experience how their decision or action will affect other people. For example, if they consume too much water, that may limit the amount of water available for their fellow students.

- There is going to be a 3D simulator that is built in Canvas so that students can do some planning upfront, then replicate their blueprint in the Minecraft context. This way, teachers and researchers can observe students' designs in place and determine how well they can implement their design in the real world.

## Feedback from Teachers

Questions:

- Do you see any barriers or challenges for teachers would have in using this system?

- Do you see other barriers or challenges that we should think about to make this experience for teachers be as easy as possible?

Responses from teachers:

- **Support tools and tutorials for teachers to answer student questions within the Minecraft world**. It's great that teachers can be on the LMS side of it and interact there, but in real classrooms, kids will ask questions which are related gameplay in Minecraft.

Therefore, if there are tutorials, videos, or help features can build in the system, it will be handy for teachers to address questions when students get stuck.

- **Tracking students' learning and ensuring progress is reaching individual student goals**.

  Questions arose about how to make sure students really accomplishing certain goals or tasks set up by the teacher and how to know when they're falling short? How to track progress?

  Response from STEM+C team: The only way to accomplish the task given to the student is to build something. For example, a task needs to produce a lot of materials, and the only way is to create an automation system to accomplish it. Because students do these works in the game, the system can track each person, know what they did, and what and where they build. Teachers can set up each area for students but only one person can develop in each block. Students can talk and discuss with each other, but eventually, they have to build their own.

- **The concern about if Canvas has feedback system for teachers and students to remind them where they need to notice**.

  What will teachers see from the LMS side to give feedback for their students? Or what feedback in the LMS is provided to students to know where they should build more?

  Response from STEM+C team: It's one of the key components that there is a 2D space to show your Minecraft simulation. If students don't meet these requirements or results, the 2D simulation will show it in visualized way. The visual feedback can help not only students, but also teachers to understand where they're falling short.

# Biographies

**EAP Member 1** is an instructional technology coach in Mesquite ISD. She works with teachers and tries to incorporate technology efficiently in the classroom.

**EAP Member 2** is a 7/8$^{th}$ grade science teacher at a STEAM school in Richardson ISD. She is a department chair and works on curriculum for Richardson ISD, which received a 6 million dollar STEAM grant in 2018. Her school had the first coding class for girls in RISD, which was made possible by corporate support.