

It's as Easy as 123

Supporting Users via Multiple Programming Approaches on a Single Device

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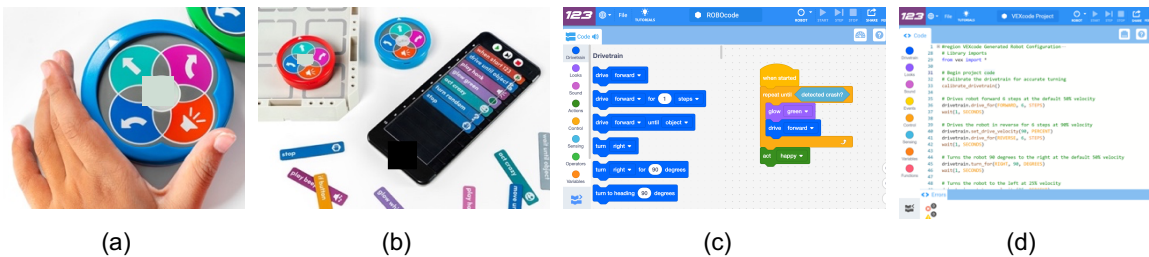


Figure 1: The ROBO 123 robot and the four distinct programming approaches it supports: (a) Touch Button programming, (b) Coder and Coder Cards, (c) Block-based programming, and (d) Text-based programming in python.

This paper introduces ROBO 123, a robot that can be programmed via four distinct methods designed to support users at all levels of programming ability. The ROBO 123 can be programmed by: (1) directly pressing buttons on its exterior (Figure 1a); (2) using a tangible programming approach based on a physical Coder and Coder Cards (Figure 1b); (3) defining instructions with a block-based programming language (Figure 1c); and (4) using the Python programming language (Figure 1d). In providing a range of programming approaches, the ROBO 123 can meet the user at their current level of ability and comfort while also providing mechanisms to help them move from basic to more sophisticated and powerful programming approaches. In supporting four distinct programming approaches that span physical and virtual contexts, the ROBO 123 contributes a novel addition to the growing ecosystem of tools designed to introduce novices to the practice of programming.

Keywords and Phrases: Design of Programming Environments, Educational Robotics, Physical Computing

Wireless Embedded Visual Programming for Novices

Wireless Embedded Programming

“Unplugging” CS education on embedded platforms

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Embedded systems are cheap and plentiful and are ubiquitous throughout the maker community. This makes them an obvious platform for hands-on, creative projects for K-12 students to increase awareness and interest in computer science and engineering. However, embedded programming platforms for K-12 education are often somewhat limited in either features or debugging capabilities, and do not typically include intuitive support for networking features that are vital to distributed computing and the Internet of Things. To address these issues, we introduce NetsBloxVM, an open-source, entirely wireless embedded programming platform which can connect to a remote server called NetsBlox to facilitate curated web API queries, support distributed computing via message passing between projects over the internet, and other features such as in-browser real-time collaborative editing.

Keywords and Phrases: K-12 education, hardware, internet of things, distributed computing, embedded programming platforms

1 INTRODUCTION

We are surrounded by embedded smart devices that control a wide range of aspects of our daily lives. Furthermore, because of the tremendous growth of student interest in maker spaces and computing, many researchers work to extend previous successes in K-12 computer science education to target embedded platforms. Ultimately, the goal of this field is to minimize barriers to entry, both in terms of cost and complexity, and allow students to spark an early interest in embedded programming and practical engineering through the creation of customized, personally meaningful projects (Martin et al. 2015). Two related projects in this area which have seen widespread success are the BBC micro:bit (Ball et al. 2016) and KidBright (Tan-a-ram et al. 2022), which are both low-cost, open-source platforms for introducing embedded programming to K-12. Both platforms include several useful features for students, including built-in sensors and the ability to connect to external peripherals driven by plugins. Their browser-based IDEs are responsible for converting a student’s block-based code into C++ source code, which is then compiled and flashed onto the board to run.

However, existing platforms for K-12 embedded programming are often somewhat limited in debugging capabilities and do not typically support intuitive networking features that are vital to teaching advanced topics like distributed computing and Internet of Things (IoT). Additionally, most platforms use their own block language, rather than building off students’ existing block-based knowledge from popular platforms like Scratch and Snap!. To address these issues, we introduce NetsBloxVM, an open-source, low-cost, block-based embedded programming platform focusing on IoT and distributed computing. It allows students to create more advanced and engaging projects than can be done with the utilities of many existing platforms alone, while eliminating the need for cables and flashing and staying within the popular block-based programming realm that many students are already familiar with.

2 NETSBLOX

NetsBlox is an educational, block-based programming language forked from Berkeley Snap!. NetsBlox adds several networking features, including the ability to 1) access an ever-expanding set of web APIs and other network-based resources through Remote Procedure Calls (RPCs), 2) send structured packets of information between projects running anywhere in the world (message passing), and 3) collaboratively edit projects in real-time, all through the NetsBlox server. RPCs can be used to create such engaging projects as a weather app that displays an interactive map background using Google Maps and superimposes weather information such as temperature, current conditions, and even real-time weather radar. Meanwhile, message passing makes it possible to create social applications like a chatroom, a shared whiteboard, or distributed multi-player games.

With only these two abstractions, NetsBlox makes it possible for students to access and control devices like smartphones, educational robots, or even Amazon Echo devices, and has been shown to be effective at teaching advanced computing topics such as IoT and distributed computing (Broll et al. 2021). NetsBlox projects run in the browser, a feature that has many great advantages, but one that limits its applicability in embedded computing. To address this, the underlying runtime environment of NetsBlox (and Snap!) has been extracted into a common Virtual Machine (VM) written entirely in “no-std” Rust. This allows NetsBloxVM to run anywhere, be it a server, laptop, browser, or an *embedded microcontroller*.

3 RUNTIME AND DEBUGGING

NetsBloxVM contains four primary components: the core VM runtime, the peripherals manager, the network manager, and flash storage. The VM runtime is responsible for compiling student projects into a compact bytecode representation that can be interpreted by state machines. Some blocks in a project may access system or network resources, which asynchronously delegate to the peripherals and network managers, respectively. The peripherals manager controls any connected hardware peripherals, including raw GPIO pins, as well as standard bus protocols such as I²C and SPI. The network manager connects projects to the NetsBlox server over the internet, which is used to invoke RPCs and send/receive messages. The network manager also provides a remote debugging server users can access over the local Wi-Fi network. Flash storage is used to save student projects, runtime information (e.g., to prevent a student project from repeatedly crashing the device due to overuse of memory), and configuration info for the network manager (e.g., Wi-Fi credentials) and peripherals manager (e.g., what peripherals are available). This full architecture is diagrammed in Figure 1.

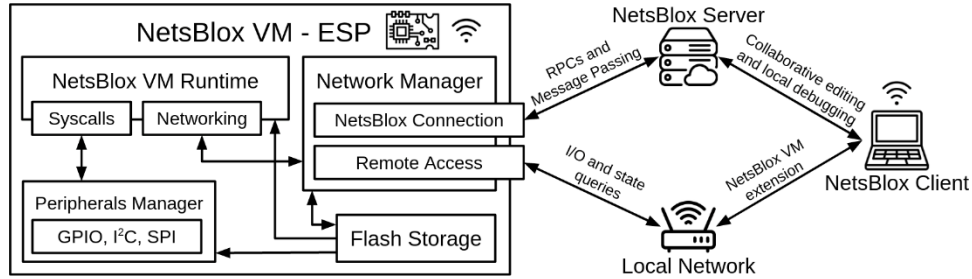


Figure 1: Architecture diagram for NetsBloxVM and a connected browser client.

The state machine nature of the execution model allows the runtime to step through scripts one instruction at a time in a non-blocking fashion, as well as query user program state at any point and perform garbage collection when needed. This information is used to provide students with detailed error messages for any uncaught exceptions generated by their code, including a visual stack trace containing a snapshot of all variables in scope, which can be viewed from a connected NetsBlox client running in the browser. Note that neither Snap! nor “regular” NetsBlox has this level of debugging support. Figure 2 shows an example of such a wirelessly connected client and an error stack trace generated by NetsBloxVM and sent back to the browser. When not connected, output and error traces are cached in circular buffers that can be viewed the next time a browser client connects to it.

4 EXTENSIBILITY

Like other K-12 embedded programming platforms, NetsBloxVM is extensible. However, rather than importing many new blocks that students would have to learn and mentally declutter, NetsBloxVM takes inspiration from NetsBlox RPCs and exposes only one “syscall” block, which has dropdown options for communicating with any hardware peripherals through simple interfaces. Each peripheral defines one or more syscalls that perform tasks such as reading sensor data or writing to a display. Support for new types of

peripherals must be implemented in the native language of NetsBloxVM (i.e., Rust); however, unlike other tools, the collection of peripherals on a NetsBloxVM device is defined by a config file saved in flash storage. Thanks to this design, so long as the *types* of desired peripherals are supported, changing the specific set of peripherals on a device requires only a (wireless) edit of the peripherals config file, rather than having to reflash the board. Thus, NetsBloxVM is a completely wireless embedded programming experience, with over-the-air configuration, project loading, debugging, and other interactions. This makes it possible for students and/or teachers to perform rapid iteration of their hardware configuration, as well as their programs that use said peripherals. Figure 3 contains a simple example of a NetsBloxVM-powered robot with three peripherals: two motors, and an ultrasonic distance sensor.



Figure 2: The NetsBlox browser client (wirelessly) connected to a NetsBloxVM device (top right). An error was encountered, and a stack trace was generated and sent back to the browser. The popup windows show the code and errors in the nested custom blocks (functions).

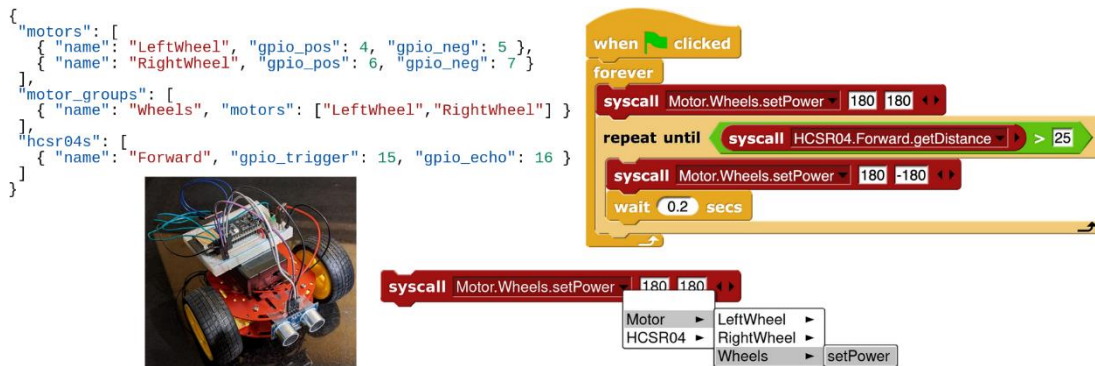


Figure 3: The peripherals config file for a robot with two DC motors and an HC-SR04 ultrasonic distance sensor (left) and the automatically configured syscall block (bottom right). Also shown is a program that makes the robot move forward and turn before hitting an obstacle (top right).

5 ADVANCED PROJECTS

As we have seen, NetsBloxVM offers many compelling features, such as a complete over-air experience for students and more informative debugging tools than other platforms provide. This already makes NetsBloxVM a powerful and easy-to-use platform for students and enables engaging embedded projects such as building and programming simple home automation tools and robots through its extensible peripherals system. However, the true power of NetsBloxVM lies in its access to the distributed computing utilities of NetsBlox. For instance, students can easily invoke RPCs to perform tasks such as language translation and geolocation or save and load arbitrary data with cloud variables. This makes it possible for students to build and program highly advanced networked maker projects which are more in line with real-world applications of IoT devices and distributed computing.

One example of using these networking features for traditional IoT purposes could be a remote weather station network. A class of students could build and configure their device(s) with any desired sensors (e.g., the BMP388 high-precision barometric pressure and temperature sensor, which is already supported) and deploy one or more NetsBloxVM devices at any locations with Wi-Fi access (e.g., school rooftops or other safe outdoor areas) to continually collect weather data. Message passing could then be used to aggregate data from all participating devices (potentially from multiple classrooms located anywhere on Earth) and generate graphics or weather predictions for a hands-on environmental science project. An example for robotics could be a robot that maps out or navigates a maze. This task is typically done with stepping motors to precisely move one grid space at a time and various sensors to detect walls (e.g., the HC-SR04 ultrasonic distance sensor, which is already supported). With NetsBloxVM, students could use multiple of these robots and utilize message passing to share the positions of found walls in order to collaboratively traverse the maze. Using other existing NetsBlox resources, students could even connect these embedded devices to their personal smartphones to serve as a customizable remote controller and/or display for any information they collect. And importantly, as NetsBlox continues to expand with new web-based features, so too will the resources that students can access through NetsBloxVM for their embedded, networked projects.

6 SYSTEM AND HARDWARE

NetsBloxVM runs on the ESP-IDF framework, which uses the FreeRTOS embedded operating system. The current prototype, which has been used in this paper, runs on an off-the-shelf ESP32-S3-DevKitC-1. To ensure that there is sufficient space for storing projects, as well as memory to facilitate Snap!'s many garbage-collected, by-reference objects, the N32R8 version (32 MB SPI flash, 8 MB PSRAM) of the module was selected. However, less powerful versions such as the N8R2 would also be sufficient. The full devkit can be bought for 17 USD, or the module itself for only 4 USD, making this a viable platform for the goal of low-cost IoT and distributed computing tools for K-12 education. In the future we will add support for additional ESP boards and more plug-and-play peripherals.

7 CONCLUSION

As we have seen, NetsBloxVM is a powerful tool which enables students to take all of their existing NetsBlox knowledge of advanced networking topics like IoT and distributed computing and apply it to real-world embedded platforms for making hands-on, personally-meaningful makers projects. In addition to supporting all of the core features from NetsBlox and Snap!, NetsBloxVM also adds a more powerful and descriptive debugging system to help students find and fix errors. NetsBloxVM also supports a fully over-the-air user experience, which most existing K-12 embedded programming platforms do not provide, and its peripherals system focuses on a plug-and-play design that allows schools to cut costs by picking and choosing peripherals or sharing a small set of peripherals among a classroom. It should be noted that NetsBloxVM has at this point not been tested with students, but we are currently planning studies to do so and collect data on the efficacy of this tool for introducing approachable, hands-on IoT to middle and high school classrooms.

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Writing as Making: Towards a Critical Constructionist Praxis with Pre-Service Educators

Author

To create classroom environments that position non-dominant youth as the agentive, creative, cultural producers that they are - particularly in relation to digital media and technology – their teachers need to have opportunities to make and play with a range of technologies within their own educational experiences. Drawing from a course taught with 9 pre-service educators, this poster analyzes how teachers engaged in writing-as-making, and in doing so revealed the ways thinking expansively and critically about literacies and engaging in a range of making (both on and off the screen) led to increased transparency into processes of students' own learning, deeper connections to theoretical ideas related to literacies and learning, and a culture of vulnerability, dialogue, and support.

CCS CONCEPTS • learning • critical literacies • making

1 INTRODUCTION

Youth from nondominant communities disproportionately experience standardized approaches to curriculum and pedagogies that limit their voice, choice, and opportunities for authentic engagement in their own learning, which is largely driven by the culture of standardization that permeates contemporary education in the United States (Ito et al., 2020; Vasudevan, 2022). Teacher education programs remain rooted in didactic approaches that are largely structured around state licensure expectations and are therefore beholden to the aforementioned agenda of standardization which includes struggling to integrate technology (e.g. mobile devices, computers) and digital media (e.g. applications, platforms) in authentic and meaningful ways (Cuban, 2018). Even when technology is available, non-dominant youth are much less likely to have opportunities to engage in creative cultural production which furthers digital divides (Dolan, 2016; Rafalow, 2020). To create classroom environments that position non-dominant youth as the agentive, creative, cultural producers that they are - particularly in relation to digital media and technology – their teachers need to have opportunities to play and make with a range of technologies, make their own digitally mediated artifacts (or compositions), and to engage in classrooms that promote a culture of tinkering, failing, and iterating. In this works-in-progress piece, I report on a semester-long class on Digital Literacies and Learning where 9 undergraduate students in our education minor, engaged in a playful, making-centered classroom that brought together Constructionism, Critical Digital Literacies, and Critical Pedagogies. Moreover, I offer insight into the ways in which moving towards Critical Constructionist Praxis created opportunities for these pre-service educators to engage in dynamic, collaborative, play-ful, critical making and learning experiences, asking the questions, “*What happens when we pre-service educators get to make and play?*” and “*what do digital compositions (writing) reveal about the nature of learning?*”

2 CRITICAL CONSTRUCTIONIST PRAXIS

In this research I am exploring a theoretical space that I'm calling *Critical Constructionist Praxis*. Constructionism considers how learning unfolds during the process of making personally meaningful artifacts (Papert & Harel, 1991). Constructionism is inherently critical because *deconstruction* is essential to the process of construction or *making*: in order to make something you must imagine it, feel your way through the process, then evaluate if what you have created aligns with your vision, and iterate, tinker, and tweak whatever you have made until you realize your vision- or tire of the project. Critical Digital Literacies acknowledge that reading and writing are multiple, multimodal, socially and ideologically situated, and shaped by power dynamics, but also require an understanding of how algorithms and data via applications and platforms shape our understanding of texts both on and beyond the screen (Luke, 2019). Critical praxis implores us to interrogate, critique, and examine structural factors that shape our learning experiences, to see the student-teacher relationship as dialogic, and to value see learners ways of being and lived experiences as invaluable to the classroom culture

(Freire, 2018; hooks, 2014). Finally, an essential part of this praxis is to center the notion of *writing as making* and to continually explore the ways in which digital compositions bring Constructionism to life through: play, tinkering, iterating, composing personally meaningful (or identity-driven) artifacts. So, throughout this paper, I refer to digital writing, making, and composing to do the same kind of relational and learning work.

3 METHODS

In order to further the exploration of the theoretical space outlined above, Critical Constructionist Praxis, this poster examines artifacts produced by students in a 15-week Digital Literacies and Learning Across Educational Contexts course, as well as the actual learning context and its significance in shaping classroom culture and the artifacts students made. The class was taught in classroom called Imagination PLAYce (see figure 1 below), launched in Fall 2022, as a space to imagine and dream about the possibilities of learning through making and play. The space is filled with materials one might find in any early childhood or elementary classroom like art and drawing supplies (e.g., crayons, markers, paints), craft supplies (e.g. pipe cleaners, googly eyes, feathers), children's books and other literature, as well as a range of digital media and learning technologies (e.g. desktops, digital cameras, ozobots, podcasting equipment). The space is designed to feel warm and playful through the use of color, prominent display of students' artifacts, and accessibility of resources to make and compose. Data includes students' artifacts made within and outside of class (e.g. data selfies, heart maps), the writing and dialogue students engaged within and outside of class (e.g. social annotation), and culminating compositions (e.g. digital story, online communities research), and students' final self-assessments and reflective writing on the course. Data analysis is in preliminary stages which includes thematic coding (Charmaz, 2014), as well as concept mapping (Maxwell, 2012) to interrogate the learning processes embedded within specific tasks. For example, peer feedback was an essential part of the students' digital composition process. Concept mapping reveals all of the avenues or pathways for learning in one small task. These analyses will continue for significant artifacts (e.g. heart maps, digital stories, community research project).



Figure 1: Imagination PLAYce, a collage of photos of the community and classroom space

4 PRELIMINARY FINDINGS AND IMPLICATIONS

The preliminary data analysis of students' artifacts revealed the identity-driven nature of what students made, the ways in which students began to think expansively and critically about literacies, and how continued making (both on and off the screen) led to increased transparency into processes of students' own learning. With regard to the nature of transparency into learning, the continued practice of *writing-as-making* as central to the critical constructionist praxis. In the first figure below, I describe the processes students engaged as part of their first major project which is titled, the *Digital Lives Project* (figure 2). This project asks students to interrogate the ways in which an individual they know comes to understand how digital media and technology shapes their everyday lives, to do so they are meant to generate an overarching question, conduct an interview, and then go about digitally composing the story, transmediating the interview into something more interactive and universal.

In Figure 2 below, I have articulated the distinct steps of the composing process for the digital lives project, which ultimately resulted in a digital story that were comprised of multiple modalities including images, videos (e.g. screen captures of digital activity, play-throughs of video games), background music, audio (e.g. narrative voice over, excerpts from recorded interviews), that were building a portrait of a person using multimodal and digital lenses. In the concept map below (figure 3), I specifically lay out the ways in which something like peer feedback, as part of a composing process can reveal all of the complexity and richness of specific kinds of compositions, in this case, the making (or composing) of a digital story.

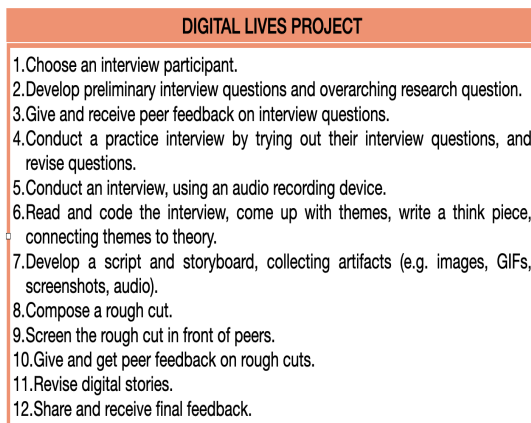


Figure 2: The process of composing the digital lives project

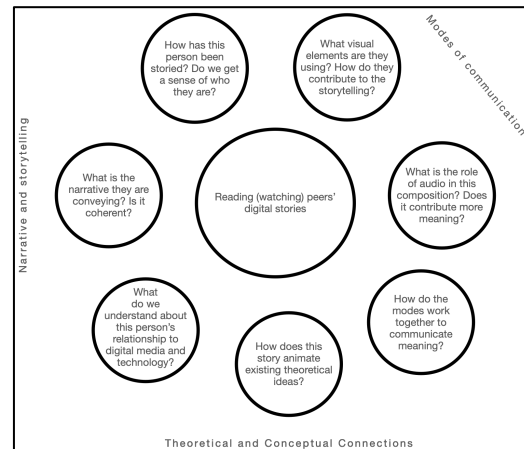


Figure 3: Concept Map of Peer Feedback on Digital Stories – Revealing Pathways for Learning

Digital stories that were created by students revealed critical insights like the social pressures young people feel to perform perfect lives through social media, or how digital media has informed their identities as artists, or facilitated the ability to forge affinity-based social connections. Students also navigated the challenges of composing digital stories – from writing a coherent script, to storyboarding that script to move the narrative and convey meaning, to ensuring the artifact had a clear sense of audience and purpose. When the students showed their rough cuts with each other, there was critical dialogue on each piece regarding the overall story, the ways in which multiple modes effectively (or not) conveyed meaning, and whether the actual arguments being made were in fact animating theory and research evident within our class discussions (see figure 3). Two days later, when the rough cuts were shown, there was tremendous growth, stories got tighter and more coherent, audio was smoothed, ideas that were not articulated effectively in the rough cuts were refined. Ultimately, the final compositions revealed how personally meaningful making -- in this case interview projects that were focused on a person students could relate to and wanted to learn more about -- can lead to deep and meaningful learning (Papert & Harel, 1991).

Through a culture of making and playing with texts and sharing and critique, students felt increasingly supported by one another to participate in class dialogue, to be vulnerable, and to try out new digital media technologies to compose more complex compositions. To change the way students learn, teachers must have opportunities to learn differently, and this is where Critical Constructionist Praxis may offer a way forward, because making and playing in schools is still unfortunately a radical idea (Vasudevan, 2022). To ensure these practices are essential, we must continue to create space for educators to play with ideas, artifacts, materials, and technologies.

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aAI-Enhanced Philosophy of Education Studies

Work in progress (WIP)

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1 RATIONALE

Contemporary education, particularly the humanities, has long been in crisis. Humanities education has not adjusted to ongoing technological innovations, constantly changing local and global market demands, social challenges of multicultural societies, and consequently, the diminishing status of knowledge. Teachers are no longer the exclusive possessors of knowledge, which undermines their authority, giving rise to doubts about their centrality in the classroom and putting in question the very relevance of the humanities to the learners' future (Blaschke, 2018; Glassner & Back, 2020; Roberts, 2021).

The proposed program aims to utilize technology to restore the glory of the humanities and respond to the new needs of learners and teachers. It proposes educational modes of action in these fields, suggesting that constructionist approach (Papert & Harel, 1991) and a self-determined learning approach – heutagogy (Glassner & Back, 2020) could leverage transforming the humanities into an innovative learning experience and a source of skills and competencies required to cope with the socio-educational challenges of the knowledge society with its frequent changes, complexities, crises, and uncertainty.

Further to previous ideas on integrating the constructionist approach into humanities teaching (Baranova et al., 2018; Hwang, 2023), we propose a philosophy of education course based on constructionism and self-determined learning to represent the humanities. The program's implementation leans on learning-by-making comprising AI applications.

The concept derives from our experience with courses combining heutagogy and constructionism. The project-based courses we have taught in a teacher education college generated critical thinking products in varied technology-rich learning environments, e.g., AR applications, podcasts, videos, or Sphero. The proposed program benefits from our two educational knowledge domains – philosophy of education and learning technologies.

The future program students will raise and explore issues of their own interest from educational philosophy and use AI artifacts as an object to thinking aids (Mioduser, 2005) to engender dialogue, debates, ideas, or any other product they choose to present to the group. The proposed group or individual learning-by-making process will yield an artifact-object created through a human-machine dialogue (Papert & Harel, 1991).

Heutagogy, our learning and inquiry method, allows learners to direct and lead their learning while wandering in virtual knowledge spaces. Wandering aims to stir curiosity, trigger critical questions, engender a dialogue, and use technological environments to improve the learners' understanding of their research object. The openness and freedom at the core of heutagogy expand the philosophical-humanistic horizons of the learner, thus promoting their ability to critically contemplate social, moral, and ethical issues raised by contemporary technology. Heutagogy assumes learners' self-efficacy, encouraging them to learn independently and scrutinize their learning through reflection and self-assessment. It aspires to develop lifelong learning skills in the learners. According to these principles, the teacher has to be accessible to the students, facilitate their learning, and offer them as much assistance as they require. Heutagogy allows for thorough, authentic learning stimulated by questions the students consider relevant. It relies on knowledge accessible in digital environments and frees learners from the locality-dependent traditional school learning. Assuming that learners are conversant with relevant technology and capable of using technological tools to promote critical, social, and ethical thinking on issues and questions of interest, heutagogy enables them to learn through the construction of a technology product (Blaschke, 2012; Glassner & Back, 2020; Vallance & Towndrow, 2016).

As educators, the proposed program will enable teachers to practice theoretical and practical tools to lead change processes based on linking the humanities education with methods using current technologies and applying a constructionist approach and self-determined learning. Incorporating constructionism and introducing AI technologies into the humanities would offer a much-required opportunity to facilitate moving from traditional teaching of the humanities to a contemporary teaching mode that would develop in the

learners the skills and capabilities needed to handle complex ethical, moral, and social dilemmas we are coping with at present.

2 The Program

Below is the program outline designed to cultivate in the learners humanistic and critical thinking via a dialogue with socio-educational dilemmas based on a philosophical way of thinking and critical and creative use of the accessible AI technologies:

- Learning and understanding educational thought ideas via a dialogue with technology controlled by critical thinking.
- Learning by doing, creating actual humanistic outcomes (constructionism).
- Changing the educational paradigm to self-determined learning (heutagogy).
- Rhizomatic learning via collaborative wandering and group-peer inquiry (Cormier, 2008).
- Lecturer/teacher role transition: from knowledge transfer to learning facilitator, designing learning environments that summon learning by doing and critical, ethical, and moral thinking.

2.1 Program structure

The program is an ongoing process based on six elements:

1. Question formulation

Introducing educational thought topics relevant to the learners' socio-educational life, and formulating comprehensive questions about them. AI tools (ChatGPT, Dalle-2) will assist the learners in phrasing the questions. For example, a learner who wishes to probe a boycott she suffered in school in her youth can consult the AI tools about how to formulate a philosophical question regarding social boycott among children. The learners will determine whether the AI tools' question is appropriate, how to improve it, and whether it covers the issue they wish to explore.

2. Learning workshops

The lecturer/teacher will hold learning workshops to acquaint the learners with canonical educational philosophy topics and thinkers relevant to the research questions. The workshops will also present optional debate models and critical thinking principles to assist the learners' inquiry and learning. The learners will generate a conceptual outcome based on interaction with an AI application in each workshop.

3. Heutagogical wandering

Once the learners have chosen and formulated their questions, they will continue to wander around learning spaces that could provide answers to their questions. These will include conventional learning spaces, such as libraries and online databases, and spaces allowing interaction with AI tools that will be partners in dialogues and brainstorming.

4. Collaborative learning

The program encourages learners to experience group learning and collaborative inquiry. In the group, the learners can exchange questions, look for information together, and use various preferred information sources. Each learning group will include a virtual AI-based learner to assist the group with questions, searching for relevant information, and proposing knowledge sources and additional research directions.

5. Reflection

Learners will use ongoing reflective-critical writing, an integral part of heutagogy, to describe their progress and inquiry methods. Although the reflective process is personal, the learners will receive ready assistance on how to write a reflection from those around them: teacher/lecturer/peers/ or an AI application. That will also be the stage to explore human-technology reciprocity.

6. Outcomes

The learners are free to choose their learning objects. They might wish to introduce and conduct a debate on their research questions, present an article they wrote jointly with AI tools, create a podcast or a video clip based on AI technology, build a model, present an artwork that corresponds to the research question, or choose any other object created through learning by interacting with AI technology.

3 IMPLEMENTATION

The program is currently at its primary conceptual stage. We have run pilots to test it, and our students have been investigating AI applications as learning tools in a constructionist approach. So far, we have been using free AI tools to realize the program. As the program progresses, we will study the practical manifestations of learners' agency, emphasizing their capability to assess and evaluate social, political, and ethical processes, both within the course and beyond. At the conference, we plan to introduce some of our experiences and discussions of the program plan.

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Co-Constructing Language Learning through Tinkering with Wearable Soft Controllers in Galician Creative Libraries for Elementary Schoolers

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This pilot study is a part of an ongoing Creative Library Project (Proyecto Biblioteca Creativa), taking place in two school libraries in Galicia, Spain, which investigates the potential benefits of co-constructing knowledge in the realms of electricity, programming, and language learning within the context of 21st-century skills. Specifically, the researchers focus on exploring the effectiveness of a constructionist approach involving crafting and gaming. This approach employs a range of conductive and non-conductive materials, Scratch, and Makey Makey kits, with the intent of facilitating multilingual language education and fostering creativity among elementary school students. Preliminary findings suggest that integrating physical and digital making processes holds the capacity to significantly enhance non-formal language learning opportunities. This highlights the unique attributes of school libraries as ideal environments for fostering such maker and STEAM education experiences.

Keywords: constructionism, school libraries, language learning, makerspace, STEAM education

1 INTRODUCTION

Technological advancements have brought about a significant transformation in the teaching and learning process, leading more educational institutions to integrate makerspaces to promote the development of 21st-century skills (Blikstein, 2018; Konstantinou et al., 2021) and provide hands-on experiences that stimulate interest in STEAM subjects (Singh, 2021). Integrating constructionist theory in makerspaces and libraries, such as those found in schools and community centers, has the potential to transform traditional classroom learning into more engaging, interactive, and effective learning experiences, emphasizing the importance of experiential learning and promoting deeper understanding (Papert, 1980; Resnick, & Rosenbaum, 2013; Ying, 2018). Makerspaces offer a promising approach to transform learning experiences, enhance student engagement, and promote a culture of creativity and innovation in education, providing a community that offers students an opportunity to expand their knowledge acquisition and learning opportunities (Peppler, 2022) while fostering the development of unique skills that are not typically emphasized in a conventional classroom setting (Halverson & Sheridan, 2014).

Co-construction and constructionism have emerged as important pedagogical approaches in foreign-language education to promote language learning through collaboration, incorporating rote learning, an approach that involves memorization through repetition (Li & Cutting, 2011). Meta-analysis of previous studies revealed that digital game-based vocabulary learning enhances students' vocabulary knowledge (Chen et al., 2018). Although previous studies have supported the effectiveness of technology in enhancing vocabulary development in elementary schools (Hugelmeyer & de Moraes, 2017; Panagiotidis et al, 2023), the potential of technology for promoting multilingual learning through programming and crafting together remains relatively unexplored.

In the northwest of Spain, the Galician Regional Ministry of Education, University and Vocational Training, within the framework of the innovative project Plan LIA (Lecture, Information and Learning) for school libraries launched the Creative Library Project in 2016. This project, following the trend of DIY and maker culture, has fostered activities aimed at enhancing students' linguistic communication, oral expression, logical reasoning, creativity,

collaborative work, research, manipulative learning, and play (Guimeráns & Rúa, 2021). Subsequent to foreign-language education in school libraries, co-construction and constructionism can serve as important pedagogical approaches for fostering language learning through collaborative and experiential learning. The motivation for our present study is the assumption that if students are proficient in one of the three presented languages in a game, they have more opportunities to acquire the lexicons of the remaining two languages through active engagement with technology and collaborative exploration alongside their peers. Scratch has been used in primary education to support programming skills and computational thinking, as studies have shown (e.g., Fokides, & Papoutsis, 2020; Vasudevan & Kafai, 2016). Therefore, we aim to investigate how integrating crafting with conductive and non-conductive materials, along with tinkering using the Makey Makey and trilingual Scratch game, can foster students' creativity and provide distinct language-learning opportunities within Creative Libraries in public schools.

2 RESEARCH CONTEXT

Two 90-minute workshops were held in the Creative Libraries of two elementary schools in Galicia. The first workshop had 16 students (10 boys and 6 girls), and the second workshop had 11 students (8 boys and 3 girls), aged 8 and 9. The workshops involved two teachers and two researchers. The differences between the two groups were that the first group had no Makey Makey or Scratch experience and were native Galicians whereas the second group had some experience with these tools and mostly nonnative Galician parents from various parts of the world because this region has experienced a substantial increase in immigration (DePalma & Pérez-Caramés, 2017).

We employed an ethnographic approach to observe students' engagement with physical and digital activities and interpret local and naturalistic actions from students' perspectives (Creese & Copland, 2015). We employed multimodal transcription (Swinglehurst, 2015) to facilitate the analysis of student interactions and experience enabling a close examination of the nuances of their engagement and the results of learning outcomes.

Each workshop was divided into six steps. Step 1 involved introducing the goal of the workshop and conducting an oral survey to gauge the students' previous experience with computational construction kits and their knowledge of English and Chinese. In Step 2, they explored conductive (e.g., Play-Doh, gummies, erasers, coins, and copper tapes) and non-conductive materials (e.g., paper, plastic, thread, and felt) through trial and error and connected them to Makey Makey. Step 3 involved initiating Scratch and tinkering with the interface. In Step 4, they created bracelets using conductive materials and a sheet of felt. In Step 5, we encouraged them to modify or hack the codes to their liking. The pre-programmed game, Fruit Language Game, introduced basic fruit vocabulary words (e.g., apple, banana, and orange) in English, Chinese (Mandarin), and Spanish. Finally, they reviewed the vocabulary words and completed written questionnaires to contemplate on their learning experience. We also conducted unstructured interviews with teachers to gather comprehensive insights.

3 PRELIMINARY RESULTS

In Workshop 1, students displayed keen interest and invested a considerable duration in exploring the properties of conductive and non-conductive materials and experimenting with Makey Makey kits to design controllers using them (Figure 1). Given that this was their first experience working with these tools, they were particularly focused and engaged. The novelty of the tools and the hands-on nature of the tasks captured their attention, driving them to explore the concepts of the materials and technologies. Also, a few students practiced foreign vocabulary words by consistently repeating native pronunciations and recognizing the written words on the fruit images, implying that they memorized the foreign vocabulary words through repetition. For example, a

pair repeated and pointed at the written form of fruit vocabulary words in Chinese, “蘋果[píng guǒ]!” as the monster was approaching those fruits. Despite the constraints of limited time, their exploration and utilization of these new tools reflect their capacity to recognize and express themselves in languages other than their native tongue.

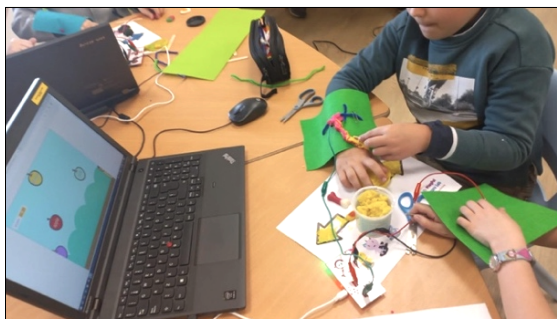


Figure 1. Experiential learning by building bracelet controllers

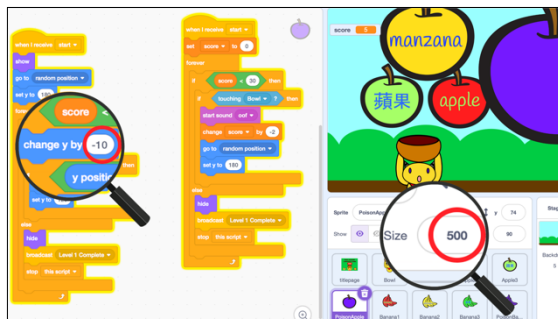


Figure 2. Manipulating sprites to create a more challenging level

In Workshop 2, we observed a more apparent constructionist approach being implemented in Scratch activities, in which students engaged and experimented with the game and made modifications based on their preferences. One student inserted a humorous Rick Roll meme image into the game background as a form of hacking. Furthermore, as highlighted in the magnified areas in Figure 2, a pair engaged extensively with sprites. They enlarged the poison apple, adjusted its speed by changing the y value from -1 to -10, and thereby customized the level of difficulty to align with their preferences. This active interaction showcases their deeper utilization and familiarity with the interface and code blocks. This demonstrates the concept of constructionist gaming, in which students use their creativity and problem-solving skills to construct and modify digital media based on their interests and goals (Kafai & Burke, 2015). Notably, when a student had difficulty connecting the Makey Makey device, others who had already figured out how to connect the wearable controller to the conductive and non-conductive materials guided others, exhibiting cooperative play and tutoring behavior. For example, a student said to his peer, “Look, it’s working! Tap left and right!” teaching how to close the circuits and coordinate with the game and the controller. In relation to language learning, a researcher posed a question to students: “How do you say banana in Chinese?” One student provided a precise response, “香蕉[xiāng jiāo],” and elaborated, “I know! It’s easy because it keeps repeating in the game,” illustrating how language learning can be facilitated through gamification and by integrating hands-on activities for this age group.

The data are being organized for the larger quantity of ongoing workshops; however, comparing Workshops 1 and 2, preliminary results from the current questionnaire responses reveal that 21% and 33% of the students, respectively, memorized and recall more than one word in Chinese; more than 63% and 74% of the students, respectively, seek to learn new foreign languages; and 76% and 83%, respectively, intend to engage in creative programming in the future. The unstructured interviews with the teachers revealed that Workshop 1 students had less time for language learning because they were first-time users of the tools, resulting in lower interest than among Workshop 2 students. The two workshop groups differed in diversity, The Workshop 1 students were all from Galicia, and the Workshop 2 students were from diverse countries, and some had just immigrated and entered the school, so they were overall more familiar with multilingual environments. Teachers indicated that Makey Makey and Scratch were motivating and versatile in promoting language learning and fostering creativity and critical thinking skills and that regular engagement with these activities would benefit students.

4 IMPLICATIONS AND FUTURE DIRECTIONS

Through the integration of soft controllers into a language-learning curriculum within a STEAM education context, we explored how students can learn about conductivity and crafting expression through a blended approach. This approach aligned with the constructionist theory, which emphasizes active and experiential learning for a holistic approach to education (Papert, 1980), specifically in learning lexicons in multiple languages. Although this brief study may not exhaustively demonstrate the benefits of maker space for language learning, students exhibited verbal repetition of words and were highly engaged in creating and hacking the game. By manipulating variables in the game, students explored and experimented with various concepts and ideas in an engaging and interactive way, which can ultimately lead to a deeper understanding and attainment of new knowledge. Overall, the workshop offered valuable learning experiences that exposed the students to various blended learning methods while promoting creativity and collaboration. Finally, it emphasized how important it is for rural students to gain exposure to diverse languages and cultures to expand their 21st-century skills, including their worldview, and enhance their communicative abilities. We plan to expand our workshop with students from diverse linguistic backgrounds by offering a variety of language options, levels, and AI features, such as the voice recognition in Scratch, so students can check whether they have memorized the words or phrases more accurately.

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Constructionist booster: a quantitative bridge program for first year university students

Constructionist Bridge Program

Introduction to an experimental bridge program to improve student confidence in doing college-level mathematics.

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This paper introduces a bridge program designed to bolster the mathematics confidence of freshmen college students right before starting school. Using the toolset of constructionism, inspired by ScratchMaths, the bridge program will prepare students who do not aim to major in Mathematics or Computer Science to perform college-level work in both of those areas. Combining a pre-introductory programming experience with a quick introduction to computational thinking, and then re-discovering the basic principles of high-school level algebra through a constructionist, programming approach, the bridge program aims to reinforce the existing knowledge of the students and embolden them to complete college level mathematics courses.

Keywords and Phrases: constructionism, math anxiety, mathematics education, computational thinking

1 INTRODUCTION

Math is understood to be hard and scary. Seymour Papert, the founder of the notion of Constructionism devoted an entire chapter in *Mindstorms* to the topic (1980), describing the desire to make mathematics, and learning itself, to be more approachable as one of his primary motivators. In this paper we use Richardson's and Suinn's definition of mathematics anxiety: "Mathematics anxiety involves feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (1972). According to a PISA study (OECD, 2012), about 30% of students have anxiety while doing mathematics – roughly the same ratio as found four decades earlier (Richardson & Suinn, 1972). This difficulty remains at university level, causing problems at colleges around the world; for example (Abraham et al., 2014; Atuahene & Russell, 2016; Büchele & Feudel, 2023). To make matters worse, poor performance leads to lower self esteem, increased anxiety and higher chance of dropping out of college (Bennett, 2003).

This paper describes an attempt to tackle the above situation through a pre-university constructionist bridge program focusing primarily on student perception of mathematics. Bloom's taxonomy (Bloom & Krathwohl, 1956) separates learning into three hierarchical models: the Cognitive domain, the Affective domain and the Psychomotor domain. The Cognitive domain primarily focuses on knowledge and mental skills, the affective domain on attitudes and perceptions, and the psychomotor domain on physical skills. While most traditional mathematics classes focus on the cognitive domain when developing curriculum, the proposed bridge program's main goal is to progress the students in the Affective domain, to make them internalize that Mathematics is something well within their power to do.

The bridge program is addressing this need in an intensely constructionist manner. It starts by teaching the students basic programming (and animation) concepts using Scratch, then this platform (designed by the very MIT Media Lab Papert founded) is used to create objects-to-think-with to understand, share and discuss the basic mathematical concepts covered. Since the students construct the programs – and with them, their understanding of mathematics – themselves, it makes the subject more approachable and less frightening. The idea here is similar to how Papert suggested using Turtle Geometry to teach children (Papert, 1980, p. 58): by utilizing the students' existing knowledge and expertise, they ground the construction of new information on known things and concepts. They feel excitement at discovery, not helplessness and confusion. This increased confidence and lower anxiety will improve both their academic performance and psychological well-being.

The target students for this specific bridge program are those who pursue an academic career that is not focused on mathematics-adjacent topic areas but for whom mathematics is a core foundational subject. By targeting these students and providing them with an opportunity that can serve as an on-ramp to university education, the hope is that they will have a less anxious experience in their calculus course, and a larger percentage of them will be able to pursue their chosen careers.

In addition to the affective learnings, the course will contain cognitive components as well by re-visiting high-school level Algebra topics and allowing the students to re-discover these areas through the tools of constructionism. The goal is not to teach new mathematics, but instead to revisit known topics and deepen the students' understanding of them.

Additional planned benefits of the bridge program will be the introduction of programming as a tool the students will be able to rely on for the rest of their lives, and an increase in critical thinking abilities.

2 METHODS

The goals of the program are rather lofty, but through constructionist methods not unattainable. The ScratchMath initiative has shown that it is possible to teach programming concepts to 5th graders, who then can use these concepts in the 6th grade to construct mathematical understanding (Benton et al., 2017, 2018; Noss et al., 2020). This approach greatly improved students' computational thinking abilities.

The use of Scratch to teach programming for late teens is uncommon but not unique; for example in Hungary the Eötvös Lóránd University uses a Scratch-based class in their Computer Science Preliminary Course, an intensive semester-long program where 4 of the 24 credits the students complete come from a Scratch programming course (*Computer Science Preliminary Course*, n.d.). Using a more advanced programming language like Python would quickly take the focus away from just basic concepts of programming to allow to transition into discussing math, and instead would be bogged down with issues of syntax, data representation, display issues etc. Building on some earlier success in providing a pre-introductory programming experience for students at university level (Margitay-Becht & Das, 2023), the bridge program would utilize the approachability of Scratch programming to make programming and computational thinking concepts accessible to students of all backgrounds. This newly constructed knowledge base can then become the basis for re-discovering mathematics and letting go of math phobia for good.

While the primary purpose of the bridge program is to change student attitudes towards mathematics and their own self-valuation, it would bring residual benefits as well. In popular business media it is often discussed that employers are looking for critical thinking and problem solving skills; this general understanding was reinforced for example in (Baird & Parayitam, 2019). As part of the pathway from introductory Scratch programming to constructing mathematical understanding, the students will be introduced to basic principles of computational thinking, which then they can use as a possible implementation of critical thinking to better organize their projects, education and even their life.

3 IMPLEMENTATION

The bridge program will take place over the first three weeks of August, 2023. This time period was chosen as the fourth week is the move-in week, and following that education starts. This way the bridge program literally transitions the students from High School and summertime to starting their college experience, not just educationally but also chronologically.

The format of the program will be synchronous online, using Zoom as the platform for interaction and a google sites website for content delivery, as some of the students might not yet have access to the university's content management system. While the university usually attracts most of its students from within a radius of a few hundred miles, the online platform enables students from all around the world to join, reducing barriers. As many of our students need to work during the summer period, the bridge program will take place for 150 minutes during the mornings and will be structured to require no work at home from the students, so they have the majority of the day available to them.

3.1 Material breakdown

The material during the three weeks will be broken down as follows:

Week 1: introduction to programming in Scratch. Loops, variables, conditional statements. Animations. Events, event-driven programming. Lists, list management. Introduction to computational thinking.

Week 2: algebraic thinking through constructionism. Initially re-introducing the basic operators (increment by one \Rightarrow addition \Rightarrow multiplication \Rightarrow power) through the use of programming with a focus on loops. Utilizing Scratch the students will re-construct their understanding of how these

operators work, and will create visual animations of the basic operations. This built-in ability of Scratch to visualize mathematical concepts is a key component to constructionist approaches; similar, non-Scratch-based constructionist university classes used student-created animations as their central features to great success before (Hoban et al., 2010; Triantafyllou & Timcenko, 2013). By empowering students to translate math to animation, the program will enable them to utilize this skillset later in their academic career if they want to visualize a complex concept, possibly through a more advanced programming language like Python or a customized tool like GeoGebra or MathLab. The program will then progress onward, discussing the fundamental theorem of arithmetic by constructing prime factorizations in Scratch, and re-discovering fractions and graphs.

Week 3: A continuation of the previous week, concluding in a student-selected project to encourage independent work and summarize the discussed material.

3.2 Evaluation plan

The bridge program will contain two sets of pre- and post-test based evaluations. For the affective domain, a Likert-scale will be used to record student attitudes at the beginning and end of the bridge program. For the cognitive domain, an algebraic readiness test will be utilized.

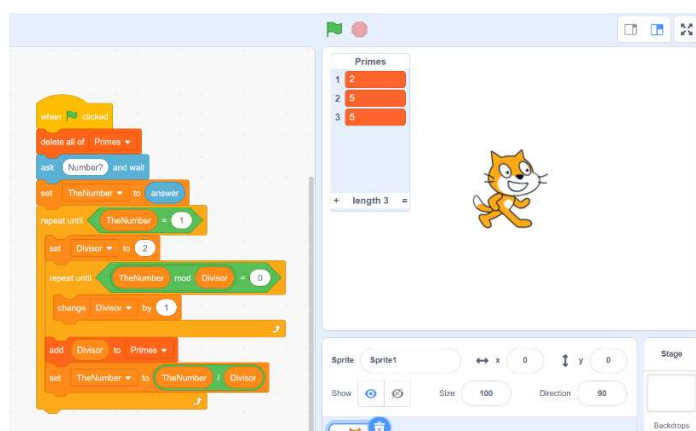


Figure 1: A simple prime factorization algorithm created in Scratch by an 11- and a 9-year-old. Own Image

4 CONCERNS AND NEXT STEPS

Implementing the above plan as a bridge program instead of a university class has the advantage that it provides an optional on-ramp for students focusing on existing material. It would be impossible to offer a high-school level course at a university setting, but a bridge program *before* the university starts is appropriate. One possible concern of this implementation is that the audience is entirely self-selected, so positive outcomes are more likely as there is at least some magnitude of motivation is a given. Another concern is that the program received little advertising support to let the students (and the students' parents) know about it ahead of time. This, coupled with the fact that the program would in essence eliminate an entire month of the students' final summer before college, might lead to a very low number of students signing up.

The bridge program can be developed further to serve a different audience. Instead of focusing on the students who have to take Calculus-level math, a version of the program can be created to fulfill the college-level mathematics requirement for students who do not want to engage with more complex mathematical concepts.

5 CONCLUSION

The constructionist bridge program is designed to help students transition into college life better. By providing them with the basics of programming in the form of Scratch it prepares them for computational work. By guiding them through a re-imagination of mathematics, it prepares them for mathematical work. By introducing them to computational thinking, it gives them a ready-to-use toolset that they can utilize both at college and later in life to tackle complex problems successfully. Overall, the program aims to make the students more successful for the rest of their lives.

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Programmable Oven Toaster: A Powerful Tool for Learning Chemistry & Home Economics in a Constructionist Way

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In this paper, we present our “programmable oven toaster” and how it can be used in a creative learning class. Our oven toaster can be manipulated via Scratch-based coding, enabling students to go through as many trial-and-errors as they want, in their process of cooking. We propose the process of baking cookies via programming, which embodies a powerful concept in developing creativity and relevant disciplinary knowledge in a constructionist way.

Keywords and Phrases: Constructionism, Programming, Scratch, Creativity, Cooking, Chemistry, Home Economics, Oven Toaster, Home Appliances, Creative Learning

1 INTRODUCTION

In this paper, we present our “programmable oven toaster”: a totally new tool for students to engage in the practice of “coding to cook”. As of today, numerous programming and creativity classes have emerged, utilizing educational programming languages such as Scratch (Resnick et al., 2009; Resnick, 2017), as well as programming-based educational kits such as Mindstorms (Cejka, Rogers & Portsmore, 2006) and SPIKE (LEGO Education, 2019) by the LEGO Group.

In the field of creative learning through programming, it appears that the available teaching materials and kits are predominantly centered around the domains of physics and mathematics (Byrne et al., 2021), as seen in the prevalence of robotics as a learning medium. No doubt, physics and mathematics play an essential role behind the scenes in our lives. A lot of past studies have explored the positive effects of such teaching materials or kits in nurturing kids' creativity, including so-called “twenty-first century skills” such as algorithmic thinking (Fanchamps et al., 2021). Also, using programming in mathematics learning is, due to the interactivity it brings to the class, reported to “help students build new mathematical ideas” (Goldenberg & Carter, 2021).

However, creativity is said to be “domain-specific”, meaning that being creative in one domain does not necessarily translate into being creative in other domains (Baer, 2012). Hence one can argue that the creativity nurtured by physics and mathematics may not be readily transferable to other fields.

So, we propose to develop creativity programs outside the domains of math and physics. The aim of this paper is to showcase how we can utilize our programmable oven toaster, and design programming-based creative learning courses beyond these well-established domains. We will discuss our creative learning course via the methodologies of chemistry and home economics (i.e. cooking). Given that an oven toaster is a familiar home appliance and thus predominantly used in domestic settings, we believe this work has the potential to go well beyond “the artificial contexts of schools and science centers” (Harel & Papert, 1991).

2 PROGRAMMABLE OVEN TOASTER

2.1 System Configuration

This section provides an overview of the system configuration of our programmable oven toaster. The oven toaster is based on NB-DT51 (Panasonic Corporation), and its physical appearance is illustrated in Figure 1. The programmable oven toaster is equipped with temperature sensors and three heaters that can be controlled through programming via IoT chips. The oven toaster has two far infrared heaters, one attached to the upper body and the other to the lower body, and a near infrared heater, which is attached to the upper body. Figure 2 shows the system configuration diagram. The oven toaster and programming terminal communicate in real-time via BLE. The hardware controls the thermostat, initiating operation at 260 degrees Celsius (500 degrees Fahrenheit). The indicator, located on the lower body of the toaster, changes color to indicate the BLE connection status and the ON/OFF status of the heaters.

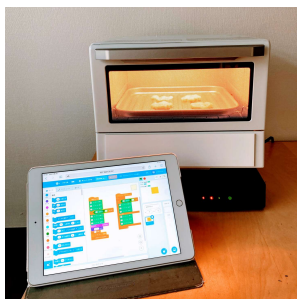


Figure 1. Programmable Oven Toaster

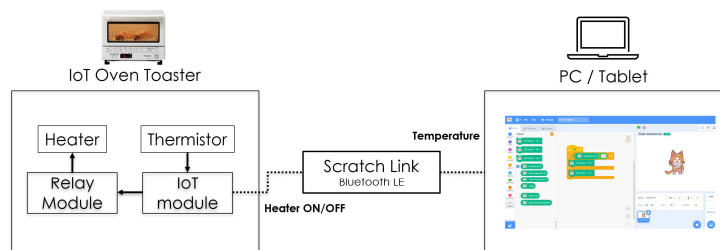


Figure 2. System Configuration Diagram

2.2 Programming

We have developed an extension of Scratch as a programming tool to control the toaster. The temperature sensor values and behavior patterns, along with the three heaters, can be manipulated via programming. Thus, programs like “increase the temperature of the oven toaster until it reaches 200 degrees Celsius (392 degrees Fahrenheit) and maintain temperature for 3 minutes” are possible. Users can have control over the oven toaster’s operation by adjusting values such as the heater temperature and heating time as they prefer during their cooking process (within a certain numerical range for each variable).

3 IMPLEMENTATION

We have so far offered creative learning courses (as programming classes or as home economics classes), using our programmable oven toaster, to 11 schools. Table 1 shows the typical content / timetable of our class, although the content may differ slightly depending on the specific needs of the school. Class images are shown in Figure 3-6. First, students were given time to think about and discuss “the ideal cookie” for them, thus becoming committed to working on “personally meaningful artifacts” (Kafai & Resnick, 1996) during the class. Then they got engaged in the activity of “coding to bake cookies”, went through numerous trial-and-errors with flavors and smells being intrinsic feedback serving as a guide, and were given opportunities to compare the cookies with those of other students. Some were able to create their “ideal” cookies, while others could not, due to time restrictions. Along the way, they learned fundamental chemical concepts, such as the

phase change of sugar and the Maillard reaction. Feedback received from participants was mostly positive, with over 90% expressing satisfaction with the class, and more than 80% indicating an intention to retake the class.

Table 1: Class Content and Timetable

STEP 1: Introduction	10 [mins]	Team discussion about the ideal cookie.
STEP 2: Coding	20 [mins]	Creating the basic code for baking cookies. *Dough is prepared during this step, unless it has been already prepared beforehand.
STEP 3: Trial and Error	60 [mins]	Tinkering with the code toward the ideal cookie.
STEP 4: Presentation	10 [mins]	Sharing with the class what they have done and learned.
STEP 5: Reflection	20 [mins]	Connecting trial and error experiences with disciplinary knowledge.



Figure 3. Home Economics Class

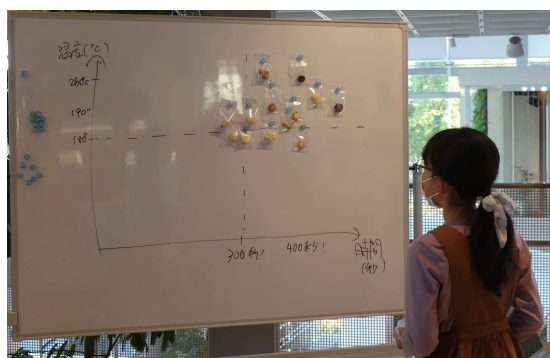


Figure 4. Temperature and Time Mapping of Cookies

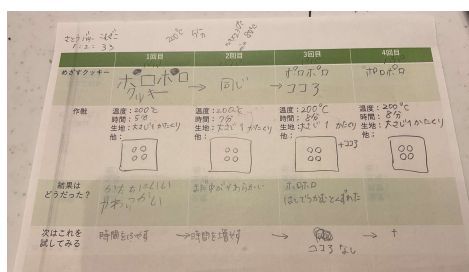


Figure 5. Trial-and-Errors History

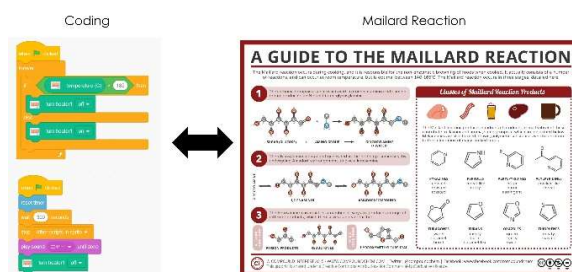


Figure 6. Relationship between Coding and Maillard Reaction (<https://www.compoundchem.com/2015/01/27/maillardreaction/>)

4 DISCUSSION

Citing the idea of kitchen math, Papert discussed the importance of what he called “a rich form of natural learning that goes against the grain of school methods” (Papert, 1993). We believe that the positive feedback received from our classes provides support for the potential of this concept to be taken one step further. Our programmable oven toaster and classes

seem to have succeeded in effectively facilitating students' ability to learn through intrinsic feedback. The subject matter of “eating / tasting” is one that everyone has ample experience with, regardless of their background, which allows for a smooth learning experience.

We foresee our possible next steps as follows; First, we need to expand our work to include subjects other than cooking (chemistry / home economics), the need of which is suggested by Baer's research on the domain-specificity of creativity. We are currently considering the possibility of developing other programmable home appliances such as Scratch-based lighting equipment, which could be implemented in an art class. Second, it will be necessary for us to identify the most appropriate method to objectively measure the impact of our classes on students. To assess the simultaneous development of creative and disciplinary thinking, we see rubric-based evaluation for creative learning as a good candidate (Murai et al., 2021). Also, ideally this would be an automated process without the need for a specialist evaluator, the possibility of which is implied in recent studies (Cropley & Marrone, 2022; Kumar & Boulanger, 2020).

We believe that constructionism has become more important than ever in the field of education, as the capabilities of newly emerging AI-enabled educational tools begin to overlap with what instructionist ways of teaching can offer. Building upon what we have to offer today as presented in this paper, we aim to make further contributions to the field of constructionism by developing tools and classroom designs that leverage them.

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Microworlds, Powerful Ideas, and What do we do Monday?

An exploration of microworlds and powerful ideas with an eye to how they are used in practical activities and projects.

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This works-in-progress proposal focuses on learner engagement with microworlds and powerful ideas, concepts discussed by Seymour Papert in his seminal 1980 book, *Mindstorms*. Recounting two workshops held early this year, the authors offer a detailed look at practical application in student-centered classroom activities and projects, with particular attention to the emergence of interdisciplinary artifacts. The discussion encompasses more than computer-based environments and emphasizes the importance of and need for students' construction of knowledge. In addition, the analysis attempts to more clearly define powerful ideas and their role in constructionist teaching and learning. This work is ongoing. The authors are planning additional workshops and intend to continue documenting, analyzing, and sharing future learning experiments that follow.

Keywords and Phrases:

microworld, powerful idea, domain, constructivism, constructionism, turtle geometry, state, body syntonicity, robotics, feedback, system, emergent phenomena, emergence, Minecraft

1 INTRODUCTION

The subtitle of Seymour Papert's 1980 book, *Mindstorms*^d is "Children, Computers, and Powerful Ideas." Chapter 5 is "Microworlds: Incubators for Knowledge." Millions of educators were introduced to the turtle geometry microworld and the powerful ideas that become accessible by engaging with it.

During February and March of 2023 we hosted two workshops entitled *Microworlds, Powerful Ideas, and what do we do Monday?* The goal was to initiate an exploration of what we mean by the terms *microworld* and *powerful idea*, and with this framework, to explore how these concepts are expressed in classroom activities and projects. We included activities and projects already in place in our classrooms as well as those to be initiated.

Our long-term goal is to accumulate, document and share examples of *microworlds* that are used in our classrooms and other learning environments, and the *powerful ideas* that they engage students and teachers with.

2 WHAT IS A MICROWORLD?

A microworld is a streamlined environment designed to support learning. The term microworld most often refers to computer-based environments, such as turtle geometry, but we also use it to refer to learning environments more generally. These include a set of kindergarten blocks and a range of interdisciplinary projects, some of which predate our work with computing. Lawler sees microworlds as streamlined environments that combine powerful ideas with neat phenomenaⁱⁱ.

Rieberⁱⁱⁱ spells out five characteristics of a microworld:

1. It is domain specific;
2. it provides a doorway to the domain for the user by offering a simple example of the domain that is immediately understandable by the user;
3. it leads to activity that can be intrinsically motivating to the user—the user wants to participate and persist at the task for some time;
4. it leads to immersive activity best characterized by words such as play, inquiry, and invention;
5. and it is situated in a constructivist philosophy of learning.

Characteristic number 2 is equivalent to Lawler's description of microworlds as streamlined environments. Characteristics 3 and 4 are equivalent to Lawler's "neat phenomena," focused on the aspects of the microworld that engage and excite the learner. The classroom is a universe of microworlds. Microworlds are explorations, constructions, and studies that immerse students in constructing knowledge and make connections to the universe of powerful ideas.

3 DOMAIN SPECIFIC OR NOT?

Rieber says that a microworld is domain specific. This allows for simplicity and streamlining, but limits making connections between different domains where similar powerful ideas are expressed. We include interdisciplinary projects, as microworlds, or rather, collections of microworlds that are related. One may also consider Scratch, Minecraft, and some other programming environments to be collections of microworlds.

4 WHAT IS A POWERFUL IDEA?

We think that microworlds do not have to be domain specific. We look at interdisciplinary projects that are microworlds, or collections of interrelated microworlds. Microworlds are valuable because they bring the learner in touch with powerful ideas. An idea is powerful if it enables one to do something with it; create something new and/or understand something that was previously hard to grasp. If an idea is powerful, it is likely to be found in many different domains and situations. Powerful Ideas articulate operating principles and phenomena to help us understand our world. In this paper we focus on the Powerful Ideas that came out of case studies and common activities from the classroom, such as systems, state, cycles, feedback, and emergence, but there are many more.

We discuss constructing Microworlds and exploring Powerful Ideas as a way to organize teaching and learning in a practical way. We also revisit activities and projects that are already underway in our classrooms from the perspective of Powerful Ideas that they carry, and which we can make explicit in our interactions with students. The Powerful Idea focus also supports relating one area of learning to other situations and domains. Making these connections rests on a fundamental Powerful Idea of learning something new by connecting with something you already know.

Turtle Geometry is arguably the best known microworld to arise in the Logo community. It is an excellent example of the streamlined aspect of microworlds. With just a few commands one can create an endless variety of patterns, designs and drawings. What are some of the powerful ideas that learners may encounter in the Turtle Geometry microworld?

Body Syntonicity - The turtle moves the way you do. If you want to tell the turtle to draw a circle, walk in a circle and describe what you're doing in Turtle Talk. This is a specific case of a more general powerful idea: when encountering a new problem or situation, try to relate it to something you already know.

State - The state of the turtle consists of its position and its heading. It is always somewhere and points in some direction. The commands FORWARD and RIGHT each independently change each of those two components of the turtle's state. They are state-change operators. If, after following a sequence of commands, the turtle ends up with the same position and heading as when it started, that sequence of commands is state-transparent. Awareness of the powerful idea of state and state transparency is valuable in many situations. For example, when creating an animation or game there is a need to initialize the state of the actors and background so that the program behaves as intended each time it runs. The concept of state and state transparency applies to many situations, including cleaning up your room, going on vacation and returning home, and regaining health after an illness.

5 CYCLES AND CIRCUITS

These concepts help us to make sense of a broad array of natural phenomena. Kids engaged in the study of life cycles, water cycles, or the cycles of traditions and seasons in a year, can begin to make sense of their world, anticipating changes and repetition.

6 SYSTEM

This powerful idea stretches across disciplines, functions, and thought, and is necessary for a game or project to take hold for students. Given the time, space, and materials, students will determine a system so they can easily play, replicate, and extend the activity. Systems, as a powerful idea, helps us to understand everything from the relationships of family members to the relationships of planetary bodies.

7 EMERGENCE

An emergent phenomenon is one in which the behavior of a whole system is the result of the interactions among its components but is different from the behaviors of the components. An example is an ant colony, where the individual ants have very simple behaviors while the colony as a whole is quite complex. Emergence is a key feature of how we organize and manage our constructionist classrooms, creating an environment in which worthwhile activities and projects are likely to emerge. Critically, the students are exercising independent thinking and acting with initiative, and the teacher sets up the classroom environment and offers appropriate input as needed. The child raises a question or presents a discovery within a microworld that leads to a powerful idea that is big enough and important enough to stop everything and explore.

Block Play is a rich microworld in which kids engage with units that have preset dimensions, shapes, and weights to build constructions, the design of which can be spontaneous, or they can have a preset notion of what they will build.

Students begin to engage with powerful ideas of **force, systems, and feedback**, and engage with geometric thinking and properties of physics. As a microworld, **Imaginary Play** has some of the same properties as block play. Though the materials are different, the imaginary play of children is not instructional, often happens over the course of days, developing **systems** through set roles, rules, and storytelling. Teachers plumb this play for themes and ideas that have larger applications and meanings in the curriculum.

Robotics

Popular robotics activities include having a bot follow a line, avoid obstacles, or escape from an enclosure^{iv}. In each case, the bot senses some aspect of the environment and then takes action based on what is sensed. Microcontrollers that sense and act are pervasive in our world: walk into a dark room and a motion sensor triggers the light to turn on, your phone recognizes your face and unlocks.

Some robotics activities, including those just cited, involve a special case of sensing and acting that includes the powerful idea of feedback. The action may alter what is sensed and based on that new information, a different action may be initiated. For example, after backing up and turning when an obstacle is sensed, the bot may be in the clear and, no longer sensing the obstacle, again moves forward. Knowing about feedback can help with understanding thermostats, climate change, how to revise an essay, and much more.

Troll Village and Main Street

An example of an emergent classroom phenomena, itself a powerful idea, is a Troll Village initiated by students in Author1's fifth grade classroom. A group of students began constructing homes for their troll dolls on the surface of tables and the project developed, becoming more complex, because the classroom encouraged students to develop a project or follow a line of inquiry, allowing students' questions, ideas, and constructions to become part of the fabric of learning happening in the classroom.

Main Street was part of an interdisciplinary project focused on the urban environment that was central to Author1's 5th/6th grade class for several years. The street was a model of a city street, above and below ground, that took up one end of the classroom. Students designed and constructed buildings and other structures. What emerged was not predetermined, but it was constrained by the initial environment and the children's knowledge and imaginations about the city they knew and what they wanted it to be.

The Bird Study

This is an example of a multi-disciplinary study created by the teacher with openings for discovery and initiative by the students. In this study the teacher had two objectives: For the students to learn deeply about a species of bird, which they would then present to the rest of the class, and to integrate digital technology into the construction of the physical and verbal presentations. As they researched and constructed the birds and their life cycles, they also learned about how circuits work through programming the Makey Makey.

Minecraft

We analyzed this versatile platform for creating interdisciplinary microworlds and three-dimensional turtle geometry programming by focusing on a multiplayer Minecraft 'graduation experience' project developed by sixth grade students in Author3's classroom. The learners used a wide range of functional and decorative blocks and explored emergent

intersections with multiple content domains. Through an iterative process programming their body syntonized virtual turtle and working alongside it, a *double spiral* process occurred whereby the learner used the computer as an object-to-think-with to create and enter a microworld with a virtual robot companion which the learner programmed to assist in the creation of that very world. The depth and flexibility for exploring microworlds and powerful ideas in Minecraft lies further within the use of in-game sensors, motors, data gathering, feedback, and also the ability to connect to both the digital world outside of Minecraft and the physical world.

8 CONCLUSION

Millions of teachers were introduced to the concepts of microworlds and powerful ideas by reading *Mindstorms*. Turtle Geometry was the microworld most prominently featured in that 1980 book. We looked at a range of microworlds and the powerful ideas that they enable learners to engage with. Our focus was on the task of creating and managing a classroom environment that made this possible with practical activities and projects. Of special interest is the powerful idea of emergence. In addition to helping us understand phenomena in a wide range of domains, we also see emergence as the guiding principle in how we organize our classrooms and other learning environments.

Over the past year we have conducted a series of video and in-person workshops in which we have been exploring these ideas with teachers, tech integrators, and curriculum innovators. Within these sessions we have invited these educators to join us in an ongoing study group, in which we develop and implement microworlds and projects, create environments in which open-ended discovery and emergent curriculum occur, and a compendium of micro-worlds and powerful ideas are developed for the larger community.

ⁱ Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: BasicBooks.

ⁱⁱ Lawler, Robert (1981). Some Powerful Ideas, p. 19. MIT Logo Memo 60, AI Memo 652, Cambridge, MA: Massachusetts Institute of Technology. Available at <https://dspace.mit.edu/bitstream/handle/1721.1/6363/AIM-652.pdf>

ⁱⁱⁱ Rieber, L. (2004). Microworlds. In D. Donassen (Ed.), *Handbook of research for educational communications and technology* (2nd ed., pp. 583-603). Mahwah, N. J.: Lawrence Erlbaum Associates. Available at <https://members.aect.org/edtech/22.pdf>

^{iv} For some examples, look at the Challenges from the annual Robo Expo <http://robo-expo.org/challenges.php>

Constructionism in the Light of Computational Creativity

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Various Artificial intelligent methods were developed with inspiration from human practices to optimize existing solutions or propose new valuable ideas. Computational Creativity is one of the emerging young fields that utilizes AI techniques to build results that are creative, novel, and represents the most impressive form of AI today. It impacts almost all disciplines and leads to continuous reports in the media, e.g. about AI generated images, stories, and music. If constructionist learning constitutes (re)constructing meaningful products students' find in the world around them, wouldn't the future of constructionist learning involve enabling students to create their own computational creativity system? In the following paper, we propose such a constructionist learning approach where students learn about and draw their own conclusions on CC systems. Students do not only learn powerful ideas of CC systems, but also reflect and apply the building blocks of the subject domain they are dealing with. Hence, they may better understand the world around them.

Keywords and Phrases: Computational Creativity, Constructionism, Artificial Intelligence.

1 INTRODUCTION

Constructionism is a learning theory that is denoted with the idea of learning by constructing (Papert, 1968). It is a student-centered approach that includes learning through discovery, and relying on information that students already know to gain knowledge. It also encourages project-based learning with guidance from teachers to lead students into constructing projects of their own, and shaping their different ideas into producing something they are learning about.

The main essence of constructionism is about students building their knowledge structures, allowing students to think in their own way and not to follow a predetermined pipeline to gain new knowledge. Having modern technology-based techniques could inspire and support students to build nearly optimal knowledge structures for topics they are learning about. It could also provide modern learning experiences to encourage them to be more resilient and utilize previous knowledge in gaining new knowledge, as opposed to passively receiving information (Kafai, 1996).

Learning is associated with creativity. Considering teaching practices that allows the students to be creative, make students more resilient and autonomous in their life, and that requires adopting newest trends and technologies in teaching environments (Cross, 2012). Vygotsky defines creativity as anything new that humans produce, whether it's a product, a thought or a mental structure (Vygotsky, 2004). He also views the creative process as a collective process that re-combines pre-existing discoveries or knowledge items into a new discovery. This can be highly relatable and important in education, to understand how students learn new concepts or build new artefacts.

Computational Creativity (CC) is a new area of research that proposes several ideas related to simulating human's creative behavior in many areas, such as developing music (Romeike, 2007), narratives (Issa, 2019), culinary arts (Issa, 2021), etc. Its main goal is to produce creative artifacts by simulating human's way of producing creativity. Boden has

argued that considering familiarity; which is based on human's previous experience, novelty; that is the non-deterministic addition to human ideas, and value; which is the usefulness of the result in the real world, are three essential components in order to create a CC system that produces creative artifacts (Boden, 2004). Building these systems does not only mimic human creative productions, but allows us to break down creative artifacts around us, and explore human's creative minds. It could also inspire in multiple domains to model their development of creative results.

In education, CC could present a new approach in constructionism, which supports the idea of learning by construction. Human's creative imagination is goal-oriented, and thinking about concepts, makes the concepts explicit in the human mind (Lindqvist, 2003), and that allows the person to connect concepts and ideas together. Building a CC system, allows students to break down concepts and artifacts and make them explicit, which leads to students thinking creatively, towards a goal of creating something new. This could participate in building the skill of learning-how-to-learn by breaking down the concepts and artifacts into basic blocks, extract patterns, and rules and constraints. Then construct a new result that is novel and valuable, and reflect on the process. This helps students not only to learn about the topic they are studying but the computational method of constructing CC systems that utilize AI.

2 COMPUTATIONAL CREATIVITY IN CONSTRUCTIONIST LEARNING

2.1 Computational Creativity Systems in Education

CC systems are created to mimic human creativity in certain fields, using AI-based techniques to produce results that are held to be creative, and to enhance human's creativity (Mateja, 2021). From different domains, a general pattern could be analyzed and rules could be extracted, to guide the process that aims at building problem-solving methods that are inspired by human creativity to achieve novelty and familiarity (Jändel, 2013).

Many researchers have studied using CC in education, for example, (Marbach-Ad, 2020), explored the potential of a CC approach in supporting students' learning of physics. They developed a computer-based platform that enabled students to create interactive physics simulations, and found that this approach led to improved engagement and understanding of physics concepts. Also, (Ramírez-González, 2020), used a CC approach to support students' learning of mathematics. They developed a system that generated creative problems for students to solve, and found that this approach led to improved engagement, creativity, and mathematical understanding. (Johnson, 2012) followed the same approach in teaching history.

CC systems are successfully and predominantly used to foster learning, but students basically only use these tools like "magic tools", without knowing how the outcomes are created and which building blocks of the subject domain lead to the results. We find an opportunity to benefit from the idea of constructing computational creativity systems and making this process explicit under the umbrella of constructionism, as students will not only construct CC systems to learn from the final output, but also learn among the process of creating the system, which will sharpen their learning-how-to-learn skills.

2.2 Enabling Students to Create Their Own Computational Creativity System

Many researchers in education discussed various approaches to foster students' creativity by applying innovative teaching methods (Siew, 2014), or by modern techniques that involve AI and technology, such as interacting with robots (Ali, 2019; Yang, 2020). Vygotsky implied that creativity is both the goal and the mean for the development of students (Vygotsky, 2004), and here, we present a new approach in fostering students' creativity by enabling them to create CC systems in a constructionist learning approach.

Constructionist learning implies that students learn best when creating something that can be shown and be proud of, and something which represents a certain concept. By creating CC systems themselves, not only can the motivation of the

students be addressed, but they also get the chance to learn and understand about AI. Previously, it was proven that utilizing computer-based systems and AI, allowed students to learn about AI and computing in general and develop skills in this area (Ali, 2019). Furthermore, creating a CC system requires a learner to really reflect on the subject domain (e.g. language, music or cooking) in which the CC system is to be built for, hence fosters learning not only about AI but also might foster the understanding of the subject domain.

The process of creating a CC system allows learners to learn how to break down the subject they are learning, into a generalized pattern of blocks, which will make them more creative, increase their ownership over the content they are learning, have individualized experiences, allow them to construct their own mental models of topics they are learning, learn how to learn further concepts in the same approach, and learn about building computational creativity systems which is a very impressive form of AI systems. This would also speed up the process of reaching a deeper level of learning by creating these creative products (Forehand, 2010). Figure 1 highlights the process of CC to achieve a creative product.

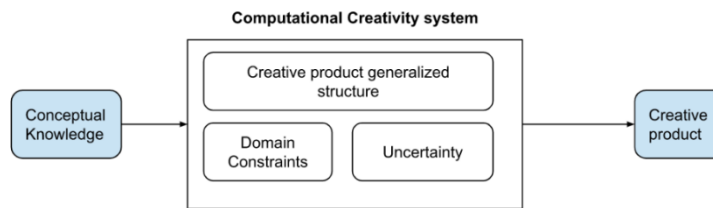


Figure 1: Computational Creativity Process

CC systems are created by analyzing the components of existing artifacts and understanding the constraints that determine how this artifact is created. Let's take culinary arts for example, the first author in (Issa, 2019), proposed a CC system that creates novel food recipes.

In order to create a new food recipe in a computational creativity system, the basic components of food recipes should be realized, which are food ingredients, then, a pattern is extracted of blocks of food ingredient categories that are put together, such as spices, vegetables, meat products, etc. Then, understanding the constraints of which ingredients go together. Furthermore, implementing uncertainty using for example, probabilistic models to model random objects, or random constraints. The last step is to evaluate the product to understand the value and novelty it brings to the audience, and reflect on the process of creation. Evaluation mechanisms could help students orient their creations towards something that is usable and novel, so evaluation can be designed around the main rules of the domain, such as food-pairing hypothesis rules of ingredients compatibility, and the acceptance of this new creative product among the related audience.

Putting this in an explicit form in a constructionist teaching approach will teach students to deconstruct existing artifacts, extract patterns, understand the constraints of creating an artifact, include uncertainty factor, and evaluate the results. It will also teach them to use AI techniques according to the CC system they are creating. For example, using probabilistic models, or rules, simulations, algorithms, and logic, etc. The teacher's role would be guiding students to get individual experiences in constructing different creative products, and to model their creativity into the system they are creating.

3 DISCUSSION

The constructionist approach revolves around exploration and project-based learning, for constructing artifacts. The CC system demonstrates the artifact being created by students which combines their pre-existing knowledge, and their understanding of existing artifacts in the field. We model this idea in Figure 2, it shows the steps of a constructionist

approach to create a CC system. Based on student's pre-existing knowledge, and domain knowledge, students will interpret and deconstruct to identify building blocks of existing artifacts, for example, the building blocks of a music track, or a food recipes, or a short story. Then, students will learn to implement a CC system which is the new artifact, including knowledge, constraints and uncertainty. Finally, students will learn to evaluate the artifact to reflect on its novelty and value. During this process, students will form a deeper understanding of the topic they are learning and understand how existing artifacts are broken down to be explicit and represented on a creative AI-based systems. This forms a practical approach for constructionist learning environments to foster students' creativity through their learning journey.

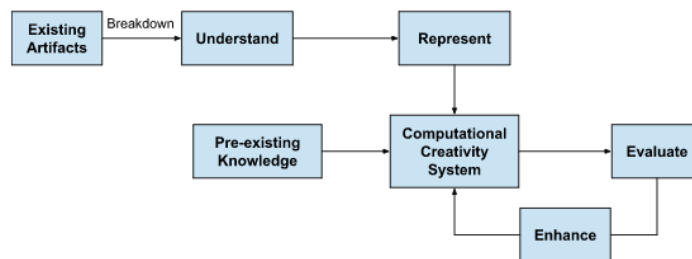


Figure 2: Computational Creativity in Constructionism

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Empowering Learners with a Low-Barrier Mobile Data Science Toolkit

Mobile Data Science Toolkit

Using MIT App Inventor to build data science mobile applications

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This paper introduces a novel data science toolkit designed specifically for children, enabling them to create mobile apps integrated with data science capabilities. The toolkit showcases new features that simplify the data science process for young users. Additionally, the paper presents a collection of example apps created using the toolkit, highlighting the versatility and potential of this innovative platform. By empowering children to explore data science through app development, this toolkit opens exciting opportunities for hands-on learning and creative expression in the field of citizen science.

Keywords and Phrases: MIT App Inventor, Data Science, Mobile Applications, Citizen Science

1 INTRODUCTION

Many barriers, such as cost, access, and complexity, can prevent students from building working prototypes for performing authentic data science practices across the data science life cycle — collecting data, data cleanup, data visualization, and prediction (Mike, 2022). For example, online tools such as Python notebooks can be too complex for students new to Python. Moreover, few products enable students to build projects that visualize data on mobile platforms — which, after all, is where many scientists and citizen scientists collect and consume data visualizations today (Silvertown. 2009).

We discuss and present demos and student examples for a low-barrier mobile toolkit that allows learners to take part in the whole data science lifecycle. The demo and discussion are relevant for middle and high school teachers and facilitators of out-of-school programs. Participants can build simple mobile apps using MIT App Inventor and test these systems for themselves during the conference presentation.

The toolkit is a free suite of new, block-based-programming data science features that allow students to solve real-world problems that affect them or their community.

1.1 Motivation: Data Literacy

Data science is a multidisciplinary field that extracts insights from data by combining principles from mathematics, statistics, computer science, and domain expertise. Its applications span across various domains. We believe that introducing data science to children can boost their motivation for standard statistics and math school subjects. By showing them how these seemingly theoretical disciplines are applied in the real world to solve important problems, students can better grasp their significance. Data literacy is defined as the essential skills required to understand and use data effectively, including problem-solving, data collection, analysis, evaluation, visualization, and ethics. In today's digital age, data literacy is crucial for making informed decisions based on data.

In addition, data thinking involves a cognitive process that encourages individuals to approach problems and decision-making with a data-centric mindset, fostering skills like problem abstraction, pattern recognition, critical thinking, and informed decision-making (Mike, 2022). The data lifecycle represents the entire journey of data, from creation to removal

or archiving, and involves defining the problem, data collection, cleaning, exploration, machine learning, iterative evaluation, and publication of results. For learners, the data lifecycle serves as a helpful guideline, reducing the intimidation that comes with learning a new field like data science. Our goal with the toolkit features is to provide learners with a platform to go through the phases of the data lifecycle, acquiring essential 21st-century data thinking skills with ease and accessibility, while solving real-world problems of relevance to the learners.

1.2 [IOT Connection and Data Management Features for Mobile Phone Apps](#)

The App Inventor IoT component enables a connection between a mobile phone app and a low-cost Bluetooth sensor. This connection allows for real-time data collection from the sensor, ensuring accurate and reliable time series data acquisition. By leveraging Bluetooth technology, the app can connect to the sensor wirelessly, eliminating the need for complex wiring and enhancing the mobility of the data collection process (Lechelt, 2020; Clark, 2019). The online spreadsheet-to-mobile-device component streamlines data transport from spreadsheets to the mobile device. This functionality allows users to visualize, clean, and analyze the collected time series data conveniently. By integrating online spreadsheet services in the form of Google Sheets, the app facilitates easy access to data from anywhere, fostering collaborative data analysis and reducing the dependency on traditional desktop software. Additionally, cloud storage services can be integrated into the app, enabling seamless synchronization and backup of data to remote servers.

1.3 Anomaly Detection and Data Cleaning Techniques for Mobile Phone Data Analysis

The Anomaly Detection component allows for identifying anomalies and deciding whether to remove them based on the type of data and the user's domain knowledge. By incorporating advanced anomaly detection algorithms, the application can automatically flag potential anomalies in the data. However, it recognizes that not all anomalies are erroneous and may reveal valuable insights depending on the domain. Therefore, the feature allows users to exercise their domain knowledge and make informed decisions on whether to remove flagged anomalies or retain them for further analysis (Vaidya, 2023). The Preliminary Visualization feature enables users to perform initial visual analysis on their mobile phone's touchscreen. By providing interactive visualization tools, the application facilitates the identification and removal of out-of-context anomalies. Users can visually explore the data, observing patterns, trends, and irregularities directly on mobile devices. This feature empowers users to make data-driven decisions on removing visually distinguishable anomalies that do not align with the expected context of the data.

1.4 [Mobile Charting for Visualizing Data in Mobile Applications](#)

The Mobile Charting component provides young designers with options for visualizing data in a mobile application. By incorporating chart types such as bar graphs, line graphs, scatter plots, and pie charts, students can select the most suitable representation for their data based on the nature and characteristics of the dataset. This flexibility allows for effective communication and comprehension of the data, enabling students to identify patterns, trends, and relationships.

1.5 Linear Regression for Predictive Insights in Mobile Applications

The Linear Regression component allows students to add a line of best fit to showcase trends in the data. By fitting a straight line to the data points, they can observe the direction and magnitude of changes, helping them anticipate future outcomes. This feature helps students understand the relationship between variables and make predictions based on the linear trend. The feature also includes presenting statistical and probability information about the data. This information aids users in assessing the strength and significance of the linear fit. For example, the feature provides correlation

coefficients to quantify the degree of linear association between variables. These statistical insights enhance users' understanding of the data and assist them in making informed decisions.

2 EXAMPLES

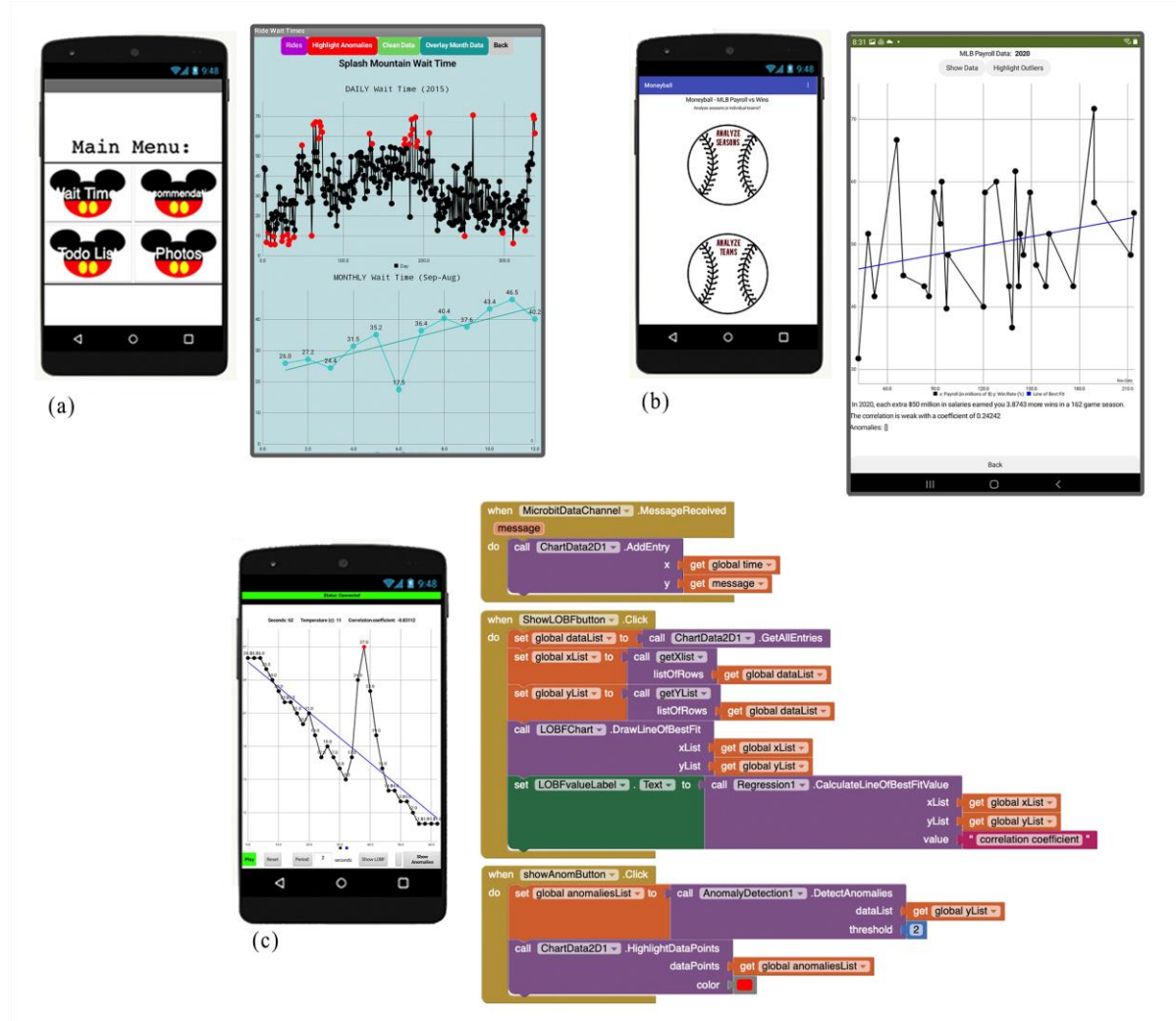


Figure 1: Images of example apps using the data science toolkit.

2.1 Analyzing Posted Wait Times for Disney World Rides: Insights for Average Wait Time Prediction

Figure 1 (a) shows an app for analyzing wait times for various rides at Disney World to determine the average time a child might have to wait in line. Raw data from a reliable source, specifically *touringplans.com*, provides information on ride wait times throughout the year. The data is graphed to identify trends in ride busyness during specific times of the day, month, or year. Additionally, the app explores the significance of extremely low and high wait times, allowing children to understand factors such as weather conditions, park attendance, or ride maintenance that contribute to these outliers.

2.2 The Relationship between Payroll and Wins in Major League Baseball: An Anomaly Detection Approach

Figure 1 (b) investigates the relationship between team payroll and wins in Major League Baseball (MLB). Using data from over 150 games played by each team in a season, the app analyzes how spending on player salaries impacts a team's performance. It also acknowledges the presence of outliers, such as teams that overspend or underspend on player salaries, as exemplified in the movie *Moneyball*. Consequently, anomaly detection techniques are employed to identify and analyze such outliers, making this example suitable for anomaly detection in the context of MLB payroll and wins.

2.3 Gathering Time-Series Sensor Data: Temperature Readings from a Wireless IoT Sensor

Figure 1 (c) shows a mobile phone app with data gathered using a low-cost Bluetooth sensor. The data show a steady decrease in temperature that is briefly interrupted by a short-term increase (in this case, a warm coffee cup on the sensor for illustration). The line in blue is a line of best fit for the data, and the data point in red has been identified in the app as an anomaly based on a z-score greater than 2, as set in the App Inventor blocks, shown to the right.

App Inventor programming blocks show the App Inventor IoT component for receiving serial messages from the Bluetooth device, which are passed into the Mobile Charting component to generate the line graph. Blocks from the Linear Regression feature allow the user to draw a line of best fit in blue and calculate its correlation coefficient. Blocks from the Anomaly Detection component identify data points with a z-score greater than 2, then highlight them in red. By engaging children in hands-on activities and data tracking, this research aims to foster interest and understanding of the application of various sensors for directly gathering and analyzing data in many domains from sports performance to climate change.

3 CONCLUSION

By providing an accessible data science toolkit, this paper enables students to actively engage as data scientists in areas aligned with their interests and experiences. The inclusion of new features empowers young users to explore data-driven concepts, analyze real-world data, and create meaningful mobile apps that reflect their unique perspectives. This approach fosters a deeper understanding of data science and encourages students to apply their newfound skills and knowledge in diverse domains, promoting a sense of ownership and relevance in their data science journey.

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Co-Constructing Expert Problem Solvers: The Power of Constructionism in the Digital Age

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Programs that situate learners at the intersection of digital literacy, collaborative problem-solving, and tangible fabrication can be potent drivers toward future success. This work examines one such initiative, called InfuseCS, that incorporates an immersive Virtual Learning Environment (VLE) utilizing problem-based learning (PBL) scenarios within a Computer-Supported Collaborative Learning (CSCL) context, catering to upper elementary school students. Conducted in a public, Title 1 STEAM-centric elementary school in the mid-Atlantic United States. This program has enriched the educational journey of 10 to 11-year-olds, predominantly Hispanic and African American. The program encouraged students to collectively build and fabricate their learning experience, essentially constructing their understanding, knowledge, and skills through active engagement with coding solutions and direct collaboration. Acting as both a physical and conceptual makerspace, it allowed learners to fuse their inner cognition with external realities, embodying the tenets of constructionism. This manuscript probes into the program's teaching methodologies, explores its unique features, and concludes with insights and wider implications for education. The paper elucidates the scaffolded journey from Self-Regulated Learning (SRL) to Socially Shared Regulation of Learning (SSRL) and then to Co-Regulation (CoRL) as students collaboratively navigate the learning environment.

Keywords and Phrases: Self-Regulated Learning (SRL), Socially Shared Regulation of Learning (SSRL), Co-Regulated Learning (CoRL), Maker-Centered Learning

1 INTRODUCTION

InfuseCS, a narrative-centered maker environment, was implemented in a Title 1 STEAM elementary school in the mid-Atlantic region of the USA. This school has held a STEAM designation for three years and offers a semester-long STEAM elective to fifth graders twice a week. The consented participants consisted of 17 students aged 10-11 years, with demographics including 16 boys, one girl, seven Hispanic, eight African American, and two White students. Among them, two students received special education services, and four were part of an English as a Second Language (ESL) program.

InfuseCS was designed over a series of iterative development cycles. Initially, educators, researchers, and technical experts convened brainstorming sessions to align curriculum objectives with technological possibilities. Drawing from feedback loops with educators, three prototypes of the program were piloted and then refined based on user testing and challenges faced by teachers and students. The inception of InfuseCS was inspired by the need to integrate hands-on maker activities with digital learning platforms, recognizing the immense potential they held in facilitating collaborative and interactive learning. The initial design was based on recognized pedagogical approaches and later refined through the iterative development process mentioned above. A storyline was integrated to lend a context-driven, real-world problem-solving angle to the activities.

In InfuseCS the learning journey begins with students being introduced to a main storyline, in which scientists have been shipwrecked on an island and must use salvaged materials to prototype survival and rescue devices. Then, they individually explore various 3-D virtual locations in tandem, discovering and managing resources that can be used in their collaborative problem-solving efforts later on in the environment. Pairs of students share a physical set of maker materials to use in their iterative problem-solving process. Depending on the challenge they have chosen, students must determine the degree of collaboration required with each other and potentially with other teams to ensure their solutions "work." For example, if the team decided to devise a solution to help increase their chance of being rescued from the island, they use their resources to construct a physical model of a rescue signal. After finding a satisfactory solution, students are asked to co-construct responses to reflection questions, acting as the seeds for a jointly created written narrative. The final step of their learning experience involves the students using a block-based coding interface to test and run scripts that allow on-screen characters to act out the narratives they created.

1.1 Empirical and Theoretical Grounding

The foundations of InfuseCS find roots in constructionist principles put forth by Papert and Harel (1991) and are further grounded in the works of Ackermann (2001), emphasizing the synergy between digital tools and hands-on exploration. These integrated activities are grounded in the principles of making, emphasizing experimentation that aligns seamlessly with the exploratory nature of makerspaces (Bevan et al., 2017). The experience of the user of the learning environment evolves as they delve into content, experiment with simulations, and gain a foundational understanding of science content. To facilitate this process, students use the shared maker materials, which include a range of inputs (such as wind, solar, mechanical, and chemical) and outputs (light, sound, motor/fan). The maker kits are used with the intention that students will creatively brainstorm potential solutions for the simulated scenario. InfuseCS promotes digital literacy and design thinking through its narrative-centered-making activities. As students work through the problem-based learning scenario, they engage in computational thinking, using algorithmic processes to create storyboards that guide their project's progression (Barr et al., 2011). This process involves not only abstraction but also leads to engagement with complex programming concepts such as conditionals, along with practices such as remixing, testing, and debugging (Papavlasopoulou et al., 2017) during the coded narrative stage.

2 REGULATION OF LEARNING

Understanding the regulatory processes in computer-supported collaborative learning (CSCL) is a critical aspect of our research, considered essential by scholars in the fields of educational psychology, learning technology, and computer science (Fischer et al., 2007). The main focus is on three modes of regulation that are often present in collaborative learning contexts: self-regulated learning (SRL), socially shared regulation of learning (SSRL), and co-regulation (CoRL). Self-Regulated Learning (SRL) refers to an individual's ability to proactively manage their cognitive, metacognitive, and motivational resources to attain learning objectives (Zimmerman, 2002). On the other hand, Socially Shared Regulation of

Learning (SSRL) emerges when a group collectively negotiates and directs its cognitive and motivational processes toward shared goals (Hadwin et al., 2017). Co-Regulation (CoRL), bridging SRL and SSRL, describes the phenomenon where learners individually regulate their learning while reciprocally adapting based on input or behaviors from others, including the interactive influences of digital technologies within computer-supported collaborative learning environments (Hadwin et al., 2017). InfuseCS incorporates these modes of regulation into a structured collaboration approach (depicted in Figure 1) in a CSCL environment.

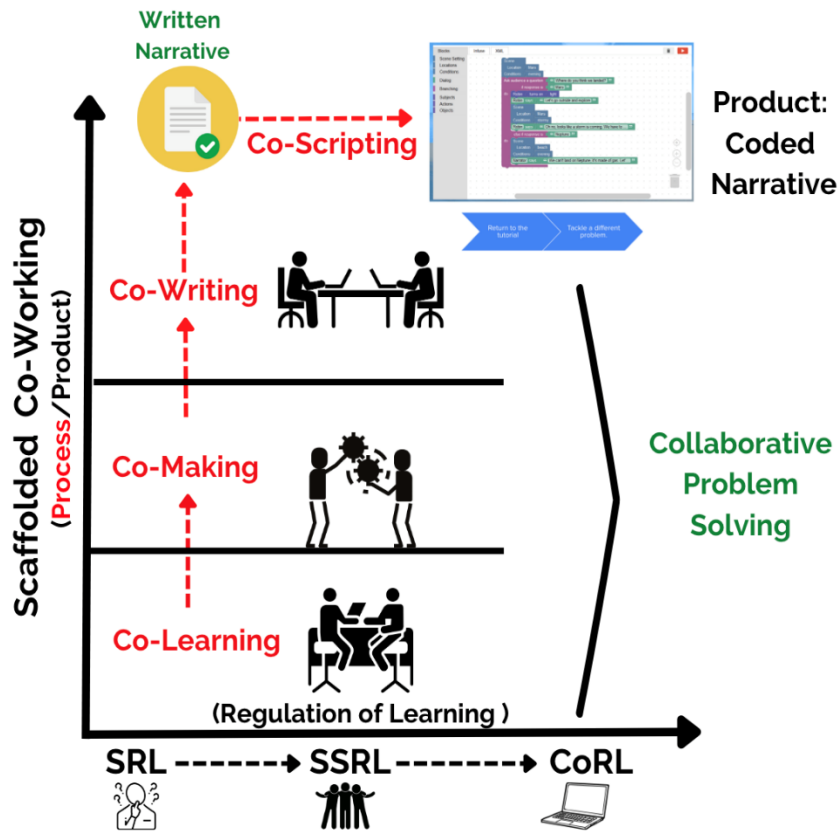


Figure 1: Co-Working scaffold showing the progression of collaborative work and the path from self-regulation of learning to co-regulation of learning.

Pairs of students used their collective prior knowledge to co-construct new knowledge together by aligning their goals, negotiating, and iterating on prototypes and coding solutions. The students engaged in activities that guided their trajectory in using SRL, SSRL, and CoRL to help them achieve their goals, with teachers playing a facilitative role that included coaching, troubleshooting technical issues, and managing materials. SRL behaviors contribute to the emergence of SSRL when the abilities of two or more individuals coalesce, enabling the group to take metacognitive control of tasks together (Hadwin et al., 2017). CoRL is observed as the flexible management of task affordances and constraints that assign acute regulatory ownership to the individuals or the group at different times throughout the problem-solving process (Hadwin et al., 2017).

Data collection procedures encompass both qualitative and quantitative measures. Qualitative data is being amassed through structured classroom observations and interviews. A coding system that allows observers to tag instances of SRL, SSRL, and CoRL is currently being developed. Additionally, focus group discussions with students post-sessions offered insights into their experiences, challenges, and moments of realization. On the quantitative side, the program interface is

equipped with pre and post-test analytics to track student learning improvements in science and computational thinking and changes in their affective states.

3 IMPLICATIONS

The observed and reported experiences with InfuseCS, thus far, have demonstrated the potential of structured collaboration in CSCL environments and the value of integrating problem-based learning scenarios into educational practices. The power of makerspaces and digital fabrication tools in fostering creativity, critical thinking, and collaboration among students was also observed. The use of block-based coding interfaces, digital storytelling, and makerspace activities seem to have a synergistic effect on the engagement of students with complex scientific concepts while also providing a platform for developing valuable 21st-century skills. Furthermore, the iterative nature of the design process encourages a culture of continuous learning and improvement, both critical components of the maker-centered learning community.

By bridging the hands-on activities inherent in makerspaces with digital narrative creation, InfuseCS aligns with constructionism's tenet of learning by making (Resnick et al., 1996). Moreover, the program design adheres to FabLearn principles by emphasizing the convergence of digital and physical mediums for constructing knowledge. For the Constructionism and FabLearn communities, our key takeaway from this experience is the transformative potential of CSCL environments that incorporate hands-on activities. When used effectively, they can provide a supportive space for students to learn, explore, and create together, reinforcing the importance of collaboration and co-regulation in learning processes.

The central lesson for educators is the significant role that hands-on makerspace activities can play in sparking enthusiasm for content learning and collaborative problem-solving, thereby setting the stage for students to be creators of knowledge rather than mere consumers. In aligning with the theme, "Building the Future of Constructionism," our work also looks ahead, considering how we can further innovate and expand upon our foundation in constructionist principles. As we move forward, we plan to continue tinkering with and upgrading this program, seeking to introduce new collaborative challenges and integrate cutting-edge technologies. Our aspiration is to deepen the learning experiences of our students and make constructionist learning more accessible to a broader audience.

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Sock-It-To-Ya: A Call for Collaboration on an Affordable Knitting Machine

Sock-It-To-Ya

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Sock-it-to-ya is a low-cost knitting machine that can be made in makerspaces. There is compelling evidence that e-textiles support student identity and draw from their funds of knowledge in computation. This machine brings the craft of knitting into the e-textile landscape. It combines 3D printer files and market circuit boards to allow students to explore electronic knitting.

Keywords and Phrases: E-Textile, Maker-Space, Computational Knitting, Broadening Participation

1 INTRODUCTION

Efforts to broaden participation in computing have successfully used E-textiles, which incorporate circuit boards and LEDs into student making (Jayathirtha & Kafai, 2020). So far, other forms of textiles, like knitting, have not been as thoroughly explored. Knitting is a highly detailed hand craft that has underpinned society for centuries. Line by line patterns are passed with shorthand notation to tell the knitter when and how to do the next step. Like computers with code, the knitter can follow an exact pattern to replicate instructions and repeat an explicit task; this offers an opportunity to explore knitting as a mechanism to broaden participation in computing. The Sock-it-to-ya, knitting machine offers the craft of knitting as an affordable aid to help students and teachers learn the basics of knitting, electronics, and code.

Textiles and Broadening CS: Previous exploration within the context of textiles and computer science includes the LilyPad which allows users to embed interactive electronic circuits into wearables or other textiles (Buechley, Eisenberg, Catchen, & Crockett, 2008). Buechley et al. also examined the combination of craft and electronics and the differences in the cognitive and philosophical approaches to creating. (Buechley & Perner-Wilson, 2012) While Foth et. al examined ways to engage new audiences in electronic fabrication (Foth et al., 2016). Jayathiratha and Kafai examine how textiles support and broaden access and learning (Jayathirtha & Kafai, 2020). The debugging process has been examined through the constructionist lens of craft (Fields, Kafai, Morales-Navarro, & Walker, 2021). Shaw et. al have explored socio-political identities within CS using quilts (Shaw, Ji, Zhang, & Kafai, 2021). Others have explored the use of physical artifacts to build conceptions of computing and computational making (Litts, Searle, Kafai, & Lewis, 2021; Schulte et al., 2021). Educationally, knitting has been deconstructed as an algorithmic process and has been used to teach people to code (Korbey, n.d.). In Finland, students learn to program with knitting needles ("The Atlantic," n.d.). Bers used Wearables and

identity to examine computation and construction (Bers et al., 2015). Jacobs et al used the principles of computational design to create drawn wearable patterns on clothing with the tool DressCode (Jacobs, Resnick, & Buechley, 2014). Others explored ways to retrofit wearables with interactive electronics (Kaye et al., 2016). Others have found that students entangle identity with creation, particularly with wearables (Jayathirtha and Kafai, 2019; kazemitabaar, 2017). Jayarhirtha and Kafai in particular call for an exploration into cultural funds of knowledge.

Electronic Knitting: The handcraft of knitting has been automated through mechanical knitting machines. People are hacking them to customize the patterns they knit. (“Overview | Electro-Knit | Adafruit Learning System,” n.d.). There are companies like Knityak and Kniterate have developed electronic knitting machines that might be accessible for well-resourced collective spaces with a starting price point is around \$15,000 (Knityak, n.d., kniterate, n.d.). In maker-spaces, people are creating their own electronic knitting machines (makerfaire, n.d.). In the academic arena, researchers are creating pipelines for 3d knitting machines, examining the feasibility of geometry, patterns, and shape, and incorporating interfaces and sensors (McCann et al., 2016, Kitamura et al., 2021, Brewster et al., 2019). We have not yet examined an electronic knitting machine in educational settings. It is a way to tie students’ existing knowledge bases to computer science and may allow them to form strong identities in computing.

2 INTRODUCTION OF THE SOCK-IT-TO-YA KNIT MACHINE

The sock-it-to-ya knitting machine is a small buildable electronic knitting machine which allows students to program to create socks and other tube-shaped wearables like hand warmers and hats. It is made with 3D printed parts and easy to source components and electronics. The pedagogical goals of the sock machine are framed here from the lenses of two major stakeholders: students and teachers. In designing for **students**, it is important that students can write their own code and incorporate their ideas and identities into the item they are knitting. It is also important the machine is clear how and why the sock machine knits, with a pipeline containing as few black boxes as possible. Each step of the process must be obvious and clear. Figure 1 demonstrates the envisioned pipeline. *Plan*: For the first implementation of the knit machine, students will be able to select the color and width of the bands and write corresponding code using a pattern planner. *Code*: Using example code and knowledge of sensors and motors using makecode or circuitpython students will be able to write, remix, and modify code to run the knit machine. *Knitting machine*: Once the code is written, students will download it to the machine and begin the process of knitting. The first step in knitting is the cast on the machine. This establishes the base that the students will knit with. If more than one student is knitting at a time, the students may elect to do a single cast on, and plan for a few rows that can be sewn off and cut *Knitting socks*: Students monitor progress.

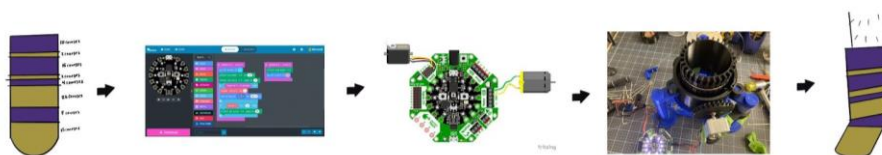


Figure 1: The pipeline for sock-it-to-ya. 1: plan 2: Makecode 3: download to the machine 4: knit the socks 5: wear.

For implementation in educational spaces the **facilitator** must also be considered. In this case we are envisioning in-school middle and high school teachers or makerspace facilitators. Some constraints that may arise are ease of initial build,

financial accessibility, modifiability, clear explanation of why this will benefit students and is worth the investment of time. Design goals include: a clear and straightforward initial build, a machine that is reliable and works with a straightforward debugging process. We envision that older grades (9-12) may be able to build it without too much teacher support. All files (CAD files, printer settings, and code examples) will be open source and well commented so that both novice teachers and novice students feel have scaffolded learning opportunities. The open-source nature of the envisioned knit machine will also allow for the machine to be modifiable. The hope is that future users and classrooms will design ways to use more than two colors, paint beyond rows, create patterns with the stitches, and modify it in other as yet unimagined ways. To meet the design goals, parts must be easy to source, understand, substitute, and replace. The entire build must be financially accessible for a classroom implementation which the designers envision as under 300 dollars.

Physical Implementation: This preliminary machine knits slowly and unreliably with resistance that is too high for the machine to work consistently. We scaled down components to 73% of the exemplar. The housing, gearing system, and hook carrying cylinder were redesigned. A motor mount and switchable feeder were added. All modified .stl parts are available but are considered preliminary prototypes with messy “under the hood” geometries.



Figure 2: From left to right CAD image of needle carrier and housing, sticky needles, modified needles, sock-it-to-ya.

The machine is viable, meaning it will hold a cast on and first round of stitches, but the scale of the machine means that the needles needed to be cut in such a way that they created additional friction, and the motor has high enough torque that the gears wear, slip, and deform. Sock-it-to-ya needs tinkering and love.

3 FUTURE WORK: CALL FOR COLLABORATION, TEACHING, SHARING, AND RESEARCH

Future work for this project includes several physical updates, code prototypes, and curriculum for teachers. The authors are seeking community and collaboration to achieve the following goals:

- A redesign of the housing with better needle guides that create less friction for the knitting process
- An improved motor mount to make it easier to debug or repair the machine
- An Improved gearing system. The current gears are fine but will not sustain long-term use.
- Code prototypes for students with options, explanations, and commenting in multiple languages
- Curriculum support for teachers to use sock-it-to-ya in educational settings
- Research and assessment on Sock-it-to-ya and it’s goals in educational settings

All current files and progress updates are available at <http://jayneeverson.com/#/knit/>.

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K-12 Computer Science Ideals in Context

Lessons Learned from Co-designing a Constructionist Computer Science Program in the Global South

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This paper describes the initial design of a Constructionist computer science (CS) program for middle school. The program follows a interdisciplinary approach and involves collaboration with a municipality in, based on guiding principles from an introductory CS course for secondary school students in another country. As we reflect on how our Constructionist ideals play out when initiating the CS program, we highlight three significant changes made during the program's implementation: maintaining a commitment to co-design, navigating between different programming environments, and encouraging metacognitive reflection. Looking ahead, we anticipate further refinement of the program based on classroom implementation and co-design activities, while also pushing our constructionist ideals further.

Keywords and Phrases: K-12 computer science education, co-design, global south.

1 INTRODUCTION

The call for incorporating computer science (CS) into K-12 education has resonated worldwide, including in the Global South. In Brazil, recent curriculum changes, such as the introduction of K-12 standards for computing, reflect the consensus on the importance of integrating CS into education (Brazil, 2022). These changes have also pushed municipalities and states to design educational programs and policies in CS considering the diverse motivations that drive K-12 CS education (Vogel et al., 2017).

Efforts to integrate computing into K-12 Education traces back to Seymour Papert's pioneering work in the 1970s with the LOGO programming language (Papert, 1970) and gained momentum with the adoption of computational thinking (CT) as a relevant skill across various fields (Wing, 2006). More recent work has pushed CT beyond its initial, largely cognitive framing to emphasize framings which situate CT in learners' lives, and which contribute to productive critiques of power structures into CT (Kafai et al. 2020). Constructionist education principles can help us further advance this work by supporting learners in drawing from their experiences to construct knowledge and then creating opportunities for learners to apply that knowledge in their everyday lives (Proctor et al., 2020).

We have collaborated with a municipality in Brazil to design a program which draws from Constructionist ideals to integrate CS into middle school education. Although preliminary, our work illustrates the ways in which our vision CS Education is being adapted to a new setting. Therefore, this paper aims to address the question: How do our Constructionist ideals play out when initiating a CS program in schools in the Global South? To explore this question, we provide an overview of the initial principles and program design, outline our partnership with the municipality, and share reflections on the changes made during the program's launch and how they align with our constructionist approach.

2 BACKGROUND

2.1 Our principles

This project stems from existing work developing an introductory CS course for secondary school students which drew from Constructionist principles to motivate, design, and implement the course (Proctor et al., 2020). In this project, we identified three themes of Constructionism as design principles for the course : (1) computer cultures, the idea that learning happens through students' participation in computing communities of practice (Kafai, 2016); (2) material intelligence, a high value placed on using “real tools” in the course that would allow students to interface with CS communities of practice beyond just CS learning environments (diSessa, 2001); and (3) liberatory pedagogy, a commitment to learning as a radical political act which can allow learners to critique and challenge oppressive power structures (Blikstein, 2008).

Extending our existing work into a new context in Brazil involved a few changes. Previously, the course had been developed for and implemented with grade 9 and 10 students as a two-year, intensive survey course of CS principles and practices. In that context, the teaching, development, and research team were fully integrated such that the full team was operating at the classroom level, contributing to both high-level decisions about the principles of the course and low-level decisions about how to facilitate classes. In the Brazilian context, we are instead developing materials for middle school learners and our team is working at the teacher level but is not involved in the day-to-day operations of classes. These shifts have motivated changes to the program which emphasizes (1) a modular curriculum which allows teachers to choose elements of the curriculum to implement in their classes (rather than doing the full curriculum) and (2) a multidisciplinary approach to CS education which helps teachers without a background in CS teach the subject by drawing connections between computational thinking and teachers' existing disciplinary training. To develop the broad, multidisciplinary expertise required for this program, we committed to co-design it by drawing both on our expertise from past experiences and on the expertise of the teachers who would implement this program (Coburn & Penuel, 2016).

2.2 Our approach

Building on our principles, our approach for a Constructionist CS program in middle school encompasses three key stages throughout an academic semester:

1. Teacher participation in an introductory CS curriculum unit (mid-March to mid-May), not integrated with any other specific subject area, to foster familiarity with computational ideas and practices.
2. Teacher implementation of the introductory unit within a classroom setting, involving at least one middle school class (mid-May to mid-June), to reinforce the teachers' grasp of computational concepts and practices from stage 1, while broadening their repertoire for effectively integrating computing into their respective subject areas.
3. Co-design of a new unit integrating CS principles into a specific topic within teachers' subject areas (mid-May to end of June). This stage aims to deepen teachers' understanding of computational concepts and practices in a familiar context, demonstrating how computing can be applied across different subjects in middle school education.

3 CONTEXT

The program was developed in collaboration with the Department of Education of a mid-size city in Brazil. Despite the city's below-national-average Human Development Index, it has achieved high scores in national exams for Language Arts and Math in primary education. The authors' affiliated research group has a history of collaborating with the Department of Education on science curriculum redesign (Hochgreb-Haegele et al., 2022). The program started with an interdisciplinary approach, focusing on mandatory K-12 Humanities subjects (History and Geography) in Brazil. This was chosen due to the lack of digital technology initiatives in these areas and the availability of teachers. For the first iteration of the program, we had a group of six teachers with no CS background: two schools designated one history teacher and one geography teacher, each, together with the redesign teachers, who are responsible for integrating resources in the schools' maker spaces into different subjects. Nine synchronous online meetings were held from March to June, each lasting two hours. At the time of writing, six meetings were facilitated by two authors, transitioning from experiencing the introductory unit (1) to implementing it (2). Co-design activities (3) are scheduled to begin in approximately two weeks. Meanwhile, the first three authors hold weekly meetings to plan actions and adjust program materials. For this study, we reviewed notes from authors' weekly meetings to track program changes that were discussed and implemented.

4 WHAT WE HAVE LEARNED SO FAR

Below, we provide an in-depth description of three selected changes that illustrate dilemmas encountered while implementing the program and reflect on how these changes align with the previously outlined guiding principles.

4.1 Maintaining a commitment to co-design

As we began implementing stage one of this project, we realized that experiencing the introductory unit could easily take more time than we originally planned. However, extending this stage would have meant that teachers would have little to no time to engage in the co-design process of a new unit integrated with their area of expertise. Despite our early inclinations to slow down and spend more time on the introductory unit, we decided to maintain our commitment to the co-design stage. This decision was informed by our Constructionist principles as we hoped that reaching the co-design process would give teachers another chance to explore foundational CS ideas by trying to identify the computational features of a discipline with which they were already experienced. As we now approach the co-design sessions, early signs are validating this hope. As the introductory unit progressed, teachers began sharing ideas for the upcoming co-design sessions, organically connecting between the foundational CS ideas they were exploring and their own areas of expertise.

4.2 Navigating between different programming environments

Navigating different programming environments presented challenges and opportunities. Initially, we planned to use the web-based IPython notebooks tool, Colab, to familiarize participants with real-world CS technologies. Yet, teachers faced language barriers and technical hurdles. We provided codebooks in the local language, but even basic terms from the programming language in English were challenging. In addition, not being able to open the Colab notebooks with institutional accounts also raised concerns about using it in the classroom. Given these challenges, we considered transitioning to Scratch, a widely used tool in K-12 settings. However, this conflicted with our goal of using real-world tools and raised concerns about diluting key ideas, given the tool's aesthetics elements. Still, teachers gave positive feedback, expressing empowerment and enjoyment using Scratch. Furthermore, we were able to preserve core CS concepts during the shift from Colab to Scratch, balancing Scratch's unique benefits while prioritizing educational goals.

4.3 Encouraging metacognitive reflection on learning CS and learning to teach CS

Since we aimed to support teachers without a CS background in teaching CS, we designed the program to start with them experiencing the introductory unit as students. In addition to helping teachers develop fluency in foundational CS ideas, this approach enabled metacognitive reflections on what it is like to learn CS (Yadav et al., 2017). As teachers engaged with the intro unit, we found that this metacognitive reflection was getting lost in teachers' focus on the foundational CS ideas explored in the unit. To refocus on teachers' pedagogical content knowledge (PCK) in CS teaching, we regularly employed thinking routines, allowing teachers to reflect on their experiences as educators (Project Zero, 2023). This allowed us to discuss components of CS PCK organically, but these conversations are still limited. Regardless, this finding prompts us to reconsider how we aid teachers in learning CS PCK, with plans to amplify this aspect in future iterations.

5 LOOKING FORWARD

Teachers' insights strongly influenced our decision-making process. Changes based on their feedback led us to reflect, for instance, on our ideal of working with professional programming tools. Similarly, teachers' interest in integrating CS into their subjects supports our idea that linking CS with familiar disciplinary ideas are a valuable resource to create interdisciplinary computer cultures. As we prepare for classroom implementation, this stage will let us review and improve previous changes. Co-designing new activities with teachers will also deepen our understanding of CS concepts' clarity and relevance in their settings. We expect the next steps of the program will inform what aspects what to keep and adjust in line with constructionist ideals, pushing our constructionist ideals further as we learn from K-12 educators and students.

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Write Your First Song: An Interactive Interface for Music Novices to Express Music Ideas

Songwriting fosters personal and cultural connections while addressing the social and psychological needs of adolescents. However, the abstract and symbolic nature of music theory often intimidates novices seeking self-expression through music writing. To overcome these barriers, we introduce “Write Your First Song,” a web-based interactive platform that enables novices to learn music theory using experiential learning and keyboard-based tasks. By avoiding conventional notation, the platform integrates storytelling and ratio concepts to facilitate music composition for beginners. Ideal for educators and self-paced learning, our design underwent preliminary user studies with 12 music beginners, providing valuable insights into the effectiveness of interactive interfaces for creative practice.

Keywords and Phrases: Constructionist music education, Music composing technology, User-centered design

1 INTRODUCTION

Songwriting connects young people with their personal and cultural understanding, addressing social and psychological needs during adolescence. By providing an expressive outlet, songwriting equips students with a lifelong musical skill, promoting active engagement with music even after leaving school [1]. However, music theory, despite offering self-expression, can often become abstract and disconnected from the joy and creativity for beginners [2]. Traditional education methods, which focus on musical details such as basic notation, may result in monotony and low efficiency [3]. Employing a constructionist approach can address this issue by reversing the roles of theory and practice in music education, enabling students to create music through firsthand experiences rather than relying on the memorization of prescriptive rules [4].

“Write Your First Song”¹ is a web-based interactive platform that provides a self-paced learning journey for young students to write their first song. Through a progressive sequence of activities, students begin with foundational skills and gradually advance to create their own songs. By avoiding conventional notation, “Write Your First Song” incorporates story writing and the concept of ratio to support novices in music composition. Preliminary user feedback collected from 12 graduate students who had limited music writing experience showed that novices could effectively grasp music theory and writing while increasing their interest and confidence in songwriting.

2 BACKGROUND

Traditional methods of teaching basic musicianship often overlook the innate musical intuition that novices have. However, research has shown that individuals possess a strong harmonic sensitivity from an early age, enabling them to recognize tonal functions and chord qualities [5]. People often possess more knowledge than they are able to explicitly express demonstrated through their construction and reflection on music compositions [6].

Music educators and researchers have advocated for alternative teaching methods in music theory, emphasizing constructionism and experiential learning. Students learn basic principles of music writing through direct experience, rather than prescriptive rules and systematized knowledge associated with the grammar of music [4]. The focus is on designing experiences and tools that foster musical thinking and doing [7]. Prominent music educators like Kodaly, Orff, and

¹ The platform is accessible at: <https://x13197.wixsite.com/writeyourfirstsong>

Dalcroze believe that musical utterance expression precedes music reading and writing. Similarly, Swanwick argued for fluency before literacy in music education [8].

Several attempts have been made to apply this constructionist teaching method through technology. A variety of educational music interfaces present non-notation-based approaches to composition by integrating music creation with programming, as exemplified by platforms like Sonic Pi and Manhattan [9]. Among solutions that focus solely on music composition, Impromptu and Hyperscore stand out as notable examples. Impromptu enables users to manipulate tunes using “Tuneblocks”—virtual blocks encompassing melody and rhythm portions—thereby fostering understanding of key musical concepts such as form, melody, pitch, rhythm, and structure. Conventional notation is de-emphasized and introduced only after initial units [10]. Hyperscore is a computer-assisted composition system designed for individuals with limited or no musical training. It uses freehand drawing as input, allowing users to visually sketch their pieces. Unlike composition systems that display musical events in procedural notation or parameters, Hyperscore offers a visual analogue for music structure. The underlying premise is that anyone, regardless of musical training, can compose short melodies and outline the large-scale structure of a piece [11]. These methods encourage the development of music-writing skills with an emphasis on music as a creative art rather than a regulatory discipline [4].

3 DESIGN

The current iteration of this interactive design is based on the findings reported in the literature above, on user testing with graduate students, and on feedback from supporting faculty. Three main design decisions are delineated below:

- **Enable playing and writing music with minimal music theory and formal instrument knowledge:** The platform features a virtual piano and a qwerty-based music notation system. Users press corresponding keys on their keyboard to play and record notes and chords on the virtual piano and can manipulate these using their mouse and keyboard. Conventional notation is replaced with keyboard key names, making it easy for anyone to start playing and composing music without learning sheet music. This prioritizes expressiveness and fluency over literacy.

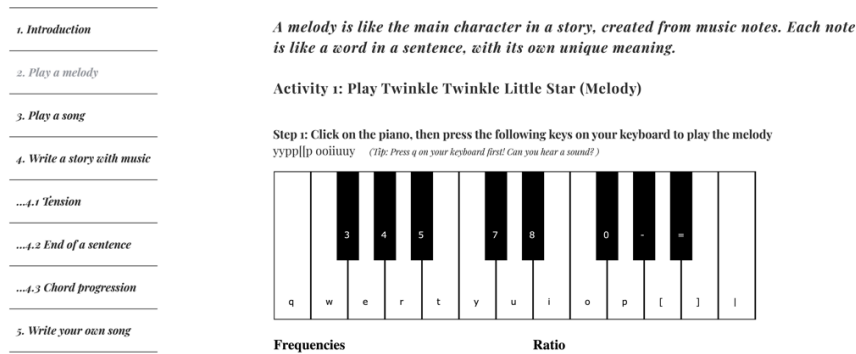


Figure 1: Selected screen of the prototype (Virtual piano shown to the learner)

- **Encourage expression of mood and storytelling through music:** The platform prompts students to describe their mood and explore note combinations that express their feelings. This approach respects students’ individuality, fosters expressiveness, and demonstrates music’s unique power to convey emotions.
- **Utilize high interactivity and data visualization for better understanding:** Students engage in drag-and-drop activities to compare different options and learn about notes, chords, and cadences, with immediate feedback on their answers. The interface also displays frequency ratios between notes as users play the virtual piano. Simple,

small-integer frequency ratios have been considered consonant and pleasant, while those with complex, large-integer ratios have been perceived as dissonant and unpleasant [12]. This visualization helps learners grasp the relationship between musical intervals and their stability or instability.

Activity: Tell your story through a sequence of chords

Step 1: Write down your moods

Mood 1 : Mood 3 :

Mood 2 : Mood 4 :

(eluc)(yip) (eluc)(eluo) (eluc)(ryl) (ryo)(eyl)

Step 2: Drag the above option blocks to one of the areas below. If this is the end of a song, how does it feel?

I feel it ends with a full stop.

I feel it ends with a question mark.

I feel it ends with an ellipsis.

Figure 2 and 3: Selected screens of the prototype (Left: Inputting moods activity; Right: Drag and drop activity)

“Write Your First Song” is a web-based platform consisting of a series of webpages, each containing an activity. Although the activities are designed to be completed sequentially, learners have the flexibility to access and choose the activities they prefer. Table 1 presents the main activities, learner actions, and expected learning outcomes for each.

- Table 1: Distribution of learner action and expected learning outcome across activities.

	Activity	Learner action	Expected learning outcome
1	Play a melody	Use a virtual piano to play and record “Twinkle Twinkle Little Star” and perform a drag-and-drop activity about pitch and frequency.	Learn note-frequency correspondence and gain confidence in playing a virtual keyboard.
2	Play a song	Play chords, accompany the recorded melody, and record both parts simultaneously.	Grasp harmony, chord playing, and the three-note minimum in chords.
3	Write a story with music		
3.1	Tension	Participate in a drag-and-drop activity studying the link between tension and frequency ratio.	Recognize how frequency ratios influence sound, creating consonance or dissonance.
3.2	End of a sentence	Engage in a drag-and-drop task examining the interplay among tension, resolution, and cadence.	Understand tension, resolution in musical phrases, and the link between music and story writing.
3.3	Chord progression	Identify four moods, explore corresponding chords, and create a looping chord progression.	Express emotions through chords and comprehend chord progressions.
4	Write your own song	Play, record a chord progression, and improvise over the chord loop.	Construct a basic song with melody and harmony.

Preliminary user feedback

The co-design process of “Writing Your First Song” involved continuous testing during its development, with preliminary user feedback collected from a sample of 12 graduate students. While this sample does not represent the target population for the final product, the gathered data provided valuable insights for an initial evaluation of the usability design.

Users found the introduction to the concept of frequency ratios illuminating, as it unveiled the inherent relationship between mathematics and sound. They expressed surprise and appreciation for understanding the mathematical explanation behind musical concepts of consonance and dissonance.

The drag-and-drop activities were a highlight for many participants. Upon encountering these elements, most users quickly became absorbed in finding the solutions, displaying a high level of focus and proactive behavior. To find solutions,

users engaged enthusiastically with the virtual piano, actively exploring to understand sound effects, which further deepened their grasp of frequency ratios and musical tension.

The process of inputting moods and crafting corresponding chords was another enriching experience for users. Regardless of their musical proficiency, they could manipulate consonance and dissonance to represent varying moods. The realization that crafting music bears similarity to constructing a narrative, complete with tension and resolution, was an appealing analogy for users.

Additional design features contributed to a comprehensive learning experience. The use of familiar songs as teaching tools for musical structure, and the ability for users to record their creations, boosted both interest and confidence in music writing. Following the experience, a notable increase in user confidence and interest in music writing was observed.

4 FUTURE DESIGN DIRECTIONS AND CONCLUSION

The study revealed that “Write Your First Song” successfully stimulates learners’ interest in basic music theory and composition. However, certain challenges require iterative design improvements: (1) scaffolding for constructing chords and chord progressions is insufficient, as very few users managed to complete a full song; (2) the interface lacks a social aspect where users can share their creations and learn from their peers. Further efforts are needed to provide meaningful scaffolding and social elements to support users in composing complete songs and using music as a medium for expression and communication.

This paper presents “Write Your First Song,” a self-paced Interactive experience for young students to compose their first song. By avoiding conventional notation, the platform integrates story writing and the concept of ratio to aid novices in music composition. “Write Your First Song” has the potential to be used by music educators and parents for introducing novices to music composition, as well as assisting music enthusiasts in learning music theory.

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CYBATHLON @school scale up inclusion – towards a new low cost, high scale STEM module approach

CYBATHLON @school scale up inclusion

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This WIP Paper presents the CYBATHLON @school STEM initiative which aims to foster inclusion and accessibility topics among pupils of all age groups by combining them with Engineering and STEM topics. The project trains (predominantly female) Engineering students to conduct courses in schools while acting as role models to the pupils. Many modules build on the educational exoskeleton Flexo which allows for new experiences and is well accepted. However due to being a complex system, the workshops are expensive to conduct, maintain and do not scale well. This paper identifies important obstacles and presents ideas on how to complement the project with a new module which scales better and adapts to certain needs of schools while preserving the positive aspects of the project.

Keywords and Phrases: Inclusion, STEM, Maker-Education, K-12

1 INTRODUCTION

CYBATHLON (cybathlon.com), a non-profit project of ETH Zurich, acts as a platform that challenges teams from all over the world to develop assistive technologies suitable for everyday use with and for people with disabilities. The driving force behind CYBATHLON is international competitions and events, in which teams consisting of technology developers from universities, companies or NGOs and a person with disabilities tackle various everyday tasks with their latest assistive technologies. The participants with physical disabilities show how to tie shoelaces with a robotic arm prosthesis, balance on rocks with a prosthetic leg or overcome uneven terrain with an exoskeleton. The projects school branch, CYBATHLON @school seeks to make teachers and pupils more aware of the everyday challenges faced by those with disabilities while at the same time foster interest in STEM subjects. The references to daily life, practical applications and an in-depth look at modern technologies inspire and make STEM in society tangible and comprehensible. This is an important factor to specifically address girls as they tend to be more attracted to STEM if meaningful tasks and storytelling are used instead of a purely technical approach (Pinkard et al., 2017).

2 CYBATHLON @SCHOOL MODULES

CYBATHLON @school modules are offered in various STEM subjects, as well as other fields, such as sports or ethics. The modules are aligned with Lehrplan 21, the competence-based K-12 curriculum of the German-speaking parts of Switzerland (lehrplan.ch) and there are modules for pupils from later primary classes up to tertiary level. Following a holistic constructionist approach, pupils usually work in teams and co-construct ideas and solutions iteratively, to be able

to learn from mistakes (Downey et al., 2022). This makes the approach compatible with the growing Maker culture in Swiss public schools (Maurer, 2021).

Engineering students of ETH Zurich (Coaches) conduct the program in the schools. The fact, that there is a high percentage of female students among the Coaches group (CYBATHLON Coaches: 65% female, ETH student body: 33% female) helps to promote female engineering role models in the classroom. Female role models are seen as an important factor to inspire female pupils to consider STEM studies (Gladstone & Cimpian, 2021; Happe et al., 2021; Spieler, 2023). Individuals with a disability (Ambassadors) help to develop the modules and play an active role in presenting them at school. One of many benefits of this system is, that the pupils can directly discuss questions about studying engineering or living with a disability with Coaches and Ambassadors.



Figure 1: 1a: Sports Module, 1b: Ambassadors, 1c: Mind-Up

2.1 Current Product development module

The product development module is the most complex but also most rewarding module. It features an educational exoskeleton “Flexo” which can be worn, programed and extended by students. Module and hardware have been presented in detail by Schifferle and Kollegger (2021). Students will assess a given situation (e.g. preparing breakfast) from another viewpoint (e.g. from a person with only one hand). They then develop and produce prototypes of grippers which are designed so that they can solve all defined tasks as best as possible. Starting with pen and paper, they have access to a laser cutter as well to 3D printing. At the end, a competition alike the original CYBATHLON (cybathlon.ethz.ch/en/events/edition/cybathlon-2024) is held where everyday tasks must be solved. The module can be combined with Sports module and Ambassador discussion up to a full two-day workshop or even more by adding other modules as well (Figure 2). Those combinations allow for a wholistic approach as they include many senses and a variety of tasks touching inclusion and STEM from multiple viewpoints. While Feedback from students as well as teachers and Coaches is largely positive, there are aspects which hinder a broader distribution. The most important issues concerning scalability were defined using observation, feedback forms and oral feedback from pupils, Coaches and teachers. They will be addressed in the following. For each main part, the problem will be outlined as well as a deduced requirement to solve it will be presented.

2.2 Main challenges concerning scalability

Hardware: Being completely developed inhouse, the Flexo exoskeleton has grown historically and uses a mix of off-the-shelve components as well as custom ones. The core features a NI myRio development board, custom battery, expensive servo motors and a lot of proprietary connections which are soldered inhouse by students. Casing and arm are HP MJF 3D-printed and dyed manually. Reproducing and maintaining the kits is expensive in terms of resources and production time. The final set consists of one Flexo including battery and gripper add-on, a laptop with power supply and cords. As pupils should be able to actively work, one set per pair usually requires at least 12 units per workshop.

Requirement: The platform should consist of affordable and broadly available off-the-shelf components. If self-produced, it must be so with little manual effort and broadly available technology.

Scope: While the general topic of the workshops would even be suitable for later primary school pupils (10 yrs.), the programming part is not. The exoskeleton can be programmed in Python using a rather limited proprietary interface. Although there are tutorials built in, the learning curve is very steep if pupils are not familiar with python or other text-based languages. This unnecessarily restricts the scope of the module to older students.

Requirement: There should be a track for beginner and intermediate programmers and the platform should be supportive.

Staff: While having students as Coaches and Ambassadors in class is beneficial in many ways, it drives costs and complexity up. This is a huge inhibitory factor concerning scalability.

Requirement: Options to reduce or substitute staff while maintaining quality should be assessed.



Figure 2: 2a: Flexo exoskeleton with gripper, 2b: Laser cutting, 2c: Gripper light prototype

3 MORE SCALABLE APPROACH

Answering the beforementioned aspects, we decided to start development of a more scalable version of the module while preserving the positive aspects as good as possible. Development is still at an early stage and will be done iteratively in multiple cycles including testing with students.

The first change was to extend the modular approach. The module was split into two parts. The first part is designed to be conducted by the teachers themselves while the second part will be done by Coaches. Both parts are self-contained and the first one only requires materials readily available in classrooms. This allows for more flexible planning and because no Coaches or special material is needed, it will scale well. A benefit of the splitting into two parts is that students will get multiple exposures to the topics which is potentially beneficial compared to only one. The first part will be supported by videos from Ambassadors and has a stronger focus on equality while the second part will be more focused on STEM.

To reduce hardware complexity, the exoskeleton will no longer be used. There will be a handpiece which serves as handle and contains the electronics including a servo to which different gripper-clamps can be attached. That 3D printed handpiece (standard low-cost FDM print) will host a BBC micro:bit (microbit.org), battery pack, servo shield and a microservo to operate the gripper (Figure 2c). The total cost of one unit comes down from several thousand US Dollars to around 40\$ per kit. The servo shield could be omitted as well but it allows for future additions as well. Different sensors, e.g. EMG-muscle sensors, buttons or self-made switches can be used to steer the gripper.

Using micro:bit as base technology has multiple benefits. It's sturdy, inexpensive, available worldwide and known to many teachers. It allows to be programmed block based with Makecode or by text using the Python language. Makecode is

suitable for usage with students around the age of 10. Due to the much smaller size of the new kit, the transport volume can be reduced significantly. As many schools own micro:bits or are familiar with using them, this would open the possibility of rolling out an even lighter module by focusing only on teaching materials. These could be downloaded by teachers or shipped with rental kits. Having the module conducted by teachers on their own would scale easily but would omit the role model aspect of the teachers. Still, it could provide interested teachers with a valuable module in terms of inclusion and STEM. Laser cutting could be replaced by using cardboard and knives. This, however, would drastically change the focus of the module as the rapid prototyping using modern technologies is an important aspect. Even if Coaches and laser cutting remain the same as in the old module, switching to the smaller kit would provide cost reductions due to less material, easier handling and better maintenance.

4 CONCLUSION AND FUTURE WORK

It seems that optimization of the module is doable and that many aspects can be made more scalable while preserving the overall style. One risk by optimizing them is that the modules could possibly become too mainstream so they lose the character they have now. Careful testing will reveal if the new module works on its own as well or in combination with others. The prospect of reaching lesser gifted socioeconomic schools and motivate their pupils to think about inclusion and maybe even a career in STEM is well worth the risk.

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“Are you doing anything I can interrupt right now?” Using Social Wearables to Support Communication in Remote Work Environments

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The recent shift to remote work and learning has people in the same household co-working and living, each with personal schedules, meetings, classes, and nuanced habits. These new social dynamics necessitate clear and effective communication between members of a household, which can be challenging. We designed and built a “supple” wearable using commercially available DIY hardware to aid in navigating the complexities of social interactions in a work-from-home environment. We conducted a modified autoethnographic study in which two couples used the device over a week. In this paper, we discuss our iterative co-design of the device and the supple design requirements we used, and present results of the preliminary autoethnographic study. Researchers used the proof-of-concept devices for communication, customized how they wore them and details of the device function, and made use of them for personal management and reflection as well as communication.

Keywords and Phrases: DIY, social wearables, autoethnographic, awareness systems, research through design

1 INTRODUCTION

The emergence of the COVID-19 global pandemic solidified options for remote work and learning as here to stay for the foreseeable future. However, it is difficult to maintain a private workspace free from unwanted interruptions, as well as maintain spatial and social boundaries with others in the household—the lack of which might negatively impact relationships. Employing technology as a method to aid in communication may help keep communication breakdowns from occurring or give opportunity to add nuanced social cues to interactions amongst friends, family, or those who cohabitate (Dai et al 2020). Flexible, ‘do-it-yourself’ (DIY), or ‘maker’ devices (e.g. Raspberry Pi¹, Arduino², Micro:Bit³) have become increasingly prevalent in recent years, as an accessible way for non-experts in the technology field to get a taste of designing and creating, or ‘making’. Social wearables are technology designed to be worn on the body that augment various types of interactions; either co-located or virtual (Dagan et. al 2019). While much research has been

¹ <https://www.raspberrypi.com/>

² <https://www.arduino.cc/>

³ <https://microbit.org/>

focused on virtual social wearables (e.g., with tracking devices like the Fitbit that connect people through a network) (Wang et al 2016), in recent years there has been research focused on co-located wearables as well (Dagan et al 2019). In this paper, we discuss designing a "supple" wearable device, inspired by the supple interface design concept focused on the dynamics that emerge from the subtleties of a design (Isbister and Hook 2007), and a preliminary user test with the device 'in the wild'. Using a modification of the autoethnographic research method (Wall 2006), we integrated the system into 4 experienced researchers' daily routines to understand the value of the device and ways it was used in everyday communication. **To conduct the autoethnography, we took on dual roles as researcher-participants. Through observations and self-reflection on our actions, along with those of our colleagues, we were able to understand how the device might fit into existing routines or form new rituals and practices among users.** Our goal was to explore how using DIY technology to build technological interventions can be useful and effective at supporting communication of nuanced social signals and enhancing the social and emotional connections between individuals working in a home environment. We used research through design (RtD) practices to aid in the design of this communication intervention for the home co-work setting (Zimmerman et al 2007). After multiple iterative co-design work sessions, we created an exploratory proof of concept that we call SCARF (Social Communication: Affords Real Fashion), which is a social wearable using the BBC Micro:Bit (Rogers et al 2017) as a base with an attached NeoPixel LED Dots⁴ strand that lights up in a specific color to indicate the user's current state. We wanted our proof-of-concept device to not only support clearly signaling state, but also take into account nuanced interactions that might occur between people in the home, and how this might affect the dynamics of their relationships.

2 SYSTEM DESIGN



Figure 1: Storyboard of two-person interaction with device. User A is in the ASK state, user B sends ping to User A. User A receives ping, sends reply to user B indicating they are free. User B receives notification User A is free through scrolling text on screen.

The SCARF system involves two users, and a pair of custom devices which can be worn or placed on or near the users' workspaces throughout the day. These devices allow each user to toggle between three different pre-specified LED colors to indicate different activity 'states', as well as use the buttons on their own device to ping the other person's device to know the state of the corresponding device. The FREE state indicates that the user has no issue with being interrupted and pulled into conversation. The BUSY state indicates that the person is focused on some task and unavailable for conversation. In these two states, if the device in question is pinged, it automatically replies to the pinging device with a FREE or BUSY status-which puts scrolling text across the screen of the Micro:Bit (see Figure 1). The ASK state is used when a person's availability is likely to fluctuate, and a ping prompts the user in question to press one of two buttons to respond FREE or BUSY. While the original intended form factor was a scarf, it was also intended to be able to be worn in other ways that the user found comfortable.

⁴ <https://www.adafruit.com/product/3631>

3 PRELIMINARY FINDINGS AND DISCUSSION

To understand the potential value of a system like SCARF, we wanted to integrate our prototype into a real-world context. As this was an example of supple design, much of its user experience would emerge through engagement over time within a social context, so we explored how it would fit into the work-from-home setting. We chose to conduct a small autoethnographic case study in which we as the research team explored and documented the experience of the prototypes. Two cohabiting couples (four researchers total) used the scarf in their home for one work week (five days). During this period of time, researchers noted four themes of interest that emerged: how the primary use case was incorporated into day-to-day interactions, how the simple and general design allowed for emergent dynamics to surface beyond the initial intended use case, and how the DIY nature of the design allowed for rapid iteration of the functionality to address design gaps. A final theme is how the reflective nature of the study environment fed back into the experience of using the design.

Table 1: Each individual researcher’s meaning making with the SCARF device

	Researcher 1	Researcher 2	Researcher 3	Researcher 4
Definition of FREE	No urgent work, free for communication or leisure	Not trying to be productive; Able to be interrupted	Asking to be interrupted	Doing a task but can be interrupted
Use of FREE	Napped, watched TV, read	YouTube videos or Reddit	Work is open and "should" be working, actually social media	Napping, watching tv
Definition of ASK	Doing non-urgent work; can be interrupted	Self-directed work; available for shorter interactions	Asking to be interrupted, but working productively	Busy with task but can be interrupted for short discussion
Use of ASK	Answering emails, preparing for meetings	Reading papers; coding	Slowly working, writing emails	Reading, thinking, quiet contemplation
Definition of BUSY	Meetings or urgent work	Unavailable for any interaction	Working productively	Concentrated on a task and no interruptions unless emergency
Use of BUSY	In meeting, teaching	Almost exclusively meetings; timed deadline	Meetings, writing, focused work	Focused reading, writing, emails

Theme 1: Successful primary use case. The device served to amplify subtle social signals in a way that affected the behavior of both the sender and the recipient of those signals. During a conversation between two researchers, one found they needed to get back to work, and mid-conversation slowly held up the scarf and set the state to BUSY, as a playful way to signal the need to transition from social to work. Rather than being intrusive or insistent, the scarf provided a softer method of communicating that a person needed to get back to work. Table 1 describes the emergent dynamics of the device, operationalized in terms of personal definitions of the states of each participant, as well as their regular use cases for each state over the course of the week.

Theme 2: Emergent dynamics of the original design. The flexibility afforded by the device (enabled through having the relatively simple and general signaling system of colored LEDs) allowed one researcher to use the device for other reasons besides communication in the home. They used it as a conversation starter during Zoom meetings, during walks at night to appear more visible to cars, and additionally wore the scarf to stay warm. The use of the system served to formalize how the pairs spent their time. During a time when work and home blurred almost completely, distractions were very prevalent during the deployment. The system helped to externalize individual goals and served as a mental touchstone for choosing how to spend one’s time. Making the intent to work an ongoing public signal improved the researcher’s focus and ability to stay on task. The suppleness of the design allowed for these emergent behaviors of fashion and utility to arise from the device without the need for modification or further development. Suppleness added an element of agility to finding new uses that could be incorporated into a user’s workflow.

Theme 3: Hardware modification to address design gap. In cases where the existing design could not easily be adapted, the DIY nature allowed for rapid iteration to address design gaps identified throughout the week. While all researchers were clear that the system had only three states, their internal definitions for what those states meant to themselves were not fully resolved, and over the course of the week, they developed in ways that led to unexpected use cases. The hardware had additional input and output capabilities built in that afforded us greater flexibility than if we took a more stripped-down approach. The initial design did not make use of a motion sensor—however, as it was available on the Micro:Bit, it was used in a modification made to one of the devices midway through the week to trigger a ‘signal check’ function. This modification addressed the initial lack of feedback in the ping function, allowing researchers to confirm that they were in signal range and their ping was received. Using DIY hardware designed to be used for a variety of maker projects gave us the option to add additional functions as the need arose during the study.

Theme 4: Element of the case study that supplemented the experience of using the device. The nightly debrief sessions allowed for interaction breakdowns to be identified and addressed, rather than allowing them to persist throughout the deployment. The fact that this system was being used in the context of an autoethnographic study placed a greater emphasis on reflection, and justified the creation of a time for communication at the end of the day for the pairs to discuss how they interpreted the different signals from the other. Using the system required researchers to articulate their feelings about specific acts or signals from the other researchers, thus improving their communication.

4 CONCLUSION

While the system as initially designed was valuable from a communication standpoint of establishing boundaries while working from home, its supple nature also allowed researchers to adapt the system to a variety of personal idiosyncrasies. This led to new reflective use cases for researchers, such as reinforcing focus and better delineating work and personal time, which were not part of the original primary functions. The DIY approach to design and development helped ensure adaptability and flexibility. Creating the device was just an initial step-- it was through use and interactions that its place in researchers’ lives was established. We suggest using such technology for future projects, as it is a cheap and efficient way to rapidly prototype designs for unexpected areas of use, such as the sudden shift to ‘work-from-home’ in 2020. Using an autoethnography method with a small expert group allowed for rich insight into moment-to-moment interactions and helped to promote iteration on the social structures and meanings that we added on to the base use of the device.

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Conductive Chemistry Learning: Critical technological explorations for early childhood

Conductive Chemistry Learning

Work in progress toward the development of a conductive chemistry kit

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Early exposure to creative contexts to develop critical technological skills is a major contributor to transforming participation in STEM. Yet, in early childhood settings, critical technological design and advanced science content is nearly missing. Here, we discuss an ongoing research and design that investigates intergenerational practices and materials related to electricity and circuits and leverages them toward the design of a novel age-appropriate Conductive Chemistry kit. This kit will support children (age 3-6) and caring adults to learn the underlying chemistry of circuits and to critically explore technology by asking what electronics are made of, how they are made, what circuits are for, and who can create them. We merge the constructionist idea that learning happens best when people design personally meaningful projects with socio-material approaches to learning that materials associated with underrepresented groups can transform participation. The project will advance a scalable kit and knowledge about critical technology practices and advanced science learning in early childhood with implications for transforming early childhood education and chemistry education at large.

Keywords and Phrases: circuitry, chemistry, early childhood, intergenerational learning

1 INTRODUCTION

In early childhood settings, technological inquiry into basic scientific concepts, such as the chemistry of electricity, is nearly missing. Although some early childhood research investigated computational thinking, robotics, and circuitry within early childhood settings (e.g., Bers et al., 2014; Bati, 2022; Wohlwend, et al., 2017), most research overlooked the social, cultural, and material practices of very young children (age 3 to 6) that encourage and resist active, critical, and creative engagement with underlying chemistry ideas that can foster technology innovation. Yet, with science and technology evolving more rapidly today than ever before, future generations will need to be increasingly critical and savvy in the ways they engage with and create new technology and scientific knowledge (Lee & Soep, 2016). In fact, early exposure to creative contexts to develop critical technological skills and conceptual knowledge in electronics has potential to transform how learners expect their lifetime participation in STEM to unfold (Peppler et al., 2023; Keune et al., 2019). This project

also answers calls for more research on young children's scientific learning and practices, especially within family contexts (Andrews & Wang, 2017), as caring adults play an important role in young children's technology engagement, especially in early technology literacy (Yu, DeVore, & Roque, 2021).

In this project, we innovate a novel age-appropriate Conductive Chemistry kit to support young children (age 3-6) to critically explore technology and to ask what electronics are made of, how they are made, what one can use circuits for, and who can create with them and when. This project focuses on circuitry as an important prerequisite to critical engagement with energy, computing, and other necessary technological skills (Tasker & Osborne, 1985), as well as chemistry as a key driver of technology innovation in material sciences, such as solutions for enhancing energy efficiency for organic photovoltaic technology (e.g., Albert et al., 2014). We are currently further developing the kit and research of the learning processes that emerge through child-adult family pairs interacting with the kit.

2 THE CONDUCTIVE CHEMISTRY KIT

To study how young children can engage in critical technology making and learn metallic and ionic circuitry, this research builds on and extends a Conductive Chemistry kit we designed based on early childhood practices and materials (e.g., threading toys, soft and stackable objects) combined with conductive materials (Figure 1). We draw inspiration for this kit from other material sets we have worked with that are meant to support hands-on science learning, such as Squishy Circuits (Wohlwend et al., 2017; Johnson & Thomas, 2010), paper circuitry (Chibitronics; Qi et al., 2015), and Lilypad e-textiles (Pepler & Glosson, 2013; Buechley, 2006). Squishy Circuits inspired us to consider early childhood practices to guide the design (e.g., stacking, threading) through material cues (e.g., large holes in fabric, oversized components). Chibitronics inspired us to consider storytelling as a way to connect intergenerational practices with electricity and circuits.

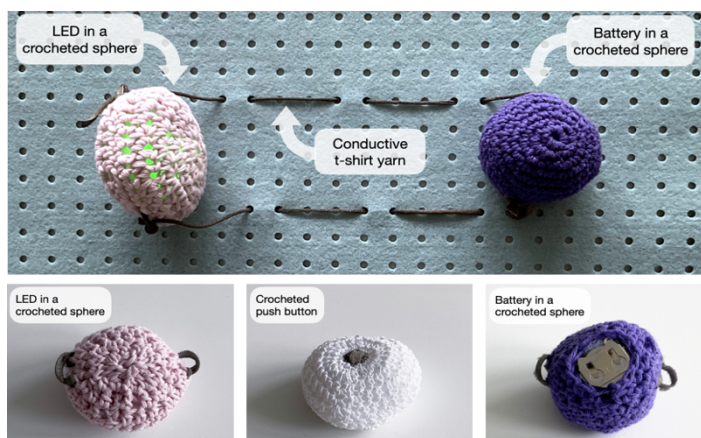


Figure 1. Prototype of a Conductive Chemistry kit for young children. Top: A light turned on by threading the positive and negative sides of a large and soft LED (pink) to a soft battery (purple) using conductive yarn. Bottom: (1) LED, (2) push button, (3) battery.




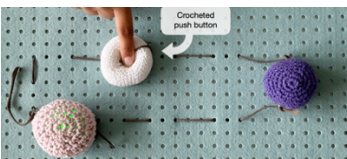
The Conductive Chemistry kit, scales e-textile components into larger parts that are developmentally appropriate for young children. For example, the LED component is a 3-inch-wide crocheted sphere with soft conductive loops extending from both sides (Figure 1, bottom left). Other components include a soft switch that activates when the conductive fabric sewn to the top and the bottom are pressed down to connect, a soft battery pack that holds a coin cell battery.

Through our planned research and development efforts, we extend the kit by designing components that support engagement with ionic conductivity. Additionally, we envision to create story cards that guide children and explain the ideas of metal and ion-based circuitry. The story cards will help children zoom out to explore where, when, and by whom conductivity is used in their everyday lives and to zoom in to explain how metal and ion-based conductivity works, functioning as instructional support (i.e., de Jong, 2019). We will investigate how children and their caring adults interact with the expanded kit to understand more about how young children can engage with chemistry learning and critical technology making in ways that build foundations for future positive engagement with and transformation of STEM fields.

2.1 Components

Table 1 showcases the current Conductive Chemistry kit prototype, the supported practices, and metallic conductivity.

Table 1. Overview of the Conductive Chemistry kit and its metallic conductivity

Conductive Chemistry kit	Practice	Circuitry
 <p>LED threaded together with battery.</p>	Threading the positive side of the large soft LED to the positive side of the battery and threading the negative side of the LED to the negative side of the battery turns on a light.	Polarity.
 <p>LED loop with conductive yarn.</p>	Looping the conductive t-shirt yarn around the loop of the LED.	Making tight connections.
 <p>Stretched conductive t-shirt yarn.</p>	Pulling the t-shirt yarn flickers the light.	Resistance.
 <p>Push button pushed to turn on LED.</p>	Pushing the large soft button to turn the LED on and letting go of the button to turn the LED off.	Circuit flow.

3 PLANNED RESEARCH AND DEVELOPMENT

Our upcoming planned research and development projects will ask two research questions to help guide the development of the Conductive Chemistry kit 2.0 and to investigate learning outcomes and processes for young children:

- RQ1: What intergenerational electricity practices and materials circulate among children (age 3 to 6) and caring adults? How can they be leveraged for critical technology making with conductive circuitry at an early age?
- RQ2: What learning processes and socio-material characteristics foster critical technology design and circuitry learning by children (age 3 to 6) with caring adults?

To answer the research questions, we will engage children and caring adults in play interviews and play-testing workshops and examine their practices and interactions related to electronics and electricity to advance understanding of critical technology making. We expect the findings to result in knowledge about intergenerational socio-material practices that intersect with critical technology making, conductive chemistry to position children in leading roles with technology. We will leverage this new knowledge to improve the Conductive Chemistry kit and to code gains in understanding circuitry learning processes, and material characteristics that foster circuitry learning and critical technology design and how we can support young children to “take charge” of circuitry learning and making.

The work seeks to expand both the age at which it is possible to begin to understand circuitry learning practices and outcomes and the range of circuitry concepts that can be introduced together. Further, this work starts early in exploring how to prepare learners toward developing critical technological literacies at a time when critical engagement with technology is becoming more necessary for participation in daily life. Our work presents the innovation of novel Conductive Chemistry kit with potential to impact early childhood education internationally.

ACKNOWLEDGMENTS

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ChatLogo: A Large Language Model-Driven Hybrid Natural-Programming Language Interface for Agent-based Modeling and Programming

ChatLogo: An LLM-Driven Interface for Agent-based Modeling and Programming

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Building on Papert (1980)’s idea of children talking to computers, we propose ChatLogo, a hybrid natural-programming language interface for agent-based modeling and programming. We build upon previous efforts to scaffold ABM & P learning and recent development in leveraging large language models (LLMs) to support learning of computational programming. ChatLogo aims to support conversations with computers in a mix of natural and programming languages, provide a more user-friendly interface for novice learners, and keep the technical system from over-reliance on any single LLM. We introduced the main elements of our design: an intelligent command center, and a conversational interface to support creative expression. We discussed the presentation format and future work. Responding to the challenges of supporting open-ended constructionist learning of ABM & P and leveraging LLMs for educational purposes, we contribute to the field by proposing the first constructionist LLM-driven interface to support computational and complex systems thinking.

CCS CONCEPTS • Interactive systems and tools • Simulation tools • Interactive learning environments

Additional Keywords and Phrases: NetLogo, Agent-based Modeling, Human-AI collaboration, LLM-driven interface, ChatGPT

ACM Reference Format:

First Author’s Name, Initials, and Last Name, Second Author’s Name, Initials, and Last Name, and Third Author’s Name, Initials, and Last Name. 2018. The Title of the Paper: ACM Conference Proceedings Manuscript Submission Template: This is the subtitle of the paper, this document both explains and embodies the submission format for authors using Word. In Woodstock ’18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY. ACM, New York, NY, USA, 10 pages. NOTE: This block will be automatically generated when manuscripts are processed after acceptance.

1 INTRODUCTION

In *Mindstorms*, Seymour Papert’s pioneering book on Constructionism, a central motif was to support children talking to computers. Instead of using computers to “program” children, children gain control of computers by programming them. Consequently, the Logo programming language family opens vast possibilities for learning in mathematics (e.g. through Logo, [10]), in physics (e.g. through DynaTurtle [4]), as well as in complex systems (e.g. through NetLogo [16]). Like the original Logo language, to empower children in learning to “talk to computers”, designers of Logo descendants strive to make their syntax close to natural languages. Whereas, programming languages, however close to natural forms of talking, still require a formal system of syntax and vocabulary.

In this proposal, we focus on NetLogo [16], the most widely used programming language for agent-based modeling and programming (ABM & P) in the Logo family. Agent-based modeling (ABM) is a powerful methodology that leverages simple computational rules for individual agents to produce complex emergent phenomena [17]. Agent-based programming (ABP) is a decentralized and often probabilistic programming paradigm that serves as the technical foundation of ABM [2]. While ABM has been widely employed in educational settings, facilitating deep engagement with ABM still poses challenges for teachers and learners, partly due to NetLogo’s formal structures and vocabulary, and partly due to ABP being a different paradigm than what is usually taught at school [2].

While many efforts have been done to scaffold the learning of ABM & P, only a number of them are dedicated to open-ended learning contexts (e.g. [11] [3]). Meanwhile, recent advances in large language models (LLMs), have opened up new opportunities for supporting open-ended constructionist learning of NetLogo. While not directly evaluated on NetLogo, codex, GPT-3.5, and GPT-4 have all demonstrated considerable performance in general

programming tasks. With their recent usage in education [9], it seems that “talking to computers” in a natural language context finally comes within reach. Building on those recent efforts, we present the design of ChatLogo, an LLM-driven hybrid natural-programming language interface for agent-based modeling and programming.

2 BACKGROUND

ChatLogo is inspired by two lines of previous literature: efforts to support constructionist learning of ABM & P; advances in LLMs and conversational programming interfaces.

While a constructionist learning approach of ABM would naturally entail ABP to support learners’ exploration, modification, and creation of agent-based models, many previous implementations stop short of coding in NetLogo (e.g. [5]). As ABMs are often integrated into science or social science curricula, programming often incurs a higher overhead for teaching and learning, since teachers and students are less prepared for the CS-related content [12]. Responding to this challenge, several studies tried to create block-based programming interfaces for NetLogo (e.g. [6]). While such interfaces could get children to start coding in 1-2 minutes [7], a trade-off always exists between the “floor” and “ceiling”: the threshold for initial engagement, and the potential for expression [3]. As the power of block-based interfaces increases, they start to ask for scaffolding as well. For example, our recent study [3] found that interactive scaffolds significantly increased online young learners’ short-term and long-term engagement with a block-based ABP environment. Pluralism was identified as a key element that contributed to the improvement: with several scripted pathways, the conversational experience for learners to build their own projects encouraged them to come back again.

However, there is always a limitation for pre-scripted scaffolds, as they became less efficient when young learners came up with their own project ideas [3]. The advent of advanced LLMs brought new hopes. Compared to earlier attempts at conversational programming interfaces that are still syntactically constrained (e.g. [15]), state-of-art LLMs such as GPT, PaLM, or LLaMA are capable of handling much more flexible or even malformed human inputs and translating them into programming languages (e.g. [13]). A few pioneering studies have been conducted to evaluate the effectiveness of LLMs in supporting the learning of programming languages. For example, [9] designed a Codex-powered interface and found short-term learning benefits for novice programmers. While promising, LLMs also come with limitations: they are prone to mistakes, hallucinations, potential biases, or harmful language. [14] found that professional programmers’ task completion rates or time were not improved by GitHub Copilot, partly because participants felt difficulty in understanding and debugging generated code. [8] found that participants felt they must learn the LLMs’ “syntaxes” and struggled to form an accurate mental model to interact with LLMs. They also performed worse in domain-specific tasks, e.g. in NetLogo.

3 DESIGN GOALS

ChatLogo is designed as a web-based system with three goals in mind:

1. **Support novice programmers to “talk to computers” in a mix of programming and natural languages.** Both Logo and NetLogo are implicitly conversational. By placing a “command center” in parallel to the main view, the user would communicate with the computer through text messages or changes in the view. However, there are always correct ways to talk to computers, which take time for learners to grasp. Our design needs to bridge the gap between natural and programming languages by accepting both of them and talking back to learners in a more natural way.
2. **Provide a more friendly interface for learners with no or little computer science backgrounds to creatively express themselves by programming computers.** Even with the latest LLM-based interfaces, learners still struggled to find out the “correct” way to interact with computers [8]. LLMs also frequently provide incorrect responses that require expertise in computer science to identify and resolve. Consequently, LLM-based interfaces are currently more beneficial for learners with more prior programming experiences [9]. While eliminating the underlying issues of LLMs are beyond our means, our design should tailor the system for novice learners - rather than tailor novice learners for LLMs.

3. **Keep the technical system from over-reliance on any single LLM.** We recognize the inherent risk in relying on a private-owned LLM. For example, many studies cited in this paper leveraged OpenAI’s Codex model released in 2022. Within a year, OpenAI would shut down public access to the model, making replications of those latest studies all but impossible if not for a selected few. There are also fresh and valid concerns about data privacy, especially when children and schools could be potential users of our design. To mitigate this risk, we intentionally build our system on a less powerful general-purpose LLM (gpt-3.5-turbo instead of gpt-4) and ensure that the design would eventually work with other (fine-tuned) LLMs that could eventually be deployed in a local and secure environment.

4 DESIGN OVERVIEW

We briefly describe the prototype design of ChatLogo, a hybrid natural-programming language interface for agent-based modeling and programming. A web-based browser-server system, ChatLogo is built with both LLMs and conventional programming. It is highly modularized: the underlying LLM could be replaced at no cost, and its features could be selectively enabled or disabled depending on the learning needs. The system could be adapted for other languages as well.

4.1 An Intelligent Command Center

ChatLogo is an intelligent command center of NetLogo. In this example, we showcase a classical mistake of novice NetLogo programmers: try to `set color` of patches. In NetLogo desktop’s command center (Appendix 1), the input box would deny the entrance of such an ill-formatted input and show an error message instead. It is as if the computer tells the user back: The way you talked was wrong. I will not respond until you figure out the correct way. In Turtle Universe, the mobile incarnation of NetLogo [1], we made a slight improvement by introducing the help feature: in Appendix 2, the computer briefly explains the primitive and suggest some alternatives. However, it still requires the user to initiate the action, and we found relatively few users would touch the “Help” button [3].

At a surface level, ChatLogo inherited this interactive design. However, its behavior diverges when the user gave a malformed NetLogo input (Appendix 3): besides an error message, it further provides two AI-driven options that could explain the error messages or fix the code. Appendix 4 demonstrates the explanation pathway. Once the AI finishes the answer, the learner could ask a follow-up question in natural language, or ask the AI to fix it for them. At this point, the AI would stress that it might make more mistakes: instead of taking away the learners’ initiative, learners are still in charge of the loop. Alternatively, if they decide to send in a new NetLogo command instead, ChatLogo would attempt to execute it directly.

4.2 A Conversational Interface for Creative Expression

An intelligent command center might serve novice learners of NetLogo better. However, it assumes that the learner already knows something about the language, or the input would become unrecognizable in the eyes of the NetLogo compiler. A novice learner might talk in a more “conversational” way: I want to change the background color to red; or, I want to make turtles move around; or more broadly, I want to create a game of ants. A younger learner might also make spelling mistakes along the way, negatively affecting LLMs’ performance. We further notice that: especially for LLMs trained to be a chatbot (e.g. gpt-3.5-turbo or gpt-4), they tend to give a long answer for most questions and make decisions for the learner before asking for clarification. For example, Appendix 5 demonstrates GPT-4’s answer to a simple question: “In NetLogo, how can I create some moving turtles?” Its answer not only assumed much on the learner’s behalf, e.g., turtles would turn back 180 degrees when hitting the edge of the world; it gave the learner step-by-step instructions to follow. In a way, GPT-4 attempts to program the learner.

Our approach differs from the pre-trained GPT-4 behavior (Appendix 5). Instead of right away writing code and giving instructions, ChatLogo attempts to clarify the learners’ needs and intention (Appendix 6). Instead of sending large chunks of code directly to the learner, it attempts to co-develop the NetLogo code. As shown in Appendix 7, the learner is free to edit the code: either in NetLogo, or in natural languages through the “Ask” feature. Instead of

overclaim the correctness of the code, it admits the possibility of making mistakes, and co-works with the learner to address the potential issues (Appendix 8). Finally, upcoming features of ChatLogo will allow learners to add the human-AI co-created code back to the NetLogo model and help learners plan out entire projects in their mind.

5 FUTURE WORK

Despite its potential, there is still a long way to go before ChatLogo could be safely and effectively deployed to K-12 educational settings. More work needs to be done to reduce its mistakes, hallucinations, and potentially harmful language. As we do not expect LLMs to solve these fundamental problems overnight, we are also interested in understanding how human-computer interaction and learning design could be leveraged to mitigate the potential harm and develop learners' AI literacy along the way. To achieve this, we are currently running a study with adult NetLogo programmers and evaluating if it would be appropriate to work with children.

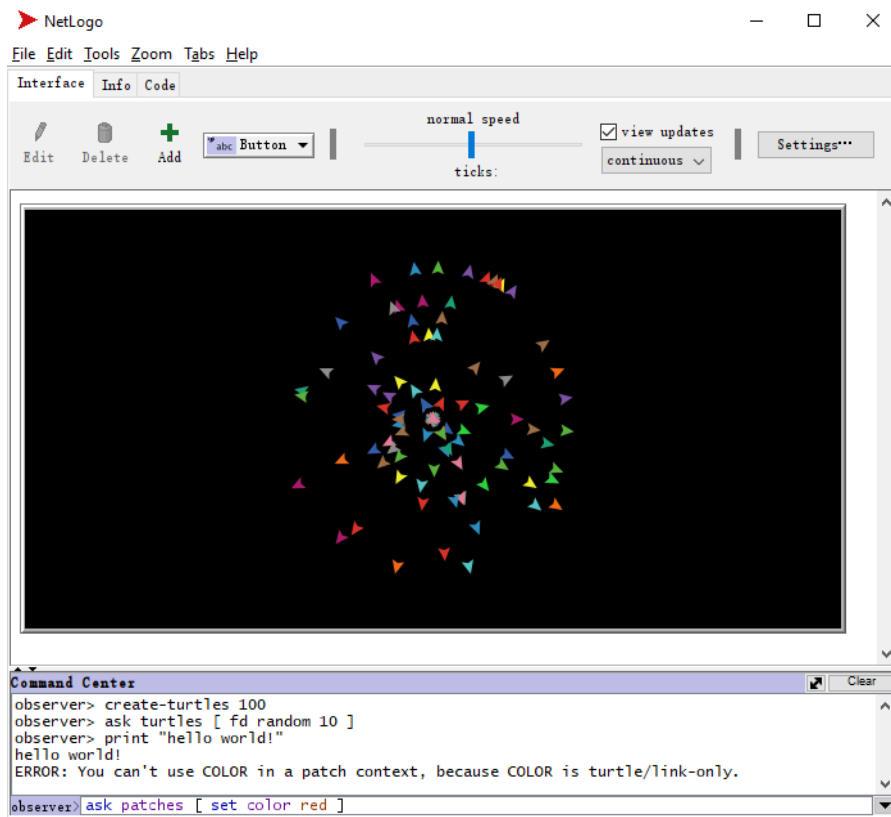
There has been much debate around LLMs and the future of humanity as of late. Our ultimate hope is that LLMs could become a liberating force, instead of an oppression one, for both children and adults. This requires children to be able to program computers for their own purposes, not vice versa. This asks for a more constructionist future for education, where children could be better equipped and supported to construct their own meaningful artifacts, not vice versa.

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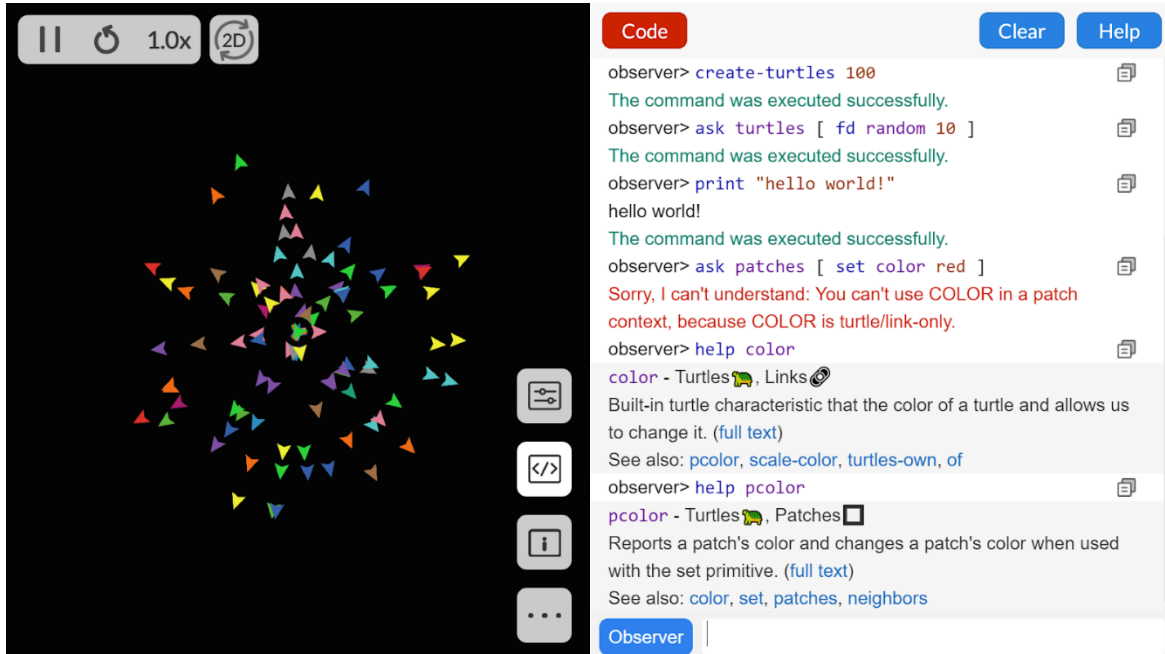
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A APPENDICES

A.1 Screenshot of NetLogo Desktop's Command Center



A.2 Screenshot of Turtle Universe's Command Center

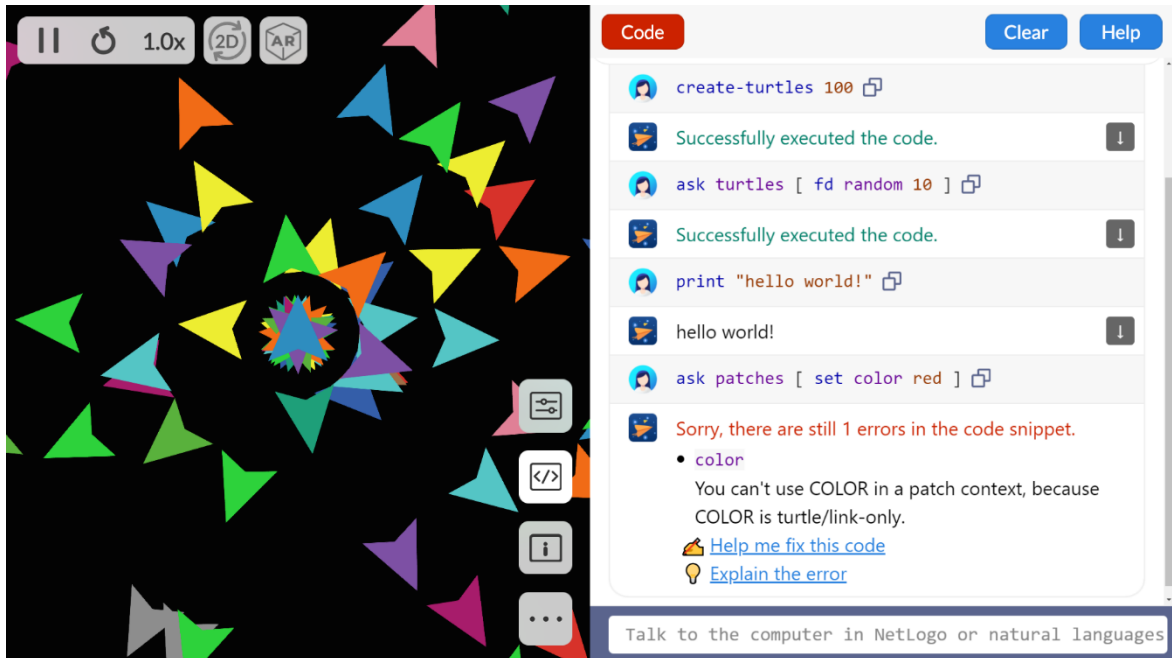


The screenshot shows the Turtle Universe interface. On the left is a 2D world view with a black background and many small, colorful triangles (turtles) arranged in a circular pattern. Above the world view are controls: a pause button, a refresh button, a zoom level of 1.0x, and a 2D button. On the right is a command console with a 'Code' tab, 'Clear' and 'Help' buttons, and a text input area. The console shows the following commands and their outputs:

```
observer> create-turtles 100
The command was executed successfully.
observer> ask turtles [ fd random 10 ]
The command was executed successfully.
observer> print "hello world!"
hello world!
The command was executed successfully.
observer> ask patches [ set color red ]
Sorry, I can't understand: You can't use COLOR in a patch context, because COLOR is turtle/link-only.
observer> help color
color - Turtles, Links
Built-in turtle characteristic that the color of a turtle and allows us to change it. (full text)
See also: pcolor, scale-color, turtles-own, of
observer> help pcolor
pcolor - Turtles, Patches
Reports a patch's color and changes a patch's color when used with the set primitive. (full text)
See also: color, set, patches, neighbors
```

At the bottom of the console is a text input field with the placeholder text 'Observer'.

A.3 Screenshot of ChatLogo running on Turtle Universe

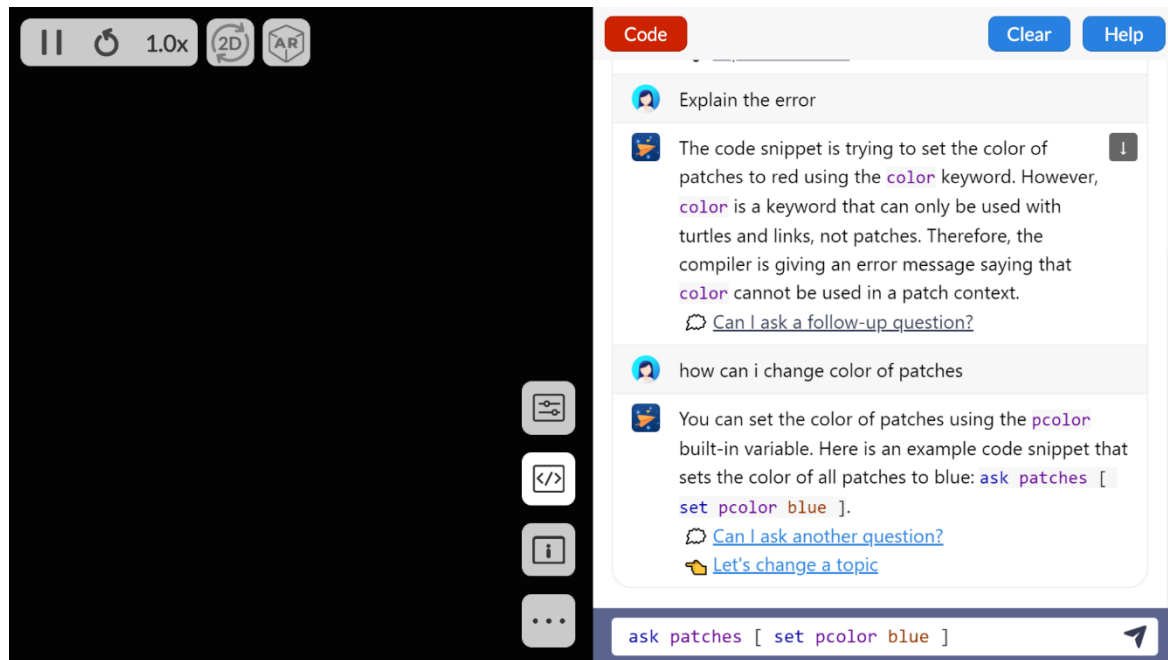


The screenshot shows the ChatLogo interface. On the left is a 2D world view with a black background and many small, colorful triangles (turtles) arranged in a circular pattern. Above the world view are controls: a pause button, a refresh button, a zoom level of 1.0x, a 2D button, and an AR button. On the right is a chat interface with a 'Code' tab, 'Clear' and 'Help' buttons, and a text input area. The chat interface shows the following messages:

```
create-turtles 100
Successfully executed the code.
ask turtles [ fd random 10 ]
Successfully executed the code.
print "hello world!"
hello world!
ask patches [ set color red ]
Sorry, there are still 1 errors in the code snippet.
• color
You can't use COLOR in a patch context, because COLOR is turtle/link-only.
Help me fix this code
Explain the error
```

At the bottom of the chat interface is a text input field with the placeholder text 'Talk to the computer in NetLogo or natural languages'.

A.4 Screenshot of ChatLogo running on Turtle Universe, Continued



A.5 GPT-4's response to "create some moving turtles"

USER In NetLogo, how can I create some moving turtles?

ASSISTANT In NetLogo, you can create moving turtles by defining a set of turtle properties and behaviors, and then using the `ask` command to update their positions in each tick of the simulation. Here's a simple example of how to create moving turtles in NetLogo:


1. Create a new NetLogo model or open an existing one.


2. In the "Code" tab, define a new breed of turtles called "moving-turtles":





```
...  
breed [moving-turtles moving-turtle]  
...
```


3. Define a procedure to set up the model. In this example, we'll create 10 moving turtles and set their initial properties:


A.6 ChatLogo's response to "create some moving turtles"

 create moving turtles

 It seems that you have several different needs. Let's do one at a time. Which one do you want to start with?

-  [Create turtles](#)
-  [Make turtles move](#)
-  [Let me clarify it](#)
-  [Let's change a topic](#)

 Create turtles

 Working on: **create turtles**

Sure, I can help you with that. Can you please provide me with more information?

What do you want to call the turtles in the code?

e.g. [turtles](#) [rabbits](#) [cars](#)

How many turtles do you want to create?

e.g. [10](#) [50](#) [random between 20-30](#)


Where do you want to create the turtles?

e.g. [random](#) [at \(0,0\)](#) [around a specific patch](#)


A.7 The First Iteration of Code Provided by ChatLogo


```
1 ; Create 10 turtles using the breed name "turtles"
2 v create-turtles 10 [
3   ; Set the turtles" positions randomly
4   setxy random-xcor random-ycor
5 ]
```

← ▶ Run ? Ask 1 / 1

 Below is a summary of my request:

- breed: turtles
- number: 10
- position: random

 I am working on a first version of the code. The code might have mistakes.

 [Let's change a topic](#)

A.8 Ask ChatLogo to Fix a Simple Bug Made by the Researcher

```
1 ; Move all turtles
2 ask turtle [
3   ; Set heading to up
4   set heading 90
5   ; Move forward random between 1-2 units
6   fd (1 + random 2)
7 ]
```



Run

? Ask

Back

3 / 3



Trying to run the code...



Sorry, but we need to fix the 1 errors in the code (marked with `__red squiggly lines__`) before continuing.



[Help me fix this code](#)



Help me fix this code



Sure, I am working on the fixed code. Note that the code can still have mistakes.

```
; Revised code and line comments and explanations
; Move all turtles
ask turtles [
  ; Set heading to up
  set heading 90
  ; Move forward random between 1-2 units
  fd (1 + random 2)
]
```



Enchanting Woods: Engaging Children in Creative Expression through Interactive Storytelling and Embodied Interaction

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Creative expression is a rising field in primary and secondary schools. Computational technology is a novel medium for creative expression that has received increasing attention in education. We propose a computational technology-supported experience, *Enchanted Woods*, that prioritizes students' creative expression for children aged between 9 and 11 years old. Enchanted Woods is a classroom-size two-phase narrative-based design with physical interactions and purposely designed plot holes. The first phase placed students in the role of a lead character to immerse in the story, and the second round positioned students as the creator of the story to express their creativity. This work proposed an approach to transforming the classroom into an environment that supports children's creativity.

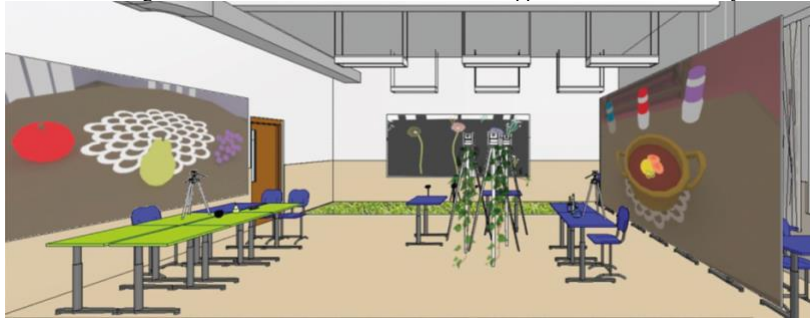


Figure 1: A 3D model of the classroom setup of the interactive narration experiences.

Keywords and Phrases: Interactive storytelling, Creativity support, Interactive learning environments

1 INTRODUCTION AND BACKGROUND

Nowadays, computational technology is more than a tool that extends human capabilities but is also a novel medium for artistic and creative expression that has received increasing attention in education (Peppler & Kafai, 2007; Peppler & Kafai, 2009; Fields et al., 2014). The intersection of art and technology used the creative and artistic expression as the approach to broadening the engagement of students in the computing field (Peppler & Kafai, 2009; Margolis, 2000). Previous studies designed and evaluated creative practices with a major end goal of learning computational skills (Peppler & Kafai, 2007; Peppler & Kafai, 2009; Fields et al., 2014). We proposed a computational technology-supported experience that prioritizes students' creative expression for children aged between 9 and 11 years old.

We designed *Enchanted Woods*, a classroom-size two-phase narrative-based design with decision-based interactions. The first phase is the undergoing phase, which is an immersive experience with decision-based interactions that positioned children as lead characters of the narration. The story incorporates scenic projections and stage design inspired by immersive theater. Sensory-based embodied and tangible interaction further improves the immersion of the story and helps children empathize with the main character. Some plots in *Enchanted Woods* were designed with *purposely designed plot holes*, where the decision made by the main character resulted in her being in danger. Having experienced the story with the bad ending, students are naturally motivated to move on to the second phase -- re-imagining and creating. Students recognized that their decisions could potentially affect the progression of the story and lead to varying endings. The purposely designed plot holes could provide incentives for students to explore how the story might unfold further. Students are asked to recall moments that different choices can be made to save the main character, design sensor-based interactions that allow opportunities to make choices, create new storylines, implement with Scratch, and present to the class.

1.1 Interactive Storytelling

Interactive storytelling approaches have been used in education to promote students' engagement and sense-making across disciplines such as environmental awareness, mathematics, computer science, etc. (Albano et al., 2019; Fields et al., 2014; Andrade et al., 2022) As a result, we take advantage of the engagement feature of interactive storytelling and created an interactive experience within the context of digital storytelling.

In the realm of interactive storytelling for computing education, Fields et al., (2014) have highlighted that many students are less likely to be engaged in "sophisticated programming" when making creative projects with Scratch. To tackle the issue, Fields et al., (2014) used "constructive criticism" as an educational approach to encourage students to imagine richer interactions, story details, and appealing visual backgrounds, as well as to engage the students' iterative revisions. We engaged students in reimagining stories and possible interactions as story creators by intentionally leaving plot holes for them to come up with alternative narratives that will ultimately influence the conclusion of the story.

1.2 Tangible and Embodied Interaction

To further bring in engagement and facilitate students' creative expression, we took the lens of tangible and embodied interaction (TEI). TEI considers sensorimotor functions as a significant component of knowledge processing and understanding. Creativity is not solely in mind, instead, creativity is deeply engaged with bodily interaction and sensorimotor experiences (Leschziner & Brett, 2019). Previous studies showed the manipulations of external artifacts and sensory experiences scaffold the creativity process (Leschziner & Brett, 2019; Loparev et al., 2017).

Liang et al. (2021) conducted a literature review specifically in the field of children's creative learning through TEI, founded out that "children's sensory engagement, active participation, exploration, and self-expression" are being motivated by tangible interaction. Throughout the digital storytelling, we incorporated tangible interactions to engage students and stimulate their expression.

1.3 Immersive Theatre

We adopted features of immersive theater to enhance the immersion of the story in this classroom-size design. In immersive theater, a fourth wall which separates the actors from the viewers is removed. The audience is mobile and is often invited to participate in the performance. Our design echoes the main ideas of immersive theater, drawing upon interaction, participation, co-creation, and co-execution (Bucher, 2017). In this kind of setting, students quickly generate sympathy

and build interpersonal connections with the characters which allow students to step into the characters' shoes and immerse themselves in the story.

2 PROJECT DESCRIPTION

Enchanted Woods adopted the classic fairy tale Little Red Riding Hood and set it up in the classroom (Figure 1). With narrated animations, participants would engage in the first phase -- experiencing an interactive, immersive story with a predetermined tragic ending. By embodying them in experiencing the stories and the purposely designed plot holes, we intended to motivate learners to the second re-imagining and creating phase. Students could create alternative narratives that involved decision-making that led to their desired ends.

2.1 Storyline Design

Designing the immersive and interactive features of the digital story required a close study of the storyline. We organized characters, locations, and key events in the form of a storyboard. Figure 2 demonstrates the overall storyline design including the interactive scenes and the purposely designed plot holes that led students to design their own stories.

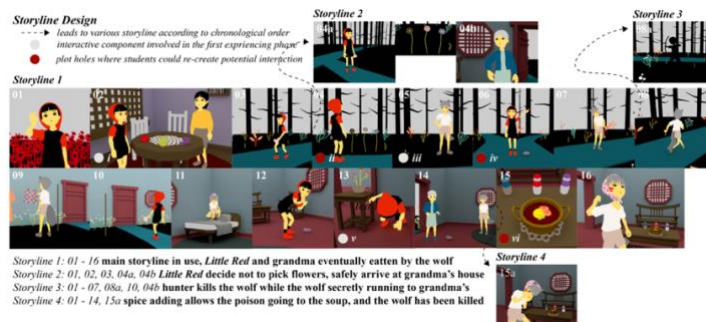


Figure 2: Storyboard demonstrating the storyline for first round experience and the potential storyline after the second-round re-creation.

Panels 01 - 16 are the main narratives that students would experience in the first round. Little Red and grandma are eventually eaten by the wolf. The gray circles indicate the embodied interaction scenes: Little Red chooses a fruit for her grandma (panel 02); Little Red introduces herself to the wolf (panel 05); and Little Red finds a place to hide from the wolf (panel 13). Panels with red circles are the purposely designed plot holes that Little Red could make alternate options to avoid the tragic outcome. We depicted the possible progression in storylines 2-4 if alternative choices were made. Panel 4 is the first plot hole. Little Red was distracted by the flowers for too long, causing her to run into the wolf. If Little Red had decided not to pick up the flower, she might never have encountered the wolf. Panel 06 is the plot when Little Red tells the wolf which is the road to her grandma's house. If Little Red had not told the wolf of the correct path, the wolf might have been shot by the hunter on the way. Panel 15 is the plot where Little Red's grandma failed to poison the soup. If Little Red's grandma had found the poison among the seasoning cans, she and her grandmother might have eventually been safe as well (Storyline 4).

2.2 Merging Physical and Digital

The design was set up in a classroom space. Each of the three main locations: Little Red's House, The Woods, and Grandma's house, was assigned a wall to project the story onto. Students would move around the room as the story progressed. Elements of set dressing were prepared to create an immersive environment. Artificial grass was laid out in

front of the wall projecting the Woods scene, and ivy vines were wrapped around the projector stands, imitating trees. Physical props such as fruits, flowers, and furniture were prepared at each scene for students to interact with.

The interactive task in each of the three locations utilized webcams, microphones, or micro: bit devices, and was integrated seamlessly into the Scratch platform. The interactive webcam task prompts students to select a fruit to bring to Little Red's sick grandmother. The webcam recognizes the students' choice and the story on the screen can move forward. The second interaction is an audio-based interaction using sound detection. It called for a dialogue between the students and the Wolf. The third interaction is a micro: bit interaction, where students interacted physically with furniture props to avoid the wolf. This will trigger the selection on the screen as soon as students select a location.

The interaction that involved object manipulation blurred the boundary between virtual and physical. Students are able to develop empathy within stories through embodied roles. It was also through the choice-based interaction that students were introduced to the idea that they could influence how the story proceeds by assisting Little Red in making different choices. As a result, when Little Red made a decision that resulted in her being in danger, students were eager to re-imagine alternative choices and anticipate a positive outcome.

3 DEMONSTRATION

Though this work is designed to be set up within an open space (i.e., classroom, event room, playground, etc.) where interactive artifacts including screens, sensors, and props can be installed, it could scale down to using only one screen with sensors to control the progression of storytelling just for the purpose of demonstration. A separate monitor could show the video of the full-size design. A demonstrative video of Enchanted Woods can be viewed [here](#).

4 CONCLUSION AND FUTURE WORK

This paper presents Enchanted Woods, a two-round storytelling environment that first engages students in experience and then fosters students' re-imagination and creative expression process. By integrating TEI into the digital narratives and adopting design guidelines of immersive theatre, the sense of immersion and engagement is further enhanced. The purposely designed plot holes naturally stimulate students to re-imagine and re-create the alternatives and take them into the creative process. In the future, we intend to investigate developing this classroom design into a learning toolkit that is more portable and accessible to a broader range of audience.

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A Constructionist Learning Environment for Accessible Agricultural Robotics in Rural Communities via Making and Remixing

Constructing Community Robotics In Rural Communities

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Robotics environments, such as the original LOGO turtle, have facilitated constructionist learning and even grown into widespread products such as Lego Mindstorms. Many of those environments have been highly successful by minimizing the cost of entry by focusing on smaller, indoor robots with cheaper parts, and building communities of learners such as in FIRST robotics competitions. In this work in progress, we have begun to design and build a physical robotics framework and virtual simulation/making environment, with the goal of enabling rural learners to make robots that might be used in their community in culturally relevant ways outside of the classroom.

Keywords and Phrases: Virtual Learning Environments, Robotics, Virtual Reality, Rural, Agriculture

1 INTRODUCTION

Rural high school students are over twice as likely to lose interest in STEM than their suburban counterparts by the time they reach 11th grade (Saw & Agger, 2021). Many factors come into play affecting these outcomes. However, a substantial contributing factor is a lack of STEM in rural students' own communities. Lacking models, mentors, and visible career paths, rural students question their ability to excel in STEM. In rural settings learners also have reduced opportunities to learn outside of the classroom including science fairs, robotics competitions, and STEM afterschool programming (Saw & Agger, 2021).

Towards increasing access to STEM education, in this WIP we will describe our vision and then our ongoing design and prototyping of a constructionist learning environment to enable culturally responsive robotics education in rural communities, for formal and informal learning contexts. Our near term vision is for learners to design robots with their local rural community and build robots for use in their local community, by targeting culturally relevant agricultural activities. Our broader long-term vision is to help enable robotics education to shift to center designing robots with and for use in learners' local communities. From a research perspective we see our work within designing constructionist learning technologies and communities that help learners design, create, and navigate across the virtual to physical/real continuum.

In this paper we will focus on addressing two specific design challenges for rural culturally-relevant robotics education: 1) a robotics software and hardware framework that can be used to build **agriculturally useful** robots and be **accessible to learners** by being designed to be **learnable** and **lower cost**, and 2) a virtual environment for designing, programming, and simulating robots based on reusable, open source components. The first is described in section 2, and the second in section 3. In section 4 we discuss open challenges and questions, raise critiques of our work, and comment on our positionality.

2 DESIGNING ACCESSIBLE ROBOTICS PLATFORM FOR RURAL LEARNING ENVIRONMENTS

Our robotics software and hardware framework is designed to 1) support agriculturally useful robots, and 2) be more accessible to learners, via lower cost hardware and designing the software stack for learnability.

To be agriculturally useful, our robot needs to be structurally sound to navigate challenging terrain, powerful enough to move tools through acres of hard soils, and weatherproof to withstand the outdoors in heat and cold, rain or shine. To be structurally sound we created a chassis using 3mm thick aluminum sheet and 100x50 mm aluminum extrusion. To provide sufficient power for on-farm working conditions we used 1Kw hobby brushless motors and over 1,000 watt hours of charge to propel 13 inch all terrain tires with 22 Nm of torque at each wheel. And to withstand the elements we encapsulated the chassis assembly in 3D printed PETG covers to reach IP65 ingress protection ratings suitable for rain and dust; as well as mounted motor drivers and power circuitry directly to internal aluminum chassis to expel excess heat in high temperature conditions.



Figure 1: Low Cost Agricultural Robotics Platform in Field

To be lower cost, our new framework uses off the shelf hobbyist additive and subtractive manufacture to eliminate lead times and high costs of manufacturing. For additive parts we used the Prusa MK3, MSRP \$649, to produce 5mm thick walled waterproof PETG components with a 0.6mm print nozzle and gyroidal infill pattern. For subtractive machining we used the Shapeoko 3 XXL desktop CNC, MSRP \$1,800, for cutting 6061 aluminum parts using material ranging from 3mm to 25mm thick. In total, fixed costs for equipment were approximately \$3,000 including CNC, 3D printer, and basic shop tools. The total marginal cost for each unit is \$5,500, approximately 4X less than local or remote manufacturing quotes for quantities less than 50 units. This includes \$450 in 32Kg of machined aluminum, \$175 in 6.7Kg of PETG 3D printed plastic, and \$4,879 in power, electronics, actuators, and off the shelf mechanical components.

Beyond being more accessible to learners by being lower cost, we also designed a robotics software framework to be more learnable by learners by using synchronous loops in routines that learners would be familiar with from other constructionist environments, modularizing robotic behaviors and controllers into bite sized abstractions, and using lightweight web API's to use familiar request and response patterns. To create familiar synchronous looping patterns the framework uses Redis as a key value store in which several separate modules access Redis to read incoming data from other modules at the top of the program routine, and writes all output to Redis at the bottom of the program routine; no two modules can write to the same key avoiding race conditions. To modularize behaviors and controllers we developed program routines in python (see modules in Blue in Figure 2) which register atomic modules written by learners (see Green Modules) and add them to the routine loop allowing learners to only focus on the single actions to be accomplished. To create familiar request response patterns between resources we developed web API facades using Flask (see Yellow modules) for maps, path planning, task management, and computer vision processing allowing learners to call these resources with simple http requests from their modules.

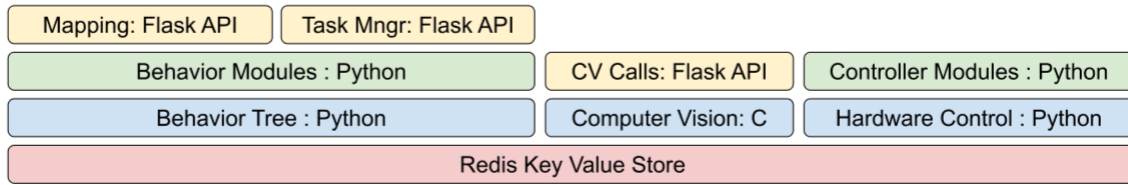


Figure 2: Module Structure of Robotic Software Framework

There are still several challenges to making agriculturally useful robotics accessible to rural learners including access to maker spaces and equipment, simulating and testing robotic designs in learner centered environments, and overcoming remaining cost barriers in low resourced communities.

3 DESIGNING VIRTUAL TOOLS FOR MAKING ROBOTS WITH CONFIGURABLE COMPONENTS

Another way to make robotics more accessible is by creating virtual learning environments for robotics (such as Zhong, Zheng, & Zhan, 2020) to not only reduce costs, but also cognitive load, while focusing on learners' higher order thinking and complex problem solving skills. We have begun to create a virtual “hands on” CAD-like environment for prototyping and simulating robots in XR immersive environments based on reusable open-source components, with metadata useful for providing automated design and remixing support. In that work one problem is how to enable learners and community members to share physical components such that the IDE can support and give feedback to learners on integrated design decisions across those components. For example, learners may import a virtual model of an actuator with mounting brackets designed for M12 metric bolts. Current CAD applications do not check for compatibility between joined objects such that the learner could use a M10 or 7/16” bolt in their design without any feedback. With compatibility metadata between virtual components learners could be guided to components that are compatible with their existing designs or shown through debugging output compatibility issues and concerns at varying levels. Alternatively the same concept can be applied to software compatibility choices for physical components where a specific actuator may only communicate over a specific protocol such as CANBUS or I2C which must be considered throughout the electronics design process. Expanding these concepts to entire virtual electro-mechanical assemblies built by community members may better support remixing of robotics projects in the learning environment.

To provide suggestions and debugging support, we have begun to design an open source component metadata layer describing how it can interact with other components, both in software and as physical components in the real world. There has been significant prior work on software components interacting with each other and publishing interfaces. However, we are not yet aware of work that considers open “APIs” for virtual 3D components representing real world physical counterparts, especially in the effort to support STEM learning (Bascou & Menekse, 2016), (Xia & Zohng, 2018). For example, in industry, the two prominent transmission formats for 3D models, USD format and GLTF 2.0, have or are planning support for physical joints between objects in the same file, but do not offer support for defining compatible objects in different files.

Our current draft design for enabling these types of interactions for learners includes three kinds of metadata: joint compatibility metadata, material compatibility metadata, and software compatibility metadata. These metadata are intended to be embedded in the open source GLTF 2.0 transmission format for component sharing across learning environments built on platforms including WebXR, Unity, and Unreal Engine using platform specific plugins to perform compatibility checks between components. In addition, our vision is to use these plugins to enable access to catalogs of open source components, using the new compatibility metadata, in XR during runtime and across virtual learning environments.

4 DISCUSSION

In this section we discuss some open problems in our work, critiques, and potential positive ideas and design from the constructionist learning community that we would like to incorporate in our work (Blikstein, 2013). We are trying to make a constructionist learning environment for making robots for meaningful use within the learner's community in rural settings. This learning environment spans across virtual components and physical robotics components. This includes 1) a robotics software and hardware framework that can be used to build **agriculturally useful** robots and be **accessible to learners** by being designed to be **learnable** and **lower cost**, and 2) a virtual environment for designing, programming, and simulating robots based on reusable, open source components, **with metadata useful for providing automated design and remixing support**.

We're trying to approach with an open mind how to address the following open problems and critiques. Will it be meaningful to make robots in virtual environments first for rural communities? Will the cost of transitioning from virtual to physical robots still be too high, even when there may be value the robots can provide to the community as a whole? How do skills developed in "hands on" XR virtual environments translate to real world hands on construction of agriculturally useful robots? Does expanded creative flexibility and reducing cost by using virtual "hands on" immersive XR environments actually impede learning due to challenges in virtual to real world skills transfer? It could also be said that developing virtual environments in STEM education that do not model the real world tool, in this case traditional CAD systems, could limit skill transfer.

We hope that our virtual robotics environment opens new possibilities for learners to explore the design process around the traditional engineering and CAD process, while also creating opportunities for learners to share and collaborate on projects within their communities. This reflects our work's broader sociocultural constructionist vision (Pinkett, 2000) hoping for learning environments enabling real world problem solving and solution design at the community level. Our long term aim is to empower learners and communities in such a way that when community members say "I wish there was X that could do Y" their first inclination could be to sketch out a solution in a virtual environment with real components in collaboration with other community members. For example, some community members may have the skills to flesh out entire designs in such a tool whereas for other community members these learning environments could simply be a tool to investigate their needs and requirements more fully before seeking outside support (such as creating a field with a 15 degree slope and crops of some size). These are examples of a wide spectrum of positive outcomes for fostering more community driven STEM making and robotics learning opportunities which may improve STEM interest development amongst learners in rural and similarly under-resourced areas.

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Constructing Sustainability: Integrating Constructionist Learning in Education for Sustainable Development

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This paper explores example of how support constructionist learning environment can support Education for Sustainable Development (ESD) by designing and making innovation that addresses environmental and social problems. In this paper, we describe an “Education for Sustainable Development through Design and Technology” course where undergraduate and graduate students from Japan and Thailand, from various disciplines were tasked with constructing “social or environmental solutions”. Data collected from interviews, student-built projects and class final reports suggest that when making is framed as being a set of practices, skills, and technologies to connect with one’s interest, students can successfully engage in an act for sustainable development. The course is designed and implemented as a learning environment that uses human-centered design, the process of empathize, define, and ideate to help the students better understand their users and generate creative ideas for their projects. After coming up with the ideas the students learn through building prototypes and testing them for further iterations

Keywords and Phrases: Constructionism, Education for Sustainable Development, Sustainable Development Goals

1 INTRODUCTION

By 2030, the Sustainable Development Goals (SDGs) of the United Nations aim to ensure that all learners acquire the necessary knowledge and skills to support sustainable development. However, universities face difficulties in implementing education for sustainable development (ESD) as there has been little emphasis on engaging students in practical learning experiences that involve environmental and community issues. This study introduces a design principle and example that advocates for a Constructionist Learning to ESD in higher education (Thanapornsanguth, 2022), empowering students to address problems and establish the basis for sustainable development.

The learning processes associated with ESD should empower students to take transformative actions for sustainability. ESD goes beyond simply adding sustainability as an additional topic to the curriculum; it involves equipping learners with the ability to contribute to sustainable societies through critical thinking and active problem-solving (Lambrechts & Hindson, 2016). The constructionist design paradigm bears numerous resemblances to the literature on the learning process in ESD. Constructionists contend that learners acquire knowledge and skills most effectively when they engage in designing and creating projects that hold personal and social significance (Papert, 1993). They advocate for experiential learning that is connected to the real world, drawing influence from Dewey's progressive education philosophy, which emphasizes experiential learning and establishing connections to the real world (Ackerman, 2001). To integrate constructionism and ESD into higher education, instructional practices should foster students' sense of belonging to a community. Students should be encouraged to perceive themselves as active members of the community who can make a difference and establish connections between their local community and global communities.

2 METHOD AND COURSE DESIGN

The study employed qualitative design-based research project that involved a total of 64 undergraduate and graduate-level students from public universities Thailand and Japan. Each implementation of the project lasted for one semester.

The primary objective of the course was to empower the students to become designers and create inventions that could address social and environmental challenges. The students' projects encompassed various areas, including sustainable lifestyles, human rights, gender equality, and global citizenship. Throughout the course, they followed the design thinking process, which involved empathizing with community problems, formulating problem statements, and engaging in brainstorming sessions to achieve their objectives.

During the course (Table 1), students discussed and explored social, economic, and environmental issues within and beyond their localities while sharing their solutions with their group members. Each group delved into their chosen social and environmental problems, employing diverse user experience research methods. Additionally, guest speakers from different fields related to the Sustainable Development Goals (SDGs) were invited to provide the students with fresh perspectives and inspire their project ideas.

The latter part of the course focused on designing and creating innovative solutions to address local or global sustainability issues of their choice, utilizing the design thinking process and fabrication tools. Students followed the design thinking process by empathizing with community problems, formulating problem statements, and brainstorming to achieve their goals. They then developed prototypes to aid in their thinking, learning, and obtaining feedback from the community, iterating on their designs as necessary. Digital tools and equipment like 3D printers and microcontrollers were encouraged for use in creating their innovations.

At the end of each class, students presented their projects and shared their knowledge with stakeholders. This hands-on, project-based course fostered a constructionist learning environment, providing students with opportunities to design and create. The final project aimed to cultivate skills, knowledge, awareness, and attitudes necessary for the students to address the identified issues and contribute to building a sustainable future.

Table 1: Structure and Design of the Class

Exploration		Execution	
# of session	Session	# of session	Session
1	Research explanation and consent form	1	Brainstorming on the chosen ESD project
2	Introduction to the United Nations' Sustainable Development Goals (SDGs) and education for sustainable development	1	Prototyping
1	Introduction to Design Thinking and d.school's Gift Giving exercise	3	Studio hours (making, group work session)
2	Workshop on Empathize and interviewing stakeholders	1	Reflecting on Stakeholders feedback
3	Perspective Sessions, exploring different SDGs through the lens of experts	1	Project Showcase

3 EXAMPLE PROJECTS

3.1 RinSE

"RinSE" was developed by six students from a Japanese public engineering university, representing four different nationalities. The students were motivated by SDG 6: Clean Water and Sanitation. Their project aimed to guide independent farmers toward environmentally conscious and drought-resistant agricultural methods. The primary objective of the project was to establish a comprehensive platform that educates farmers about drought-related precautions and assists new farmers in embarking on their agricultural endeavors in a sustainable, resilient, and confident manner.

3.1.1 Problem Statement.

Cyprus stands out as one of the most water-scarce nations globally, relying on groundwater, dam water, and desalination to fulfill its population's needs. The issue encompasses two primary aspects: A decrease in annual rainfall attributable to global warming. Intensified rain events due to global warming, leading to erosion and damage.

Problem Statement: Small to medium-sized farms and low-income farmers in Cyprus face challenges such as damaged crops and an inability to harvest sustainably, primarily because of extremely limited access to clean water supplies during frequent drought seasons. Recycled water usage for vegetable crops becomes impractical under such conditions.

3.1.2 Process.

Students followed the Design Thinking process of Empathy, Define, Ideate, Prototype, and Test. They began by collecting ideas while aligning an impact and complexity gridline to implement each proposed solution. During their analysis, they discussed and listed several potential solutions that varied in terms of flexibility, ease of implementation, and impact (Figure 1). Two top choices stood out, each involving drastically different implementation methodologies. The first idea entailed constructing a physical water storage tank to provide drought-proof farms with extended water supply periods. However, due to the limited duration of the course and the high costs associated with material procurement and sensor acquisition, the construction and implementation of the project were deemed infeasible. Consequently, the students decided to develop a comprehensive digital platform offering farmers a multi-layered information system and tools to assist them in their planting journey, drought management, and water utilization calculations.

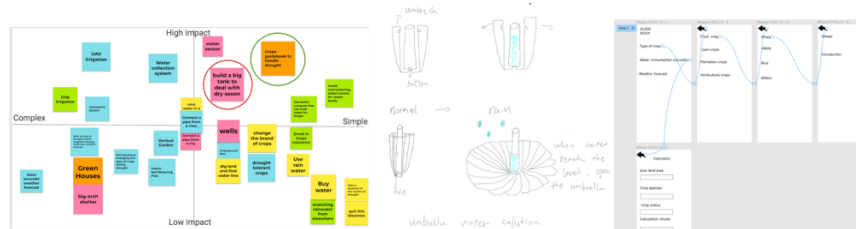


Figure 1: Students' design and brainstorming processes.

3.1.3 Solution.

The project aimed to develop a robust and comprehensive platform to address diverse challenges faced by farmers in Cyprus and globally, with a particular focus on drought. The platform addresses multiple aspects, beginning with the provision of accurate climate forecasts and predictions regarding droughts, rainfall, storms, and heat. It also highlights how these predictions can impact farmers' cultivation and planting processes.

Furthermore, it assists both experienced and novice farmers in combatting drought by offering a detailed guidebook and analysis of drought-resistant crops, as well as stress management strategies. Additionally, the platform incorporates image processing technology to identify different soil types and provide tailored consultations based on specific parameters. To ensure accurate data, accessibility, and effective technological utilization in battling drought, the platform integrates four main components: 1) Soil Recognition: A program that enables quick identification of the current planting soil by uploading a photo taken with a smartphone. 2) Water Calculator: A tool with various settings and scenarios for calculating water requirements. 3) Chat Bot: An intelligent answering robot programmed through Slack and Google Flow, capable of automatically responding to user questions based on pre-programmed information. 4) Information Hub: A centralized hub providing farmers with a wide range of resources, including expert articles, case studies, and best practices for combating drought and practicing environmentally conscious agriculture.

3.2 BraceMed

The "BraceMed" team comprised seven students from Thailand who shared a mutual interest in SDG 3: Good health and well-being. Six out of the seven students were pursuing Pharmaceutical Sciences. Initially, the group aimed to tackle

the problem of online learning fatigue among freshmen university students during the COVID lockdown, as it directly affected them. However, a class session featuring guest speakers discussing caregiving for dementia patients prompted them to alter their focus..

3.2.1 Problem Statement.

Based on the post-interviews, the students conveyed their lack of knowledge and skills to research new medicines for dementia but showcased a keen interest in elderly patient care. To gain a deeper understanding of the needs of their target users, they chose one member's 81-year-old grandmother as the representative elderly patient, and their mother assumed the role of the representative caregiver. Through interviews with these individuals, the group uncovered that "Grandma" frequently forgot to take her medication. Additionally, they discovered that despite consistently wearing her favorite bracelet, she often left her medication behind when going outdoors.

Problem Statement: How can we develop a solution that assists in reminding Grandma to take her medication?

3.2.2 Process.

Working as a team, the students engaged in brainstorming sessions to generate novel ideas. They translated these concepts into sketches and made a basic prototype utilizing available items through Google Jamboard. They subjected their initial concept to testing via a prototype and sought feedback from Grandma. Her input included a suggestion that the bracelet should be convenient to wear and not overly bulky. Additionally, concerns were raised regarding possible skin irritation due to Grandma's sensitive skin.

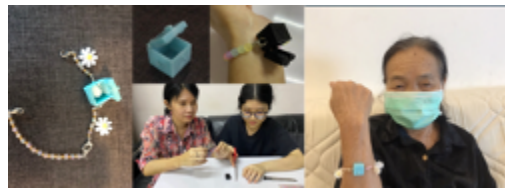


Figure 2: A student and her mother made "BraceMed" for the grandmother.

3.2.3 Solution.

Despite the fully online format of the class necessitated by the COVID-19 outbreak in Thailand, the students adeptly collaborated on the design of Bracemed. Some dedicated themselves to crafting the pillbox using Tinkercad, while others employed a 3D printer to produce and refine the design. Bracemed emerged as the collective creation of team members who shared a common objective: addressing a prevalent issue and fostering improved habits for their users (Figure 2). Crafting a Bracemed could evolve into a meaningful family activity, with each family member contributing to the creation of a bracelet for Grandma.

ACKNOWLEDGMENT

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Political Activism in a Youth Community Garden

How the making of a community garden supports youth's political activism in heterogeneous engineering

Community gardens afford effective STEM learning because they provide contexts that are meaningful and relevant, so youth can draw their funds of knowledge when learning in these spaces. Analyzing data from youth in a public high school constructing their community garden, we present a case where constructing a community garden becomes an avenue for the youth to engage in heterogeneous engineering. This engineering project that was motivated by their deep care for their community supported their participation in political activism.

Keywords and Phrases: Community garden, community-based engineering, political activism, heterogeneous engineering

1 INTRODUCTION

Engineering has traditionally been conceived as objective and technocentric (Cech, 2014). But recent work argues that in real life, technical problem-solving and social interactions are both central to engineering practices (Law, 1987). The traditional engineering narratives do not support youth to see their assets valued in engineering and can cause a sense of unbelonging (Danielak et al., 2014).

Recent research in engineering education advocates situating engineering in youth's lives (Wilson-Lopez et al., 2016). And community-based engineering (Dalvi et al., 2016; Wendell et al., 2019) is a promising avenue in these efforts. It calls for designing a learning environment that situates in local communities. This asset-based approach (Gravel et al., 2021) is authentic to the youth because the contexts of communities allow them to engage their lives in engineering. Their funds of knowledge (Moll et al., 1992; Wilson-Lopez et al., 2016) become resources that support their learning.

Community-based engineering supports heterogeneous engineering, defined by Law (1987), as engineering that takes place in the real world where not only the technical, but the social, material, and political aspects are all woven together in design problems. It works with complex systems that involve multiple, often competing and "unruly" elements and contingencies (Suchman, 2000; Gravel & Svihla, 2021). Among the various aspects of heterogeneous engineering, the study of the political aspect that resists oppression and empowers marginalized groups in society (Vakil & Ayers, 2019) is relatively new compared to others (Ozkan & Andrews, 2022).

While community-based engineering has traditionally focused on the human-made world (e.g., Andrews et al., 2020), we imagine situating engineering within broader nature-culture relations that describe humans' interactions with the natural world, that is, their "more-than-human" others, like plants, air, water, winds, and the sun (Bang & Marin, 2015).

Gardening is a space that connects nature-culture relations with STEM learning, bringing assets and non-dominant ways of being to the fore (Bang, 2016). Gardening encourages its members to share their expertise to actively explore and make sense of the environment (Rahm, 2002). Community gardens provide space for personally meaningful questions for the youth (Rahm, 2002). They break down the power dynamic in classrooms as teachers and students become collaborators to solve these questions. Youth are positioned as creators not consumers of the STEM curriculum (Rahm et al. 2003).

While most of the existing research focuses on the community garden as a science learning space, we think that the community garden also affords a heterogeneous engineering learning space. In 2022, we worked with a public high school to construct a community garden on their campus. In this paper, we lay out a description of the program, show examples of heterogeneous engineering in constructing the garden, and provide an episode where the youth engaged with political activism through gardening and engineering.

2 DESIGN AND CONTEXT

The construction of the youth community garden stemmed from a long-standing partnership between a private university and a public high school in New England. The authors of this work-in-progress paper are educational researchers at the university. The high school is a large comprehensive urban high school that is racially, ethnically, and linguistically diverse. The partnership is ongoing for over 20 years, with various collaborative efforts including transforming a dormant woodshop into a thriving makerspace in the high school and co-designing the high school's new engineering curriculum.

At the end of 2021, the high school's engineering teacher and environmental science teacher expressed an interest in building a youth community garden together with the students. Starting in early 2022, youth gathered in their makerspace to experiment with different types of hydroponic systems (Figure 1), to design the outdoor garden space, to reach out to local gardening communities and the city for support and advice, and to start building raised garden beds (Figure 2). In the summer of 2022, the university funded a summer program where 13 youths from the high school were hired to finish the construction of the garden. Together, the youth built 23 raised garden beds for over 20 species (Figure 3).



Figure 1-3 (from left to right): Hydroponic systems inside the makerspace;

Youth building a raised garden bed in their makerspace; Plants thriving in the youth community garden.

3 RESEARCH METHOD

To study the youth's engagement with the youth community garden, we collected data from the end of the spring semester to the end of the summer of 2022. These data include 2 hours of audio recording of focus groups, over 200 hours of video and audio recordings of every day's activities during the summer program, interviews with 13 youths and 2 teachers we worked with, photos of artifacts, and 69 field notes taken during the summer program by the first author and 4 research assistants who also participated in the summer program.

We employ qualitative research methods to analyze the data. The examples and episodes provided in this work-in-progress were constructed through content analysis (Vaismoradi, 2013). We condensed the large amount of raw data into events and themes based on interpretation. Here, we provide descriptions of some phenomenon in their conceptual forms.

4 FINDINGS

4.1 Community garden as a heterogeneous engineering space

From field notes, we saw the youth engaging with heterogeneous engineering when designing and constructing a community garden. They engaged with a complex system that contains technical, social, material, and political dimensions. The technical aspects were reflected in developing and improving raised garden bed designs in response to environmental

conditions. The material aspects were reflected in the youth seeking ways to make use of existing materials due to budget constraints. Since the makerspace was once a woodshop, it had a large amount of wood materials from decades ago. The youth dug into the pile of old wood, identified and labeled those more suitable for construction, and created a template for building more than 20 beds. The social and political aspects were reflected in the youth considering the community garden's accessibility. When designing the layout of the whole garden, the youth made the space between the garden beds to be wider so people in wheelchairs can go through. They also built taller garden beds so people who are not comfortable bending their back can easily reach inside the garden beds to take care of the plants. The youth engaged with heterogeneous engineering by taking these competing elements into consideration when designing and building engineering solutions.

4.2 Political activism to sustain the community garden

Here, we present an episode where the youth engaged with political activism when building the garden. We highlight how their relationships with the plants and the community supported this activism.

At the beginning of June, the youth learned that the city council passed a resolution to move a historic house onto the space where the garden was located. A private real estate developer purchased the land where the historic house was originally located and promised the city to cover the cost of preserving and moving the house. The city decided that the moving destination should be on the only lawn of the high school where the youth community garden was located, without collecting much input from the high school. The council made these decisions after the youth had already put 14 garden beds out onto the lawn, filled the garden beds with soil, and transplanted some of the plants outside into the garden beds.

The youth were frustrated when they heard about the news. In a focus group on June 17th, Camila (pseudonym), a youth that actively involved in constructing the community garden said:

"The house. (...) And the fact that they didn't even alert us about it is just shocking because we are the ones who occupied the space. (...) that one moment, I just, I felt very frustrated and angry at the fact that they're just doing this for money. They're not doing this because they care about the only green space that we have in the high school. (...) There was nothing I could see that will benefit students, and also the plants."

Camila was angry that the city and the developer made a design decision that did not take her community's well-being or the plants' health into account. Because the school has little green space, the youth built the community garden so the students could connect more with nature. Especially during the COVID-19 epidemic, the garden provided a precious space for students to go outdoors, relax, and interact with their peers. However, the garden they built for their community was at risk because of the city and the developer's decision. The youth were aware that the decision was not made for their community's benefit and were frustrated that they had no say in the existence of the garden they built themselves.

The youth initiated multiple conversations with the city and the developer to seek ways for a change in the decision. They familiarized themselves with the city's point of view by watching recordings of recent city council meetings. On July 12th, the youth found some inconsistencies in what the councilors said regarding the plan to move the house. They crafted questions for the city and the developer and sent them the list of questions on July 19th. Some of the questions include: *Why is there a requirement for a 30 feet space in front of the house and how will it be used? What are some statistics about stormwater runoff implications of the loss of green space?* The youth's questions showed how poorly the information was conveyed to them, and reflect their proactive stance, demanding clarity, and committing to fighting for their acknowledgement. They effectively used evidence such as the inconsistency in the city councilors' meetings, and their knowledge about environmental conservation, to convene a meeting with the mayor, councilors, and lawyers.

While the house move was to move forward, the meeting the youth facilitated resulted in the developer covering the cost to move the community garden to a different location on campus. The youth worked with the city to compose a plan for the garden in the new location. When the garden was moved on August 4th, the youth were devastated to find many plants not surviving the move. But after the youth's restoration effort, the garden once again thrived in the new location and the youth were hopeful about planting new plants the next year.

5 DISCUSSION AND CONCLUSION

We demonstrated an initial view on how constructing a community garden provided a community-based engineering space where youth brought in their assets to participate in political activism. The motivation of constructing a community garden came from the youth's care for their community and their demand for more green space on campus. They designed the community garden by centering their community's need. As they cared for and interacted with the plants, the plants also became a part of the community. Therefore, when they encountered policy that impacted the well-being of their community, they stood up and participated in political activism.

In the future of this work, we plan to investigate the youth's perspectives with questions such as, how do the youth see their political activism in the garden? Does it influence how they see engineering? Does it influence how they see themselves in engineering? We will also investigate how the nature-culture relations in the community garden contribute to how they see their engineering work and how they see themselves in engineering.

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Turtle Geometry Today and Yesterday

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In this paper we illustrate how the interplay between two artists can lead to a plethora of designs. Explorations were done in TurtleArt and TurtleStitch, two microworlds based on Turtle Geometry.

Keywords and Phrases: Turtle Geometry, TurtleStitch, TurtleArt, Logo, Collaboration, Design, Microworlds.

1 TURTLE GEOMETRY IS ALIVE AND THRIVING

It's 2023 and Turtle Geometry is alive and thriving. It was invented by Seymour Papert in 1969 as part of the Logo programming language. Logo with turtles was first used by children in the 1970/71 school year. The focus of this paper is on the artistic explorations in two distinct microworlds, both offshoots of Logo: TurtleArt and TurtleStitch. TurtleArt is an environment for programming two dimensional images using code as the medium. It allows you to explore color, shading, shapes and composition, amongst other things. TurtleStitch has opened up the makerspace world to embroidery design and creative stitchery using a computerized embroidery machine. Both environments embrace a visual world, enticing beginners as well as experts. Explorations can lead to intricate designs where the user will discover concepts from programming and mathematics.

In this paper, we want to share with you a kind of collaboration we have experienced over the past years. We are each familiar with the other's work, but are also an expert in different traditions and practices. Artemis is an artist and uses TurtleArt as a creative medium. Cynthia is a teacher and researcher and has latched on to TurtleStitch as an expressive medium, and an enticing learning and teaching tool. What is described here links turtle geometry, TurtleArt and TurtleStitch. Both of us enjoy playing off one another's ideas and building on the other's designs. Because each of the two artistic mediums allows for things that are not possible in the other, adapting each other's design from TurtleStitch to TurtleArt or vice-versa can be challenging. However, it is always fun and stimulating.

2 THE STORY BEGINS IN 1971

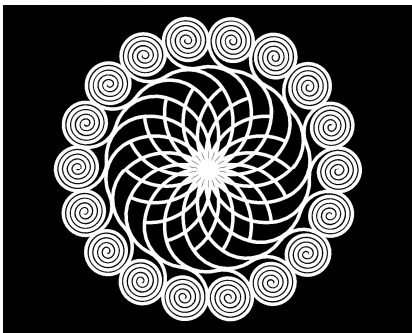
In 1971, a local Boston TV station (WCVB, Channel 5) made a documentary on technology and education, and included a segment of the 10-year old children who used Logo and had been exploring turtle geometry the year before. One project consisted of a baby swan with its mother. When the child ran her program, a bug appeared: the orientation of the swans relative to each other. However, in this paper it's the shapes of the swans that we are interested in.



Figure 1: Screen image of the swans project.

3 THE STORY CONTINUES IN 2023

Artemis sees the video during a presentation made by Cynthia and decides to re-construct the swan objects with TurtleArt. Artemis sends her design to Cynthia, saying ‘here’s some swans!’



Cynthia ’s first reaction was:

‘Nice! But where are the swans?’

Artemis replied:

‘Don’t you see them? They are going round in circles!’

Figure 2: Design inspired by the swans project.

To make it clearer, Artemis sent the image below to Cynthia.



Figure 3: a single swan

Cynthia sighed. The trick to the design was replacing the swan’s petaled head with a circular spiral. Artemis’s decision about the swan’s dimensions and how many of them to have in a circle is an artistic choice. Although the Turtle does the drawing, the artist is the ‘artistic director.’ The final design is the result of trying many different things, for example pen width, sizes of the spiral, neck and body, as well as the total number of swans.

As we continued our explorations and interactions, there was a lot of commenting on the intermediate results. For example, small changes in the pen size or the embroidery stitch made a big difference to the overall aesthetic. What was particularly enlivening was having feedback from a partner who was getting fully immersed in the project details. We spent several hours exchanging ideas and designs.

Before adapting it to TurtleStitch, Cynthia modified Artemis’ original design in TurtleArt.

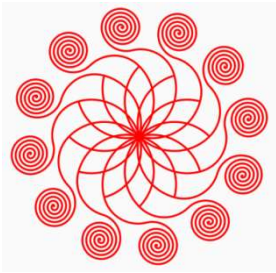


Figure 4: Cynthia 's adaptia of the design.

The next step for Cynthia was to program the swans in TurtleStitch. She had to make several adaptations to have it be better suited to the medium. For example, one turtle step is not the same size as one turtle stitch. She also made changes to the size of the body, neck and head, as well as the number of swans in the circle. The spiral heads were adjusted to be less dense. Finally, Cynthia had to decide on which embroidery stitch to use and, not least important, on which medium to stitch it on. Along the way she was showing Artemis her explorations.

Cynthia settled for a white thread on red felt, using the running stitch.



Figure 5: Stitched version of the design

Both TurtleArt and TurtleStitch focus on turtle graphics, i.e., what you can do with a computational creature that has a pen or a stitch. The act of exploration can set off a rippling effect of creativity. What was so exciting for us about collaborating together is the plethora of designs that emerged. Below are some variations spawned by the interplay between us and the dialogues we had.

Cynthia: 'What if there was a hole in the middle?' Artemis: 'You mean like this?' And sends this image to Cynthia.

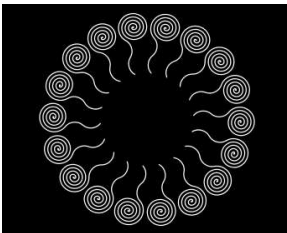
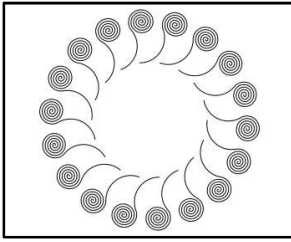


Figure 6: A hole in the middle.

Cynthia quickly responds: It's dizzying! Artemis's response was a new design.



Cynthia: Maybe a hole isn't a good idea after all.

Artemis: let's fill in the hole then.

Figure 7: A different middle hole.

4 A PROLIFERATION OF DESIGNS

It takes less time to draw than to stitch, so more variations were done in TurtleArt than in Turtlestitch. Below are some of the designs that were made during our explorations. Not all of the designs turned out to be good ones, but they all allowed us to explore spirals and curves and circles. It also allowed us to explore how small variations in sizes, shapes and angles can have a huge impact in the final design.

Collaborating together allowed us to bounce design ideas off each other and it increased the impetus for creating more and more images.

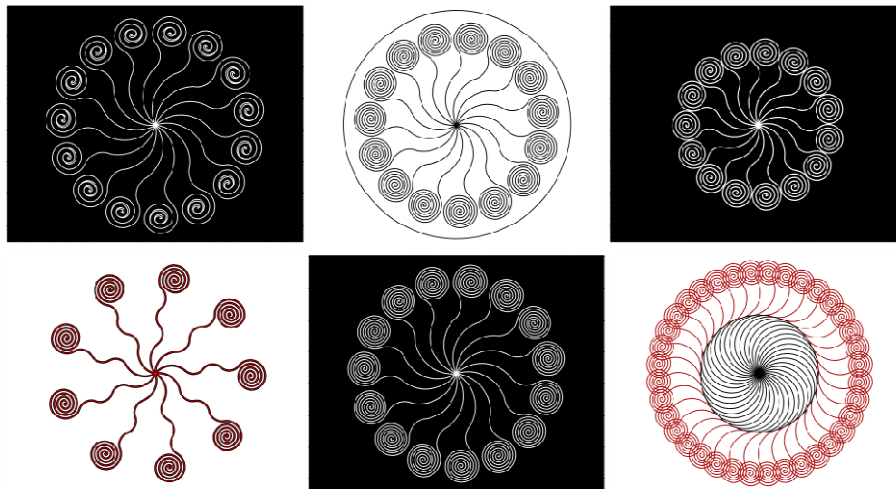


Figure 8: Some TurtleArt designs that emerged from the interchange between Artemis and Cynthia.

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The authors would like to thank Rehana Al-Soltane and Brian Silverman for their help with the manuscript. Brian Silverman has inspired Artemis for some of the variations of the TurtleArt images.

Supporting Knowledge Construction in Making via Collective Process-Oriented Documentations

Collective Process-Oriented Documentation for Making

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This three-year design-based study aims to explore knowledge construction in making and to present effective design of using collective process-oriented documentation as a means to enable learners and facilitators to recognize and reflect on learning collectively. Built upon previous research on process-oriented documentation, this research adds a collective perspective to students' documenting process in making. In addition, this study presents how auto-generated knowledge maps using natural language processing and network analysis techniques could be potentially integrated in a collective documentation practice to help students see the connections among different projects and learn from each other. The contribution of this work is two-fold: First, it suggests design and practices on supporting knowledge construction in making. Second, it provides rich descriptions on the process of knowledge construction in making that might not be able to be captured without such an interface.

Keywords and Phrases: maker education, process-oriented documentation, knowledge construction

1. INTRODUCTION

As pointed out by Petrich et al. (2013) in a reflection of their learning framework for makerspaces, "It looks like fun, but are they learning?". Activities in makerspaces tend to emphasize on building a physical artifact or learning how to operate different tools and machines (Blikstein and Krannich, 2013), but what about knowledge construction? It is sometimes assumed by teachers and practitioners that the production of physical artifacts in making represents the successful development of concepts and knowledge in learners' minds, but is it true? Valente and Blikstein (2019) suggested that through trial and error, a product can be successfully constructed without the learner necessarily being able to understand all the concepts involved in the process. Conceptual understanding doesn't always naturally happen during the making processes. Instead, such understanding needs to be intentionally constructed as learners interact with their objects, machines and peers. Thus, despite the notable excitement and suggested affordances of making (Peppler et. al., 2016), more work needs to be done on supporting teachers or facilitators in this context to take explicit and deliberate actions to encourage learners to go beyond this initial building phase. In addition, tools and frameworks to foster learning activities to support the process of constructing knowledge in making are needed.

Many tools have been developed for supporting knowledge construction in classrooms, such as Knowledge Forum which foster continual knowledge-building discourse among learners (Bereiter and Scardamalia, 2014) and Idea Thread Mapper which trace how ideas progress through collaboration in the classroom (Zhang, 2018). Yet there are limited studies reporting tools and practices to support knowledge construction and reflection for learning taking place in making. Platforms like Scatach and Instructables enable learners to share their making projects, but they are designed mainly for sharing and community building purposes, overlooking the need to deliberately facilitate the reflection and knowledge construction processes in making. Formative assessment tools like Beyond Rubrics (Murai et. al., 2020) or e-portfolios (Keune and Peppler, 2017) did help capture some aspect of learning in making, but more work is needed on designing effective and easy-to-use tools to support teachers and learners to go through this process of knowledge construction in

making. Tseng (2016) in her proposed designs to facilitate process-oriented documentation, and this work builds upon it by adding a collective perspective to the process-oriented documentation. In addition, this study presents how auto-generated knowledge maps using natural language processing and network analysis techniques could be potentially integrated in a collective documentation practice to help students see the connections among different projects and learn from each other. To examine this collective process-oriented documentation approach and provide rich description of knowledge construction experiences when using this approach, our work is guided by the following two research questions:

RQ1: In what ways does the act of building a collective process-oriented documentation support adult learners' knowledge construction in making?

RQ2: What factors of the collective process-oriented documentation support adult learners' recognition and reflection of learning, and contribute to its effectiveness?

2. METHODS

This study employs a design-based research approach (Armstrong et. al., 2022) to a) understand how learners reflect and construct knowledge in making and b) generate effective design and design guidelines. It involves 31 adult learners (7 in the year one, 15 in the year two and 12 in the year three) participating in a maker-centered design class in a R1 university in the United States from 2021 to 2023 in two phases of implementation and data collection. This maker-centered design course consisted of two parts: weekly theory-oriented lectures and hands-on labs. During the practice-focused labs, students were immersed in making activities, in which they learned to use digital fabrication tools to realize their design projects. By the end of the class, students were required to build a final project by identifying a problem of interest, brainstorming solutions, prototyping, testing, and iterating the design, and then finally presenting their functional prototypes. According to self-reporting, 24 out of 31 students had no prior experience with digital fabrication tools before taking the class. At the same time, due to special departmental arrangements for studio classes, there was considerable support for each student in the class. With a 1:2 teacher-student ratio (there were one instructor and four part-time teaching assistants), the teaching team was able to provide sufficient support to novice learners whenever needed in the learning and making processes. Such a setting provides a valuable opportunity for us as researchers to observe the needs and behaviors of novice learners when interacting with new technologies and tools, and how collective documentation might help them to learn and problem-solve.

2.1 Design Iterations

In the first implementation (2021-2022), iterations of the collective documentation interface design (implemented via the Miro Platform) were tested in the maker-centered design course. Based on insights from Implementation 1, a student-facing knowledge mapping dashboard was introduced in implementation 2 (Spring 2023). The dashboard is built using natural language processing and network analysis techniques based on the student inputs on the collective documentation interface, with an aim to help students see the connections among different projects and learn from each other. Figure 1 shows screenshots of the collective documentation interface design and the student-facing dashboard.

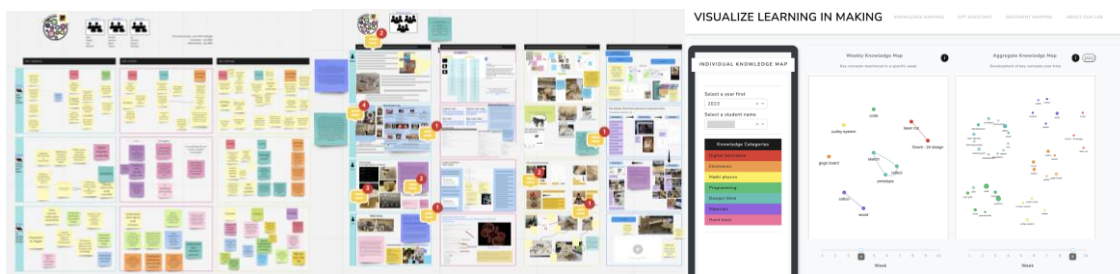


Figure 1: Screenshot of the collective documentation interface designs and the student-facing dashboard

2.2 Data Collection

Four types of data were collected during the two implementations: (1) individual testing sessions with think aloud protocol, (2) focus groups, (3) student-generated artifacts and (4) observation field notes. Individual testing sessions with think aloud protocol were conducted with each student during the semester to understand students' perceptions and interactions with the collective documentation interface and the student-facing dashboard. Focus groups (5-6 students per group) were conducted at the end of the semester to guide student reflection on their use of the collective documentation interface and their documenting habits throughout the semester. A total of 29 hours of conversations (15 hours for Implementation 1 and 14 hours for implementation 2) were recorded with consent and transcribed. In addition, student-generated artifacts include students' weekly posts on the collective process-oriented documentation, written assignments, and projects (328 boards of written artifacts were collected in total). Field notes consisted of written notes about critical incidents that happened in the course and photos of students' making processes and final products (15 pages of field notes and over 200 photos were collected in total).

3. PRELIMINARY DATA AND FINDINGS

Thematic analysis, following the methodology suggested by Swain (2018), is employed in our data analysis, and involves a three-step procedure: Firstly, a priori codes are formulated based on the research questions, interview questions and previous literature. Secondly, a posteriori codes are generated during the coding process. Finally, after one coding cycle is completed, both a priori and a posteriori codes are amalgamated into clustered codes. In addition, a case study approach (Creswell, 2009) is adopted to ensure the triangulation of data and to increase the credibility and validity of the research findings. The transcripts from individual interviews, testing sessions and focus groups, along with other data collected (i.e. field notes, written assignments, photos, and physical artifacts), are extensive and allow us to draw on multiple sources of information and develop case studies of how each student learned with the collective process-oriented documentation interface and dashboard.

This project is currently in the data analysis phase. Our preliminary findings reveal that adult learners utilized the collective process-oriented documentation to support their learning in three major aspects: 1) reflect on past projects, 2) get inspiration from others' progresses, and 3) develop a sense of community and a sense of achievement. With regards to the student-facing dashboard, students reported that the dashboard was particularly helpful in *making visible their transitions from novices to experts* throughout the semester and *highlighting implicit or hidden knowledge* in the learning community. Besides, the dashboard enabled them to see both *the overall trends/ commonality* in the class and the *diverse learning trajectories* that different people took at the same time. However, data from testing sessions and field observations also pointed out things for improvement, such as *the inflexibility of the dashboard layout* and the *lack of proper scaffold* on navigating and utilizing the collective documentation interface and the dashboard. Next, we would like to have a closer look at our data and the emerging themes. Additionally, we will explore details on how students interacted with the collective documentation interface and the dashboard, and what their process of knowledge construction in making looked like. A design framework to support knowledge construction in making and case studies of different students will be present in the future work.

4. SIGNIFICANCE OF THIS STUDY

The purpose of this study is to explore knowledge construction in makerspaces and to present effective design of using collective process-oriented documentation as a means to enable learners and facilitators to recognize and reflect on learning collectively. To sum up, the contribution of this three-year study to existing literature is two-fold: First, it suggests effective design and practices on supporting knowledge construction in making. Second, it provides rich descriptions on the process of knowledge construction in making that might not be able to be captured without such an interface.

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Multivocal Play an Interactive Exhibit

Multivocal Play

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This interactive exhibition centers the Multivocal Annotated Layers method to showcase and explore children's play across different cultures. The exhibit presents annotated posters from New York, Chiba, Tokyo, and California adventure playgrounds and invites visitors to contribute their own reflections, fostering an evolving dialogue. The result is an immersive experience that illuminates the universal aspects of play, builds international connections, and emphasizes the unique perspectives of young participants.

Keywords and Phrases: Adventure playground, Multivocal Annotated Layers, Participatory Research

1 THE MAL METHODS EXHIBIT

1.1 What You See

In line with Papert's (1980) constructionist approach of meaning through making the connected exhibit aims to highlight the transformative power of play and the inherent creativity and agency of children. The proposed exhibit will showcase a series of 30" x 20" annotated posters, capturing the essence of the authors' Multivocal Annotated Layers (MAL) method, with images collected from adventure playgrounds in New York, Chiba, Tokyo, and California. Each poster becomes a visual testament to the vibrant dialogue conducted among international play peers (see Figure 1 as an example exhibition layout). From the forgotten islands of New York to the forested landscapes of Chiba, rushing streets of Tokyo, and the abandoned school playgrounds of California, the images transport viewers to various cultural contexts and play communities. Each photo was captured and annotated by the users of the adventure playground free from the hands of the researcher. The annotations on each poster bring forth the unique perspectives and experiences of the participants from these distinct locations. Through their visual cues, the international play peers engage in a dynamic and multilayered dialogue, highlighting the similarities and differences in their play experiences across different regions.

The exhibition aims to foster a sense of global connection and appreciation for the universal language of play and its many imagined boundaries. Visitors will be able to immerse themselves in the rich tapestry of voices, memories, and interpretations captured in the annotated posters. The visual richness of the exhibit invites viewers to explore the nuances of each adventure playground, connecting with the participants' narratives and gaining insights into the diversity of play.

1.2 What You Do

In addition to experiencing the annotated posters, visitors to the connected exhibit will have the opportunity to actively engage with the methodology firsthand. As they explore the curated display, they will be invited to add their own thoughts, reflections, and annotations to the exhibit. This participatory element not only enriches the dialogue within the exhibition but also allows conference participants to practice and understand the methodology in real-time. This firsthand engagement deepens their understanding of the MAL method and empowers them to become active participants in the exploration of

play cultures and children's voices. Through this additional layer of annotation, visitors become part of the living exhibition, contributing to the evolving narrative and further enriching the multivocal dialogue.



Figure 1: Example display of proposed exhibit

This interactive element not only serves as an embodiment of the MAL methodology but also allows visitors to experience the constructionist perspective firsthand. In addition to the materials on the adventure playgrounds acting as “objects-to-think-with” these annotated tapestries also become artifacts to think with as makers deconstruct and reconstruct meaning (Papert, 1980). The exhibit thus becomes a space where visitors not only observe and learn about the research methodology but also actively practice and engage with it.

1.3 Where this came from

The MAL method adapts Joseph Tobin’s video-cued multivocal ethnography (VCME, (Tobin et al., 1989, 2011) to create a dialogue between participants (Figure 2). The method was imagined as a vehicle to hear voices often not included in conversation by creating the opportunity to have a more direct dialogue with ethnographic participants. These interactions expose participants and observers to a window of the unfamiliar, with the potential of new imagined practices. However, Tobin points out that while the participant can somewhat inform the editing, the research team still chooses where to point the camera (Tobin & Hsueh, 2007). Tobin argues that the researcher's subjective perspective and decision-making are an integral part of the research process and that they should be transparent about their choices and the potential impact on data. However, users are both the creators and players in adventure playgrounds therefore there is a need for the camera to change hands. Due to the age range, language use, and unique perspective of the adventure playground users, it is more important that participants have an imprint on the media from the first step of production. Handing the camera to the participant is crucial as we seek to forefront the participants' input, perspective, and physical viewpoint of the playgrounds.

The MAL method seeks to capture a range of youth voices, so the methods must be flexible enough to support a concrete, icon and indexical-based language for all ages. There is no doubt that most research prioritizes adult voice over youth voice. Even with the best intentions, bringing in or framing child-perspective in published research is extremely difficult. In a recent article, Sun and colleagues conducted an extensive review of 58 qualitative studies from 2012 to the early 2020s that claimed to include children's voices (Sun et al., 2023). The study revealed the challenges and complexities to including young children's perspectives in research. Many studies often used triangulation of methods and different perspectives of caregivers and school workers to increase credibility. However, the authenticity of children's voices may be compromised

when triangulating with adults' interpretations, as the caretaker or teacher's voice often overshadows youth's voice (Pearlman & Michaels, 2019).

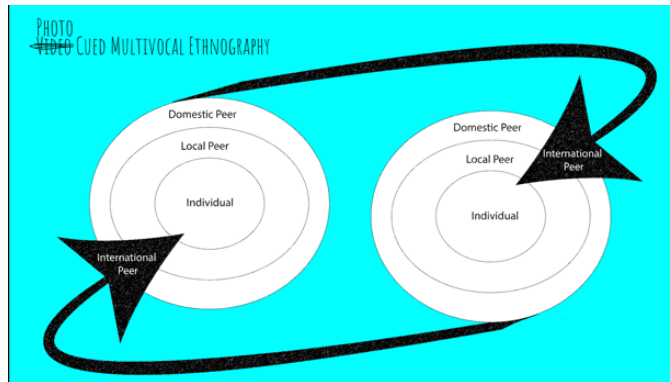


Figure 2: Diagram of Multivocal Layers Annotation method

Sun and Colleagues' review also found that interviews were the most common strategy to capture young children's voices, often combined with child-friendly methods like drawing or the use of emojis. Many other studies also used photos to elicit responses from children. However, the reliance on interviews may disenfranchise some children who are unable or unwilling to communicate verbally. This challenge is particularly salient in the authors' work because participants may not share a common verbal or written language. The review suggests that including multiple data collection methods can generate rich, credible data while enabling multiple modalities of expression for children.

Sun and colleagues (2023) also found that the practice and process of building rapport and addressing power imbalances were not consistently discussed, practiced or reviewed. In response our research combines three influential methods to include voice and dialogue among young people. The MAL method uses Cowan and Potter's (Potter & Cowan, 2020) technique of using youth participatory research and Templeton and Luttrell's (Luttrell, 2010; Templeton, 2020) technique of handing over the camera to participants. Both Luttrell and Templeton hand the camera to the participant not as an apprentice of photography but as a photo essayist. Luttrell encouraged participants to make a 27-image series using a wind-up disposable analog camera, where Templeton supplied digital cameras that could take several photos. Each parameter of these photo storytelling techniques adds a playful set of circumstances for participants.

This iteration of our MAL method is situated between the digital and analog. Participants are given a DSLR camera with the simple cue of photographing areas they have thoughts or memories about in the adventure playground site. The mechanical reflex of the camera helps with the tactile understanding of a captured image. Before participants are given the camera, they are asked how many photos they imagine taking. This cue question is set to help participants remember and imagine in their mind's eye the photos they want to capture. This simple process helps to dig into the user's perceptions of the playgrounds. This photo technique hands the camera over to the participant who is free to photograph away from the researcher's gaze. The participant then chooses two of the digital images they captured to be printed on-site on letter-size photo paper.

Adventure playgrounds often have very little technology present, and many playworkers rarely have a phone out in front of users. Therefore, it was crucial to minimize the level of technology brought in for this research. While there may be technology that comes in and out of the lots, novel researcher tech devices may be a distraction for playworkers and

users alike. Just as Templeton traced participant photos to notice components that the user had captured the MAL method created the opportunity for users to directly on the photos. These annotative practices help the researcher notice details that would be overlooked by only visually surveying the photo. The MAL method allows participants to both imagine and add context to what they directed the lens towards. After the first annotation layer is drawn by the original photographer, photos are blown up and printed for other site users to respond through additional annotation (see Figure 3). The twice annotated photos start a visual multivocal ethnographic dialogue. The photos continue on to other far off adventure playgrounds for distant playmates to respond to, adding a third layer of annotation. This process creates a dialogue between distant play peers as they witness, imagine, and respond to similar counterculture pockets of play.



Figure 3: Visual outline of the Multivocal Annotated Layers method alongside annotated photo

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Kaleidolight: An Interactive Device for Exploring Additive Color Theory Through Hands-on Creation

Kaleidolight: An Interactive Educational Device for Young Students to Explore Additive Color Theory and Create Visual Art Through Hands-on Learning Experience with the Integration of Light, Color, and Shapes

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Additive color serves as a vital component of both tangible and digital realms. However, comprehending and applying additive color theory can be challenging for learners in the absence of adequate visual demonstrations and scaffolds. Additive color theory employing light also offers immense potential for artistic creation, yet at school, it is often overshadowed by pigment and subtractive color theory, which are predominantly covered in school art curricula. In response to this gap, Kaleidolight is designed for learners aged 6 to 18 to facilitate an exploration of additive color theory and art creation utilizing light as a medium through hands-on playing and art creation combining RGB color and geometric shapes.

Keywords and Phrases: Additive Color Theory, RGB Color, Light, Creative Art, Constructivism, Tangible User Interface

1 INTRODUCTION

The world we live in is abundant with color, spanning both the world of atoms and the world of bits. Diverse combinations of varying intensities of primary colors create a vast spectrum of colors, both physically and digitally. Nevertheless, lacking a simple, effective, widely accessible method for presenting additive color mixtures (Figure 1), trichromatic principles of additive color mixture are still poorly understood by the general public (Travis, 2021), especially when subtractive colors with paint and pigment are the dominant color system taught and used in formal art education scenarios. Inspired by Constructivism, which advocates that learners are cognizing beings, actively making meaning through interplay with the surroundings (Fosnot & Perry, 1996), Kaleidolight facilitates learners' active understanding by interacting with this analog device to enhance their comprehension of additive color theory utilizing LED RGB light combined with colored filters. Moreover, coupled with basic geometric-shaped lenses, learners can construct their own artistic visual effects creatively.

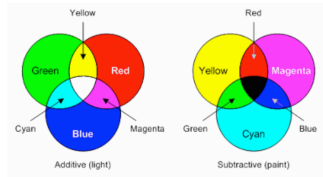


Figure 1: Additive color and subtractive color mixing.
Via Html Color. (<https://htmlcolors.com/additive-and-subtractive>)

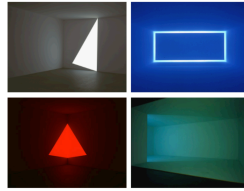


Figure 2: James Turrell's artworks using Light, Color and Shape.
Via J James Turrell. (<https://jamesturrell.com/work/date/>)



Figure 3: Color mixing mode.

2 RELATED WORK

2.1 Color Theories

Color wheels and color charts have been powerful tools for teaching color theory, yet they often fall short of providing comprehensive demonstrations of the color mixing process. Kelly (2015) situated traditional color wheels and color charts in an archaeological dimension engaged with history, but this solution can be time-consuming with too much distracting information and overload knowledge for learners. Sun and Wang (2019) used a projector with a manual focus function to produce defocus blur and reduce image quality for subtractive color mixing. Travis (2021) developed a method for observing, demonstrating, and teaching additive color mixture by using colored mosaic patterns displayed on computer screens in combination with a simple optical

diffuser. However, both of these methods heavily rely on instructor's operation, pre-designed images, and additional equipment. At the same time, they did not offer experiment opportunities for young students to actively engage with the color mixing process or opportunities for creative exploration. Ruiz and Ruiz (2015) developed a web app capable of analyzing the proportions of primary colors within any given color, yet this approach presents a more mechanical and passive learning experience.

2.2 Tangible Interfaces

Tangible learning experiences have been shown to enhance task performance and lead to higher learning gains for students (Schneider, Jermann, Zufferey, & Dillenbourg, 2010). Online RGB Color simulators, such as PhET (n.d.), provide interactive features that allow users to control the color mixing process. Carvalho and Hahn (2016) developed a device using Arduino Uno, intended for classroom settings, enabling young students to manipulate different light intensities for RGB colors to match a provided color. However, these products fail in offering learners opportunities for creative exploration and expression.

2.3 Art Creation with Light and Color

Handmade light projectors such as the star projector from cans and LEDs (Show Maker, 2017) can be a good example of artistic creation using light and colors. Yet, it is limited to one form and hard to be transferred into more open-ended structures. Meier (1985) developed BUCOLIC (Brown University Color Instructor) a series of exercises where learners can create all kinds of patterns and visual effects by changing colors while studying color theory. Unlike traditional painters working with paint and brush on canvas, American artist James Turrell works with light, color, and basic geometric shapes to create distinct visual effects for audiences (Figure 2). These projects inspired Kaleidolight, combining learning color theory and art creation in the same device.

3 DESIGN ELEMENTS

Kaleidolight enables learners to learn additive color theory by combining LED light sources with colored filters, subsequently facilitating the creation of unique artistic visual effects by applying the acquired concepts. The device features two main components: a portable light box and a filter kit. The light box is equipped with LED lights on the top, allowing learners to control and witness the process of additive color mixing firsthand. By incorporating filters of varying shapes and colors, learners can gain a deeper understanding of additive color theory and produce distinctive artistic creations.

3.1 Two Modes

Well-designed tools should provide novices with an easy entry point while also allowing sophisticated use (Myers, 2000). This device features two distinct modes: a basic color mixing mode for initial learning and an advanced color wheel mode for more advanced creation, both controlled by a microcontroller development board, micro: bit. In the color mixing mode, learners can adjust the brightness of the LED lights in red, green, and blue separately. The brightness of the LED lights emulates the amount of RGB colors contributing to the resulting color. By moving the three slide dimmer switches, representing three primary colors, from right to left, the RGB value alters from 0 to 255. Learners can regulate the speed of the color mixing process to observe subtle variations among colors (Figure 3). In the color wheel mode (Figure 4), learners can toggle between a static color wheel and a rotating color wheel, which can be employed to study complementary colors and generate artistic patterns.



Figure 4: Color wheel mode.

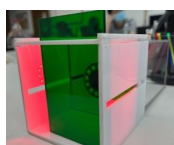


Figure 5: A green filter with red light.

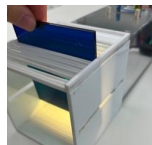


Figure 6: A blue filter with yellow light.

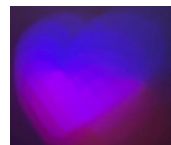


Figure 7: A magenta filter on the full color wheel.



Figure 8: Shaped filters.

3.2 Filter Kit

Creativity thrives when individuals can experiment with various alternatives, and the creative process is typically facilitated by a range of tools, each supporting a specific aspect of the task (Resnick et al., 2005). By placing filters in different translucent colors, shapes, and lenses atop the lights, learners can deepen their understanding of light absorption, reflection, transmission, and complementary colors. For instance, when a green filter is applied to red light (Figure 5), all colors are blocked because green absorbs red and only allows green to pass through. A similar effect occurs when a blue filter is added to yellow lights (Figure 6). In the color wheel mode, learners can experiment with various colored filters to eliminate unwanted colors. For example, by placing a magenta filter on the full-color wheel (Figure 7), only blue and red, and the colors created by mixing red and blue can be seen. In addition, by incorporating filters with various shapes (Figure 8) into the device, learners can generate an array of patterns and animations. Creativity support tools ought to encourage and facilitate extensive exploration (Resnick et al., 2005), so learners can utilize transparent film, vinyl, and Sharpies to create their own shapes and drawings, and then experiment with the lights. By introducing an additional layer of convex or concave lenses with varying focal lengths (Figures 9 & 10), learners can reconfigure the patterns they have created, enhancing the enjoyment of their learning experience.

3.3 Interface Design

Creativity support tools should ideally integrate effortlessly with other tools (Resnick et al., 2005). By employing analog slide dimmer switches (Figure 11), learners can determine the amount of RGB colors they wish to add by adjusting the position of the switches. With visual tags depicting the varying saturation levels of RGB colors, learners can effortlessly discern the direction for increasing or decreasing the RGB color values. The retractable filter holder (Figure 12) is connected to the main light box, ensuring adequate space for adding multiple filters and allowing learners to observe the differences when the light is at varying distances from the projection surface. To prevent light leakage, opaque vinyl has been added to the sides of the filter holder, and blinds (Figure 13) have been designed and attached to the top, which learners can open and close when changing filters.

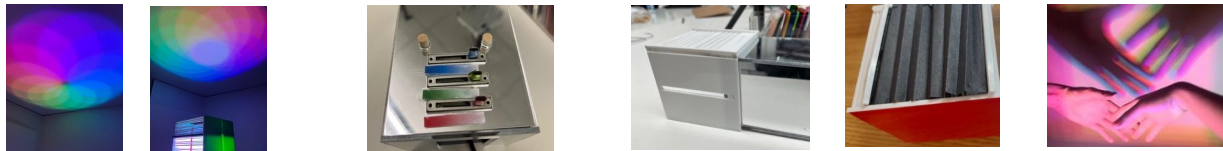


Figure 9 & 10: Adding convex lenses with different focal lengths. Figure 11: slide dimmer switches. Figure 12: Retractable filter holder. Figure 13: Blinds on the filter holder. Figure 14: Shadow play.

4. PRELIMINARY LEARNER FEEDBACK

When observing about ten learners without prior knowledge of additive color playing with Kaleidolight, I found several issues with the current prototype. Firstly, the learners had trouble understanding the functions of the buttons of two modes, leading to aimless interaction that quickly lost their interest. However, when they were given clear instructions and specific color-creation tasks, their interest and focus on the color-mixing process increased. Yet, despite successfully completing color mixing challenges, such as creating the color orange, their process seemed random and they could not recall how they completed the task, indicating that little effective learning happened. Secondly, the current design of the retractable filter holder allows for more than ten filters to be added simultaneously. This led some learners to add as many filters as they could to the light box, without any clear learning outcomes. Thirdly, the original design concept of the 12 LED lights was to create a static and rotating color wheel, allowing learners to create colors by filtering out certain hues. However, this design confused some learners who questioned the need for 12 lights, which results in overlapping and blurry images projected on the wall. Additionally, during the art creation process, the multiple light sources caused frustration because the multiple light sources made the shape that learners attempted to create not clear. Fourthly,

the use of acrylic filters with pre-cut shapes seemed to limit the learners' creativity. While some learners would like to create their own shapes more freely, the filters they made by drawing on transparent sheets did not create ideal visual effects. Finally, before I introduced the learning goal of this device, some learners started making shadow play (Figure 14) in front of the light, which is unexpected. These observations indicate that further redesign of the current prototype is needed to enhance its usability and effectiveness as a learning tool.

5. CONCLUSION AND FUTURE WORK

Kaleidolight is an effort to provide young students with hands-on opportunities to explore additive color theory through color mixing and filtering. The main light box and the supportive filter kit are tightly-coupled, allowing for creative space that supports learners in making unique visual effects freely. Currently a prototype, Kaleidolight still heavily relies on the instructor's assistance. In further design, the following elements should be considered: First, clear instructions, prompts, and step-by-step tasks are needed here to guide and support the learning and creative processes. Second, the filter holder should be redesigned and the instructions for adding filters should be more structured to better align with the intended learning objectives. Also, the color-mixing learning process and art creation process should be divided into two stages so the learners will not be overwhelmed. Third, to make the art creation experience more straightforward, a mono light source can be added in the middle of the 12-light wheel. Learners can toggle between a single light mode and a color wheel mode, thus enabling them to produce clear or abstract visual effects as desired. Last but not least, learners should be able to create their own filters in different shapes freely. Current materials such as acrylic and vinyl are not practical for learners to DIY. In the next prototype, Paper cutting could be a more efficient and low-cost strategy for learners to create shapes freely and quickly.

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SPATIAL: An Embodied Learning Design To Support Geometry Learning Through Collaboration and Physical Movements

Spatial

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This paper describes SPATIAL, a three-dimensional embodied learning space where geometry objects can be constructed, perceived, visualized, and expressed through collaboration and physical movement. As target objects appear on a computer screen, learners work collaboratively to create the object using the buttons distributed around them, comparing their creation with the target object by rotating it and viewing virtual representations from different angles. This paper reviews the theoretical frameworks and design elements that inform SPATIAL and briefly explains how learners can benefit from this design by visualizing, communicating, and experiencing mathematical concepts in a physically immersive way.

Keywords and Phrases: Embodied learning; geometry; spatial reasoning; collaboration; physical movement

1. INTRODUCTION

Students often find mathematics challenging to learn, as it is often considered obscure and abstract (Abrahamson and Bakker, 2016). For geometry in particular, it's difficult to transition from physical models (e.g., tangible objects) to symbolic representations of those mathematical entities and work entirely in the symbolic or mentally imagined space (Abrahamson and Bakker, 2016). These challenges motivated the design of SPATIAL, a 3D interactive space that aims to offer students an embodied learning experience in which they recreate target geometrical objects through physical movement, so that 2D and 3D objects can be constructed, visualized, situated, and shared in a physical context.

The idea of students building their own knowledge echoes constructivist views which regard cognitive development and understanding as agentic acts by learners. The concepts of embodied learning and action-based design are also associated with constructivist pedagogy as they aim to provide students with a meaningful learning environment and resources to support them in constructing their own understanding of mathematical concepts (Abrahamson, 2013). Thus, our design doesn't aim to focus on the direct teaching but instead emphasizes an agentic experience in a highly-designed mathematical space.

1.1. Background and Related Work

Geometry is a core discipline in mathematics teaching (Cesaria and Herman, 2019). The Common Core State Standards in Mathematics for fifth graders and up (our target audience) are included but not limited to classifying 2D and 3D objects into categories based on their properties, finding the surface area and volume of 2D and 3D objects, as well as drawing, constructing, and describing geometrical figures and the relationships between them.

When trying to achieve the above geometry learning goals, many students struggle to visualize abstract and complex objects. Research has documented several difficulties, such as transferring or reapplying their knowledge across contexts (Cesaria and Herman, 2019) and transformation errors (i.e., when students know what the problem asks but cannot determine what mathematical formula to apply, Arifah and Retnawati, 2020). Further, students often struggle to

distinguish relevant from irrelevant visual characteristics within configurations (Gal and Linchevski, 2010). This issue arises from a lack of visual perception and spatial reasoning, the ability to identify and manipulate objects' characteristics and spatial relations. Spatial reasoning correlates with children's ability to learn and achieve in mathematics and can be developed with practice (Rosenbaum et al., 2020). Geometric knowledge relies heavily on this ability and the skill of visualizing and imagining 2D and 3D objects. Hence, the design aims to provide students with an interactive learning experience where they discover patterns and construct their own understanding of the learned objects.

Scholars have suggested that physical movement plays a critical role in learning mathematics (Abrahamson, 2009). As students approach the same problem differently, turning mathematics into a physical experience that can be expressed physically and verbally, helping move to deeper sense-making. Our work is heavily inspired by the foundational design of Geometris (Durán-López et al., 2017), which offered resources for children to learn 2D geometry collaboratively. In Geometris, a tactile mat is connected to a computer screen. Other work, such as Walking Scale Number Lines, also offers geometry learning experiences that are similar to Geometris, but with fewer functionalities and technology support (Kelton and Ma, 2018). SPATIAL expands on these designs by moving to a 3D space, and adding different types of interactions and collaborative activities.

2. DESIGN ELEMENTS AND PRINCIPLES

In SPATIAL, a large computer screen is placed in front of a 2m x 2m x 2m space. Target objects appear on the right side of the screen, prompting students to create them by pressing different buttons on the four sides around them (left, right, up, and bottom). These 22 buttons are connected to an Arduino Mega board, and our software translates button presses to 3D coordinates, which are then shown on a digital simulation of the physical learning space (see Figure 1, left). These virtual representations are rotatable to help students observe objects from all angles (360°) to grasp the manipulated object thoroughly (see Figure 2, bottom row). Using movements in physical space, players work collaboratively to create 2D and 3D objects. Their interactions within the space are tracked and reflected on the screen. Students can receive real-time feedback while creating objects in various dimensions through their movements and comparing the virtual representation to the target object.

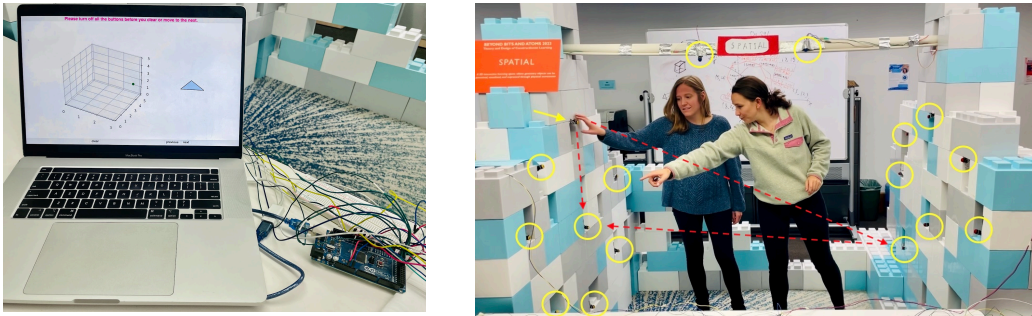


Figure 1: Right: When engaged in learning activities, students discuss and work together; Yellow circles highlight the buttons, with an example of one way a 2D triangle can be created within the space (red dotted arrows).

There are nine buttons arrayed in an octagonal shape on each of the left and right sides and two more buttons above and on the floor for a total of 22 (see Figure 1, right). As students press the buttons trying to build their planes or objects, the system offers real-time feedback on the screen. Figure 2 shows an example of a student recreating a triangle using three button presses (left) before rotating the simulation space for confirmation (right).

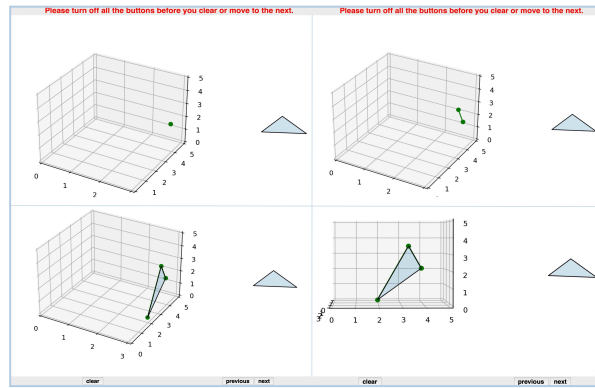


Figure 2: The above figures show from the students' view, how geometric objects can be constructed step-by-step (from left to right, top to bottom.) using the computational interface, compared with the target object, and rotated at different angles to observe by the students.

SPATIAL includes three activity levels: (1) recreating 2D objects (Figure 3, left); (2) building 3D objects (Figure 3, center), and (3) constructing a 3D object from a 2D net in the third level¹. As students press the buttons to create their objects, they have to make many decisions about their physical movement, planning, and sequencing them, since there are many valid ways to create objects.

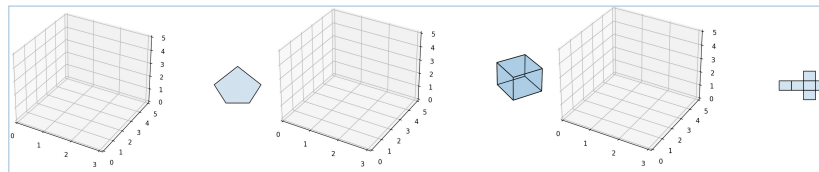


Figure 3: Illustrates the three different levels included in SPATIAL, with each level's difficulty increasing progressively. Starting with 2D shapes to 3D objects and moving to the net of a geometry object (left to right).

The above interactive design was supported by our research into previous designs and design principles:

- 1.Real-time Feedback of the Created Object:** Visualization is critical in understanding geometry concepts and abstract representations (Jones, 2002). In SPATIAL, real-time feedback is given on the screen, allowing players to track their movements and visualize the geometric objects they create. This design feature allows students not only to imagine the target figure they aim to create but also to track their movements as they create it in real time.
- 2.Rotation of the Virtual Representation:** One challenging part of learning 3D geometry is that the same object can look different when viewed from different angles. It is fairly difficult for students to mentally rotate objects and imagine their appearance from different perspectives due to the lack of visual and physical scaffolds. Accordingly, SPATIAL's "rotate" function allows students to rotate and view both the target object and its virtual representation as they create it (Figure 2).
- 3.Physical Movements:** Mathematical objects are rooted in sensorimotor models (Abrahamson and Bakker, 2016). Thus, students can better grasp mathematical concepts via activities designed to incorporate movement and action.

¹ In the third level, the goal result (a 3D solid) is not visually the same as the prompt (a 2D paper net), requiring the extra visualization step of imagining the 3D solid before creating it in SPATIAL.

4.Collaborative Learning: SPATIAL's learning goal extends beyond completing target movements in designed learning activities. Rather, it also includes important aspects related to collaboration (Laal and Ghodsi, 2012). Students need to communicate and express themselves to comprehend the meaning of their movements. Sharing created objects can foster students' domain-specific communication skills, and help them recognize various ways to perceive or describe a figure (Rosenbaum et al., 2020; Durán-López et al., 2017). In SPATIAL, students can collaborate while engaging in the designed learning activities, communicate and think together to connect with each other's ideas on how to construct the desired object (see Figure 1, right).

In initial user testing, several users emphasized that collaboration made the experience more unique and entertaining, allowing them to communicate and think aloud together. Users also pointed out that real-time visualization highlighted the steps of creating the target object and helped make their actions more intentional. Future design iterations will make the wall heights adjustable, increasing user accessibility, and include a physical grid system to mirror the virtual simulation, allowing students to situate themselves better.

3. CONCLUSION

SPATIAL offers students a tangible and interactive geometry learning experience. Importantly, its design could support students to think, experience, and communicate geometry objects differently by allowing them to create 2D and 3D geometric objects collaboratively via physical movements, empowering them to construct their own understandings of geometry concepts and develop spatial reasoning abilities.

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Creative Expression through Color and Sound: A NetLogo Model for the Sonification of Color and the Visualization of Sound

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This paper presents a Constructionist Model for students from age 8-10 to create multimedia abstract art that focus on the manipulation of color and sound. The design of the model is inspired by Wassily Kandinsky, an avant-garde artist of abstract drawings who experienced synesthesia in which he visualized music as colors and shapes and heard sounds while painting. Kandinsky explored and incorporated his senses of sounds and visuals into his artistic practices. The model referred to Kandinsky's famous drawing Concentric Circles and provided space for students to explore the relationship between color and sound.

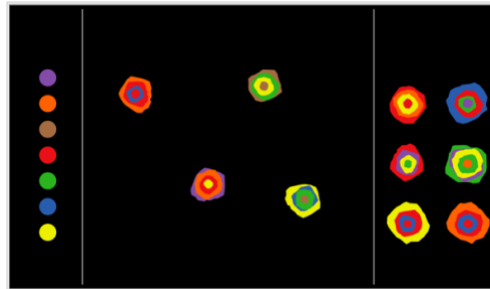


Figure 1: Demonstration of the NetLogo Model inspired by Kandinsky's famous work Concentric Circles

Keywords and Phrases: Constructionism, Creativity, Multimedia art, Arts education

1 INTRODUCTION

Children's creative expression through art and design is essential to their development (Barton, 2015; Boone, 2008). Dewey also brought up the four impulses of children, which is the “natural resources” of children's learning and development (1915, p.62). Specifically, the expressive impulse, which is the art instinct, is primarily determined by their "communicating and constructive instincts" in which the artwork expresses themselves (Dewey, 1915, p.60). Greene (1995, p.7) claimed that arts education is “integral to the development of persons – to their cognitive, perceptual, emotional and imaginative development.” As creativity and creative thinking skills becomes increasingly important, arts education on creative expression is a growing field in primary and secondary schools (Rosen et.al, 2020; Cho et.al, 2017). For example, Cho et.al (2017, p.2) emphasized that creativity development in the classroom would be beneficial for students' future “academic performance, learning processes, and lifelong learning”. However, research indicates that children between the

ages of 8 and 10 show a decline in their creative efforts, tend to conform to their peers and create things in the way they “should” appear, and lose the playfulness and originality of their artworks (Moran et al., 1983; Anthony, n.d.). Therefore, designing learning opportunities in and out of school to foster art expression becomes increasingly important in children development, especially for children between 8 and 10. In this paper, we present a constructionist computational model for this age group to create multimedia abstract art to promote their self-expression and support their creative efforts.

1.1 Self-expression through color and sound

Our constructionist model specifically focused on the manipulation of color and sound. Color has been used in artwork to express emotions. The evolution of abstraction, such as neo-impressionism, fauvism art movements around 19th and 20th centuries, were the first time in history that the independent effect of color was given center stage (Wisotzki, 2021). Art was no longer required to depict the physical world; instead, it became a personal reflection of the artist's emotional state and sentiments. The Blue Rider association founded by several artists at that time revolutionized arts by bridging colors and nonrepresentational forms and positioning them at the center of painting.

Wassily Kandinsky, an avant-garde artist of abstract drawings, one of the founding members of the Blue Rider association, experienced synesthesia, in which he visualized music as colors and shapes and heard sounds while painting. Kandinsky explored and incorporated his senses of sounds and visuals into his artistic practices (Miller, 2014). According to Kandinsky's theory of colors, “color directly influences the soul” and “produces a corresponding spiritual vibration. (Kandinsky, 1910)”

Drawing from Kandinsky's theory of colors and modern abstract art concepts, our constructionist model encouraged the creation of paintings as compositions of sound. Different colors and shapes represent a variety of sound and instruments, as well as different emotions. Our model introduced children to color and sound as a foundational step to express themselves in their artwork. Multimedia expression through both visual and sound enables children to fully exert their creative talents.

2 PROJECT DESCRIPTION

We chose NetLogo model as a medium for self-expression, allowing students to manipulate colors and receive audio feedback, which help students develop an understanding of how Kandinsky associated color and sound and used it to express emotion and feelings (Wilensky, 1999; Wilensky & Reisman, 2006). This also served as a scaffold for students to further express their state of mind through their own selection of the mapping of color and sound. Creating concentric circle patterns and sound has additional benefits of understanding complex systems (Martin et al. 2000). Through interacting with the model, students could see how each color sounds, how constructing different combinations of colors would sound differently from single notes, how locating and modifying the positions of the concentric patterns on the patch affected the sound of the chords. These variations address the concept of thinking rules for a single agentset and constructing them to build a complex system.

The educational activities would be two-phase exploration of color and sound in NetLogo (Wilensky, 1999). Inspired by one of Kandinsky's most representative works, the concentric circles, the model adopted the patterns, and associated with sound that each color represented in Kandinsky's depiction. Each color represents an instrument. Each concentric circle drawing is a chord. The first phase introduced students to Kandinsky, as a representative example of blending color and sound and emotions to further lead students thinking about their own self-expression through multimedia. After exploring the model that represented Kandinsky's artwork, the second phase provided students with more freedom to play

with colors, sound, and create their own patterns without the restrictions of recreating Kandinsky's color schemes. Students are encouraged to build their own color patterns and color-and-sound mappings.

2.1 First phase: exploring Kandinsky's color and sound mappings

Our first NetLogo model used the color and sound mapping based on Kandinsky's book "Concerning the spiritual in art" (1911), where students could listen to the sound of each color imagined by Kandinsky and hear the composition of simplified Kandinsky concentric circles. For example, Kandinsky thinks Yellow is "warm", "cheeky and exciting", "disturbing for people", "its sound is that of a trumpet or a bugle"; blue is a color that "moves concentrically, like a snail in its shell ... its sound resembles that of a flute, a cello, or an organ, etc. (1911). According to the representations of different colors, some of the colors would be in a lower range, and some of the other colors would be in a higher range. For example, blue is peaceful and deep, so it would be in a lower note range; red is youthful and joyful, but also symbolizes maturity, so it would have an intermediate note range; yellow would have a higher note range.

Referring to the above rule, we associated seven colors to seven instruments with a range of pitches. In order to create the sound of each concentric circle, the bottom layer is the root note of the chord, the second layer is the major third and the third layer is the perfect fifth, then the upper layer will repeat this mapping. Since each color is also associated with a lower pitch and a higher pitch, if the chord note is not within the pitch range of the color, we transpose the notes in corresponding range.

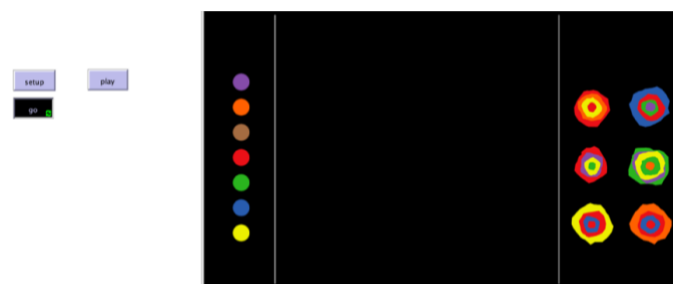


Figure 2: Screenshot of the NetLogo model where students could explore the mapping of color and sound by clicking on each color and the concentric circles to hear the sound and dragging the color to the middle of the patch to create different concentric circle patterns.

As figure 2 shown, the model displays all the colors and the concentric patterns. Students could click on the color to hear the sound of each color, or click on the fixed patterns from Kandinsky to hear the chord of each circle. Students could further make their composition by dragging the circles and making their own concentric circles on the patch. The location of the pattern would be their mouse position. Students could click on the play button, to hear the composition. The chord will be played from left to right, based on the x position of the concentric circles. From bottom to the top, the y position of the patch represents 7 chords of a major. Here's a [demo video](#) of the composition.

2.2 Second phase: creating personal mapping of color and sound

Our second model added an additional step of selecting color and sound. Students will be asked to choose their favorite colors and to envision an instrument for each color. Figure 3 is a demonstration of how students customize the color. By selecting a color for the circle, an instrument from the midi instrument list, and defining the pitch range, they could assign the color with the certain instrument and pitch. The rest of the interaction for composing and creating concentric circles would be the same as what previous model showed. Here's [demo video](#) of the composition and the interaction of modifying the location of the concentric circles.

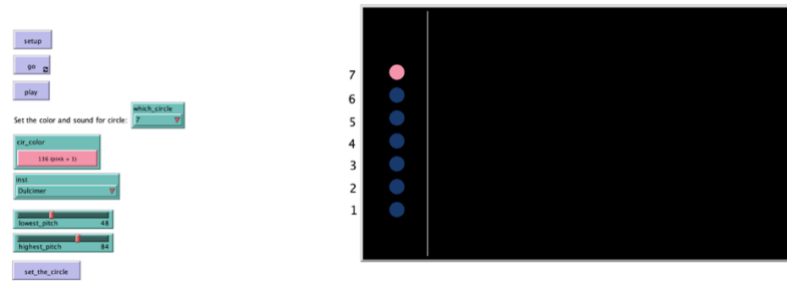


Figure 3: Demonstration of the color customization function.

2.3 Demonstration

The project could simply be demonstrated at the conference with a laptop and would not require much space.

3 CONCLUSION AND FUTURE WORK

The design goal of our activities and Netlogo models is to scaffold students to first understand the concept of the mapping between color and sound and play with Kandinsky's mapping of color and sound. Then, they are provided with open spaces to imagine and create their own associations of color and sound. We expect that the activity would support students' learning of abstract art and provide a multimedia approach for their self-expression. For future work, there could be more rules added to the platform, such as different shapes, different rhythms, or even real time interactions such as improvisation with patterns while performing, etc.

ACKNOWLEDGMENTS

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Stories and STEM: Designing for Relationship Building and Meaningful Forms of Expression in a Family Computing Workshop

Stories and STEM in a Family Computing Workshop

Designing for Relationship Building and Meaningful Forms of Expression in a Family Computing Workshop

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In this paper we share about the design and rationale of a computing activity aimed at centering storytelling and relationship building for families with children ages 7-12 engaging in a local library program. This activity was designed as an iteration of the Family Creative Learning workshop series and was collaboratively imagined and iterated on by the two authors, a graduate student researcher and a Library Program Assistant working within a makerspace in a metropolitan library branch. This activity, called Family Light Boxes, combines the Circuit Playground Express and Neopixels with everyday materials to allow families to explore how they might bring family stories to life using light, shadow and code. In this paper we share about the details of the activity, considerations behind the choices that were made in its design, and reflections about the affordances and constraints of designing for meaningful engagement with computing, storytelling, and everyday materials using these tools.



Keywords and Phrases: Culturally Relevant Computing, Storying, Family Learning, Community-based Design

1 INTRODUCTION

“Broadening participation in STEM” is a rare bipartisan issue with calls regularly veiled in language of the moral imperative to expand racial and gender equity. However, as Philip et al. point out in their piece, “Articulating the “how,” the “for what,” the “for whom,” and the “with whom” in concert,” these calls are often premised on a nationalist interest in economic and military dominance, rather than justice-oriented and liberatory purposes (2018). Literature across HCI shows the ways in which those who are most marginalized in society along lines of race and class are still *considered* less frequently in the design of new technology (Harrington & Dillahunt, 2021) never mind being at its forefront. It has become crucial to find new methods to extend whose visions of the future are being represented and brought into reality. This paper aims to show an example of a computing activity designed for families, not with the goal of expanding access to a CS education rooted in capitalism with the goal of all young people becoming coders and contributing to the US economy, but

instead motivated by all people having the same opportunity to design their futures, without their success being pre-determined by an unalienable aspect of their identity.

Informal learning environments like libraries can play a key role in inviting people into meaningful engagement with STEM learning, particularly by creating a supportive environment that helps learners develop their interest and identities as people who are capable and motivated to pursue STEM fields (Ito et al., 2009; Bevan & Michalchik, 2010). Making and tinkering spaces have spread widely across informal learning organizations with researchers documenting how they can support diverse learners to engage in STEM-rich explorations (Barton & Tan, 2018). These spaces have the opportunity to legitimize non-school based practices, like problem solving, design, iteration, and creativity for youth who may feel out of place or marginalized in traditional school settings (Resnick & Rosenbaum, 2013). Additionally, they are also spaces that can foster meaningful intergenerational learning experiences by building on children and families interests, recognizing situated family and community knowledge, and engaging families in socially supportive environments (Tzou et al., 2019; Vossoughi and Bevan, 2014).

Increasingly, justice-oriented approaches to computer science learning are emphasizing the importance of rooting the design of learning experiences in personally meaningful and culturally relevant practices for learners, drawing on constructionist traditions of learning (Papert, 1980). One decolonial method of developing STEM learning environments that repositions technology and supports expands modes of learning is centering storytelling. Storytelling allows for consequential engagement with disciplinary ideas while centering the interests, experiences, identities, and relationships of participants (Jayathirtha et al., 2020; Tzou et al., 2019; Pinkard et al., 2017; Roque, 2016). As a decolonial method, storytelling centers historically excluded voices, allowing for self-representation, testimony, and agency (Zhang, 2021). This paper aims to continue to push this literature forward by showing an example of a computing activity that also centers storytelling in its design and make visible some of the design choices made in order to support this form of engagement. .

2 ACTIVITY DESIGN AND CONTEXT

This activity was designed as part of Family Creative Learning (FCL) workshop series. FCL is a community-based program that invites families to design and invent together using creative technologies (Roque, 2016). An FCL implementation typically has five workshops and are held in a community center once a week for two hours each. This paper reports on themes across the design of two iterations across two years that were collaboratively designed and implemented with staff from a Mountain-West Library branch. Families for both workshop series were recruited via word of mouth from regulars who attended the makerspace in the library, posters in the library, advertisement on the libraries events calendar and a listserv specifically advertising events for emerging bilingual community members who speak Spanish and English. Throughout the workshops families are supported to work together as well as with other families participating in FCL. During this implementation families were invited to create digital lightboxes, or family light boxes, depicting a meaningful family story using a combination of familiar materials (construction paper, felt, plastic cups, mirrors, pipe cleaners etc.) alongside the Circuit Playground Express (CPX), neopixels and servo motors- physical computing tools that allowed families to add movement, light and sound to their boxes.

This activity was inspired by Light Play from the Tinkering Studio. The Tinkering Studio describes Light Play as an activity that encourages participants to build understanding of science phenomena like light and shadow in an artful way. Previously Light Play explorations have been centered around creating “vignettes” that emphasize exciting and often surprising effects created by combining everyday materials like mirrors, colorful plastic cups and strawberry cartons. In our workshops, however, we were excited by the possibility of using these materials to *bring family stories to life*.

Each FCL workshop is typically divided into four parts: Eat, Meet, Make, and Share. However, due to Covid-19 concerns, “Eat” was not included in this implementation. In Meet, families split up into two groups and facilitators meet separately with parents and children to talk about their experiences in the workshops and engage in activities related to the content in the rest of the workshop. In Make, parents and children work on their projects together. During Share, families talk about the progress that they made on their projects during that workshop to other families and receive feedback and questions. The four workshops were organized as follows: In workshops 1 and 2, parents and children began planning the family story they would like to depict in their light box. They began exploring the Circuit Playground Express independently in the “meet” portion of the workshop but worked mainly with craft materials during the “make” portion. In workshop 3, they continued collaborating on their family project and worked on incorporating code into their light boxes using the circuit playground, neopixels and motors. During workshop 4 they completed their projects and engaged in a community showcase where they were able to talk more in depth about the process of making their project together. This arrangement allows parents and children time to focus on being creators during kids and parents “meet” first, before they engage with each other as collaborators.

2.1 Articulating Our Design Criteria

Code in service to family stories

The first design criteria that emerged as we discussed potential activities for families during FCL was around how code was presented and positioned in the workshops. It was important to us that code was framed as a tool that could also be used for creative expression along with other materials families may be more familiar with like colored pencils, pipe cleaners or popsicle sticks. In this way, the emphasis was placed on families working together to bring their stories to life with a range of materials, rather than on only learning to code.

Encourage collaboration between, as well as among, families

Next, it was important to us that this workshop series fostered a strong sense of community among participants. For many families, this series would be their first in-person programming at the library since the onset of Covid-19. Especially since we were not going to be eating together to start out the workshops as a Covid precaution, we wanted the activity to serve as another way that families could build relationships as they learned with and from each other.

Seeing everyday materials as objects to make with

Finally, it was important to us that we balanced out the potentially intimidating technological tools like the Circuit Playground Express with materials that families were familiar with. However, we also wanted this activity to show families that those everyday materials around them can behave in surprising ways, be experimented with, and used to express your ideas.

3 DESIGN CONSIDERATIONS TO SUPPORT STORYTELLING AND RELATIONSHIP BUILDING

3.1 Introducing coding tools by highlighting their potential to make stories come to life right away

One way that we supported families in creating their Family Light Boxes was through the use of generative examples that showed the storytelling potential of the coding tools provided. For example, in one of the examples showed below Author 1 explained to participants how their own family’s favorite thing to do together is to play cards. She then showed how an input like a loud noise from people cheering if they won their hand in cards could trigger the neopixels to light up in flashes of rainbow colors, or how shaking the CPX in an act of frustration if you were losing might make the lights in the box flash red and play a “power down” sound to embody that emotion.

3.2 Allowing for responsiveness to materials in storytelling

Although families were given various scaffolds to them plan and articulate the story they may tell in their light box, they were also supported in being responsive to what they discovered while engaging with the materials. During the first workshop families were given time to “fearlessly explore” the various materials in order to see what might spark their excitement. Image 2 shows a family discovering that shining a flashlight into a crystal cut blue plastic egg created an effect that they said resembled bubbles underwater, inspiring them to tell a story of a dream they have as a family to go snorkeling together.

3.3 Playing with scale to encourage collaboration and community building

Finally, since the cardboard boxes that families were creating their light boxes in were large, this necessitated families collaborating to communicate with each other on either side of the screen what they were seeing. This interaction gave family members multiple ways to participate, either by manipulating shadow casting objects and light sources within the box, or by narrating what they see through the screen and helping direct potential changes to how materials are arranged. Also, this scale allowed for cross-family interaction as the families noticed what other participants were doing and asked each other questions to support their own making process, offered a helping hand to arrange objects, or expressed what they were noticing as families worked within their light boxes.

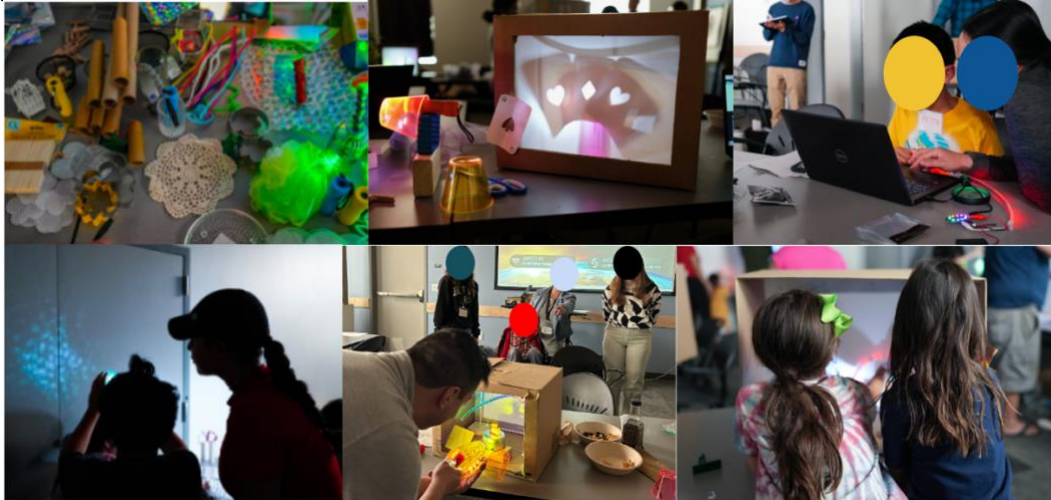


Figure 1: Collection of images from workshops. Image 1: sample of materials provided. Image 2: example light box about playing cards as a family. Image 3: mother/son pair coding a neopixel strip. Image 4: a mother/son pair exploring materials using a flashlight and plastic cup. Image 5: family working together on either side of a light box. Image 6: two un-related participants collaborating

4 CONCLUSION

This paper aims to show an example of intentionally designing a computing activity that engages families in constructivist learning and storytelling as a model of a justice-oriented approach to computing that is decolonial and rooted in participants interests, relationships and family knowledge.

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Civic Engagement in the Scratch Online Community as a Case for Civic Imagination in Creative Computing

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Learning to program can help young people see themselves as creators and scaffold their ability to participate in a technologically-mediated society. This paper proposes a framework for understanding the ways in which young people engage civically through computational making. We aim to represent the various ways that civic engagement is actualized in young people's media production practices via the Scratch online community to draw attention to the need for the incorporation and promotion of speculative pursuits that move toward civic action. We also consider opportunities for educators to design civic-focused experiences for young people learning to express themselves using digital tools. We define the four components of the framework—civic identity, civic awareness, civic imagination, and civic action—through discussion and analysis of example projects shared by young people on the Scratch online community.

Keywords and Phrases: Civic Imagination, Creative Computing, Equity

1 INTRODUCTION

Around the world, not only do young people vote, march, and protest in physical spaces, they also engage in civic participation through digital modalities: creating, critiquing, and remixing digital media artifacts. Young people's engagement with digital media creative production has the potential to support their abilities to expand their civic imaginations and envision possible futures and forms of civic engagement (Gargroetzi et al., 2021; Jenkins et al., 2020). One online community where young people are already developing their capacity as civic agents is Scratch, where learners can create and share block-based programming projects about anything they care about with an online community (Roque et al., 2016).

There are many logics underlying the need to broaden access to computing; several of these logics focus on the need to support learners in developing their computational creativity such that learners can communicate and participate in our technologically-mediated society (Vogel et al., 2017). Within the last decade, there has also been increased interest in supporting learners to connect their interests, as expressed in informal learning contexts, to academic disciplinary content, in formal schooling environments (Ito et al., 2013). Creative learning theorist Mitch Resnick draws from Seymour Papert's influential writing on constructionism to argue that learning to code should take place within environments that support the "4P's", where young people are working on projects, inspired by their passions, in collaboration with peers, in a playful spirit (Resnick, 2017). Each of these "P's" can support young people's motivation to persist through the challenges that come with working on computing projects, but in our work as educators and activists, we have also noticed how young people, particularly from non-dominant populations, can also become inspired to learn to program through the desire to create projects that allow them to engage civically.

Rooted in constructionist and creative learning design principles, Scratch is a programming language and online community that was first launched in 2007 as a tool to enable young people to create and share interactive games, stories, and animations (Resnick, 2014). Young people in the Scratch community (primarily aged 8–16), "Scratchers," engage with other Scratchers by creating, remixing, liking, and commenting on projects. Scratchers can also participate in and contribute to Scratch studios, project galleries curated around a specific topic or interest. Today with over 100 million unique accounts created in Scratch to date, more young people have access to engage with creative computing.

However, because computing has historically excluded learners with non-dominant identities (race, ethnicity, gender, sexuality, socioeconomic status, etc.), there still exists a need to consider how creative learning and computational making can occur in an equitable environment that centers the ideas and interests of non-dominant youth. (Margolis et al., 2008). When non-dominant youth are given the opportunity to use technology as a tool to express themselves and create change within their communities, they can expand their civic imagination, develop critical computational literacy, and further develop capacity for civic engagement (Jenkins et al., 2020; Lee & Soep, 2016).

In this paper, we propose a framework for civic engagement that serves a case for civic imagination in creative computing by highlighting examples of projects created and shared in the Scratch online community. We aim to support researchers, curriculum designers, and educators in designing learning experiences for young people to cultivate their creativity, computational fluency, and capacity as civic agents. Using Scratch as a point of exploration, we ask, how does civic engagement show up in the Scratch online community and what insights does this offer for how we might support civic imagination?

2 A FRAMEWORK FOR CIVIC ENGAGEMENT

We have identified four categories in the framework for representing how civic engagement is represented in Scratch projects shared in the online community: civic identity, civic awareness, civic imagination, and civic action. They are summarized in Table 1.

Table 1: Civic engagement framework

Civic identity	Civic awareness
engaging with and sharing personal stories about aspects of one's social location (e.g., race, class, gender, sexuality, ability)	expressing solidarity, allyship, or general support of the experience of a social group or cause that a person may or may not directly be a member of or impacted by. Awareness may be raised through sharing information in ways that communicate an acknowledgement, appreciation, and/ or understanding of other people's lives and experiences.
Civic imagination	Civic action
envisioning new and/or alternative circumstances, conditions, and futures based on aspirations for a better society. Imagination emphasizes the importance of collective hope and creativity.	participating in action taken toward a desirable end that directly identifies and/or combats systemic issues to address a perceived societal need. Action may include petitions, marches, protests, and engaging with community representatives.

While the categories proposed in the framework above are not meant to exist as distinct delineations they are meant to serve as ways for classifying the various ways in which civic engagement may manifest itself through creative computing. Civic identity is explored in ways that young people answer questions about the origins of their name and family heritage, and in consideration of role models that they identify with. Scratch projects classified under civic identity articulate an in-group experience about the navigation, negotiation, or representation of identity in public or private life. Civic awareness is embodied through making projects with the goal of educating others about topics like gun violence, climate change, and mental health. Civic imagination projects explore what a community may look like if an issue (or set of issues) no longer exists. Civic action can be explored by considering the steps towards enacting change in communities and can occur on different scales.

In establishing an understanding of civic engagement through these projects, we find that engagement more centrally refers to the topic and content of the project. Our notion of civic engagement in creative computing does not directly necessitate the real-world applicability of the final product. It does, however, encourage creativity in the act of civic dreaming that is integral in achieving justice-oriented outcomes (Yu et al., 2020). In the same way that creative learning refers to play as being playful in spirit and in process, we conceptualize engagement as an indication of a learner's desire to make things based on their interest in social justice topics.

3 CONTEXT AND ANALYSIS

In the Scratch online community, young people practice civic engagement by creating projects about recent world events and/or advocating for change within the platform itself (Roque et al., 2016). We conducted a content analysis of over 80 shared projects and over 30 studios represented in the Scratch online community to explore the diverse ways in which civic engagement shows up in computational creation. The project package included the Scratch programming blocks, as well as the instructions, media assets, and the notes and credits provided by the project creator. As we recognize our work contains potentially sensitive information involving children, to preserve the anonymity of the creators, we do not include project titles that are searchable on Scratch or usernames that may identify a specific individual. All projects shared on Scratch have a "See Inside" option that allows viewers to access the editor interface to view project assets and code blocks. Some projects used as few as two code stacks, while others used many sprites and backdrops, each with their own sets of block stacks controlling the animation and user interaction with the project. Projects collected for the analysis were obtained using the publicly available search feature on the Scratch website that searches all projects shared in the community based on provided keywords or phrases. The query returns specific projects and studios matching the search term. Search terms included phrases such as: "diversity", "identity", "justice", and "ideal". Projects were collected and coded using the four components of the framework as themes, noting the topic, content, and composition of each project. We selected one example project in each category in the study with references to others also noted as support. Based on our descriptions many of the projects sampled in the analysis could apply to more than classification (i.e., one could argue that civic action requires a certain level of civic awareness) but, for the sake of the analysis we offer examples that highlight the key distinguishing attributes of each component.

3.1 Civic identity

Figure 1a shows a project in which the Scratcher talks about their experience as a transgender person. The project shares the journey of how the person came to understand their gender identity and how being a member of the transgender community is

a point of pride that makes them who they are. Civic identity is also commonly represented in Scratch projects through the creation of custom sprites that represent diverse cultural or ethnic identities. These various identities include examples such as Hmong dress-up, acknowledgments of Asian Pacific heritage month, and interactive Aztec masks.

3.2 Civic awareness

Figure 1b shows an interactive game created for the purpose of teaching friends (on Scratch and in-person) about the significance of Juneteenth and how to celebrate the holiday. The example project's instructions offer definitions like Emancipation Proclamation that give the viewer useful background knowledge for understanding the context further. They also make recommendations that encourage others to do their own research on the topic.

3.3 Civic action

Figure 1c is an example of civic action in which the project itself is a petition to stop climate change. In addition to signing the petitions in the digital realm, the project creator notes that for every signature 5 real trees will be planted. Other Scratch project examples representing civic action include candlelight vigils and virtual protests/ marches for various causes ranging from animal abuse to the Black Lives Matter movement.



Figure 1: Scratch project examples – (left to right) (a) civic identity, (b) civic awareness, (c) civic action.

4 THE CASE FOR CIVIC IMAGINATION

We define civic imagination as envisioning new and/or alternative circumstances, conditions, and futures based on aspirations for a better society. Imagination emphasizes the importance of collective hope and creativity. Through creative computing, young people have the ability to envision and create computational solutions that address societal issues, promote civic engagement, and foster positive societal change. Scratch provides young people, particularly those with non-dominant identities, with a tool and platform to develop their technological fluency and creative abilities to address complex social problems and disrupt deficit narratives about their ability to contribute to civic and social discourse. Additionally, Scratch provides young people with the opportunity to produce a computational artifact that conveys their vision that can be shared with others in their communities.

Scholars have theorized Afrofuturist perspectives in constructionist learning through a framework that emphasizes the need for Black youth to critically interrogate sociotechnical systems by taking both an individual and communal lens to reflect on lived experiences (Holbert et al., 2020). Combining critical design and critical pedagogy explore the physical spaces and mechanisms through which the making of artifacts enables young people to “define new visions of STEM, their visions of future technology, systems, and societies elevate priorities and perspectives that are uncommon in these domains as they are currently conceptualized”.

A constructionist approach to civic engagement allows young people to explore the impact of civic action and develop “a critical lens and set of working theories through hands-on design” (Soep et al., 2020). This approach disrupts the traditional way of teaching computing and allows for participation from young people who have been historically excluded. Furthermore, it supports the theories of scholars such as Seymour Papert, Sherry Turkle, and Mitchel Resnick in believing that young people can be epistemologists and have the ability to construct their own knowledge by building/creating. Engaging in creative computing activities that encourage and support civic imagination allows young people, and in particular non-dominant youth, to actively learn about and design the positive changes they want to see in their communities.

5 DISCUSSION AND FUTURE WORK

While this analysis helps to support the framework for conceptualizing civic engagement and provides a lens for scoping the space for civic imagination in creative learning experiences with computing, it also highlights the types of societal issues that young people are interested in and already engaging with. The numerous projects collected indicate that young people have the desire and see value in practicing their civic agency and voice. There is an opportunity for educators in informal and formal learning environments to facilitate these types of computational making experiences as a mechanism for offering authentic learning experiences based on interests (National Academies of Sciences, 2021). This supports our emphasis on the importance that constructionism places on the process of making over the resulting product, even when learning key computational concepts.

Through this study, we have explored how computational media can support civic-oriented intentions by classifying the ways it is represented in projects shared in the Scratch online community: civic identity, civic awareness, civic imagination, and civic action. This framework can inform the design of creative experiences that support educators in facilitating purposeful computational making for their students toward equity and societal topics (Authors, 2022). Strongly connected to civic purpose, each of the current elements of our framework also supports young people in developing their civic imagination as they create in ways that encourage “other youth to ‘imagine better,’ to envision alternatives to current conditions, and develop new pathways into political and civic engagement” (Gordon & Mihailidis, 2016). Scratch enables young people to connect with the imagination of others through computation and encourages an exploration and interpretation of civic purpose that is centered on creative process.

Although we identified many project examples that could be classified as civic identity, civic awareness, and even civic action, there was a lack of representation for projects that exemplified civic imagination. In our previous work, we designed a civic engagement curriculum with activities that supported young people in exploring civic identity, civic awareness, and civic action. Our next step is to expand the curriculum by developing and implementing creative computing activities that encourage and support civic imagination.

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MAKING AT SCHOOL: EXPERIENCES FROM THE DESIGN-BASED RESEARCH PROJECT

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This paper explores the transformative potential of Making in fostering self-guided, hands-on learning among students in grades 5 to 9. It presents the two-year initiative, "Making at School", wherein Zurich University of Teacher Education (PHZH) created and tested different Maker Education scenarios. A cohort of 13 educators received professional development, subsequently implementing the designed scenarios across approximately 60 classes, thereby engaging around 600 students. Applying the principles of design-based research, the training programs were iteratively enhanced, leveraging methods including teacher interviews, focus group discussions, and student questionnaires. Preliminary results indicate that while educators could introduce new concepts within their classrooms successfully, there emerged a need for additional support, particularly for advanced courses.

Keywords and Phrases: Maker Education, Teacher Development, Maker Tools, Design-Based Research, Embroidery Designer

1 INTRODUCTION

Maker Education is becoming increasingly important in education that is being initiated and developed in the educational community (Schön, Ebner and Kumar, 2020; Schad and Jones, 2020). Making - the process of tinkering, designing, and crafting with digital tools - creates opportunities to engage students, teachers, and pupils in problem-oriented approaches through creative project work in an open learning environment, bringing together disciplines such as computer science, natural sciences, art, and technical/textile design (Schön/Ebner 2020). In computer science, the focus is on process-oriented assessment and a fearless failure culture with open tasks for creative problem-solving in the sense of computational or design-based thinking (Schön, Ebner, and Kumar, 2014). As part of a digitalization strategy, Making enables learners to build a bridge between the digital and analog worlds.

With the introduction of the Swiss Curriculum 21 (lehrplan21.ch) in German-speaking Switzerland, a strong focus on general competences and future-oriented skills such as creativity has been observed in schools (Petko, Döbeli-Honegger, and Prasse, 2018). Here, Making offers children and young people the opportunity to engage in the production of creative designs or digital projects. However, Making is still in its early stages in schools and many teachers are not familiar with the concepts (Maurer and Ingold, 2019). The few existing tools and applications either assume that teachers have prior knowledge and understanding of Maker concepts, or they are limited to single, self-contained activities. Making, therefore mostly takes place in workshops or electives and is rarely recognized as a holistic teaching concept.

In this paper, we would like to share our first experiences from the "Making at School" project and provide insights into the five workshops designed for teachers.

2 THE “MAKING AT SCHOOL” PROJECT

The project "Making at School" (explore-making.ch) is a two-year research and development project of various Maker courses for school levels 5-9, supported by the Digitization Initiative of Zurich Universities (dizh.ch). The innovative aspect of this project is the interdisciplinary approach of the Maker activities by including natural sciences, robotics, art, and design. In the following, the five courses developed in the project are presented alongside the relevant literature.

2.1 Making Basics & Methods

The basic course consisted of two parts and was conducted in March and May 2022 (3.5 hours each). The aim for teachers was to build an understanding of Making and to become familiar with different Making tasks (Schön, Ebner, and Narr, 2021). Teachers were encouraged to learn about and try out methods such as design-thinking or documentation options (e.g., with BookCreator). To support teachers, an instrument was developed that structures the planning process while providing ideas for specifications, methods, and topics (Spieler et al., 2022). Between the two courses, the participants carried out their own teaching projects. The following 8 projects were carried out: masks were crafted for the school ball, materials were recycled and made into games or decorations, towers were built from different materials, and they used creativity against digital terror (e.g., surveillance) was designed in textile designs (see Figure 1).



Figure 1: 1a: Masquerade. 1b-c: Textile creativity. 1d-g: Upcycling. (CC-BY-SA 4.0 “[Making im Unterricht](#)”)

2.2 Making & Digital Fabrication

"Rapid tooling" machines such as 3D printers, CNC machines, or laser cutters are very common in Makerspaces. Laser cutters and 3D printers in particular offer the potential to realize creative and innovative projects in form of "digital fabrication" (Iversen et al., 2015; Iivari et al., 2016). A specific course followed in August 2022: "Lasercutter 1x1". During the course, the online tool "vectr.com" was used. An introduction to the laser cutter was given and the possibilities of using different materials such as glass, wood, or acrylic were discussed. The implementation in the classroom, as well as challenges and opportunities, were addressed.

A 3D printing course was introduced in March 2023. This time the participants used "TinkerCad". It started analogously with different shapes from which an animal or building was to be built. In addition, examples were shown, and own ideas were implemented. This time 6 teachers did projects with their class using the laser cutter. For example, key rings and other shapes, or Christmas tree decorations with the "word of the class" and fruits were cut into pieces, scanned, and cut out to create lights (see Figure 2). Classroom projects with the 3D printer are still ongoing.



Figure 2: 2a-c: Cut out fruits. 2d.: Christmas tree ornaments. (CC-BY-SA [4.0](#) “[Making im Unterricht](#)”)

2.3 Making & Digital Pattern Creation

The concept of digital patterns implemented with an embroidery machine is not new. The Vienna-based project TurtleStitch (Wolz, Auschauer and Mayr-Stalder, 2019) already presented this idea in 2015, and the Maker movement has also become aware of these possibilities. With the development of various physical computer products, digital fashion can also become wearable and interactive (Kafai et al., 2021). For example, embroidered fabrics can be equipped with conductive threads or LED lights, turning them into “e-textiles” or “smart wearables”.

In the advanced course “Digital Patterns” the focus was again on the workflow: from one’s own sketch to the embroidered fabric (Spieler et al., 2020). An important step in this process is abstraction (Angeli and Giannakos, 2020). This means simplifying the design step by step and transforming complex designs into the simplest possible programmable geometric shapes (e.g., circles, lines). Since most of the teachers had no programming experience, the introduction to the app Embroidery Designer was less a free experimentation and more a step-by-step programming. Three teachers have tested this way of Making in class. The students either created their own designs or made programmable patterns from the children’s wire faces (see Figure 3).



Figure 3: Digitized wire portraits. (CC-BY-SA [4.0](#) “[Making im Unterricht](#)”)

2.4 Making & Physical Computing

Physical computing projects overlap with other disciplines such as textile and engineering design, art, science, and technology (Grillenberger, 2023). Microcomputers, e.g. BBC micro:bits, are specifically designed for educational purposes to enable hands-on experimentation and exploration and to show how to connect the physical and virtual worlds (Hodges et al., 2020). This course was piloted with educators in March 2023. Participants received an introduction to micro:bit, sensors, and actuators and learned how to integrate them into their lessons. This time, teachers with a background in science subjects were explicitly targeted. In June 2023, projects (e.g., class mascots) will be carried out with two teachers.

3 DISCUSSION & CONCLUSION

This intensive two-year mentoring of teachers has led to a certain rethinking and increase in competence. In particular, the teachers from the area of technical/textile design became familiar with modern technical tools, programs, and programming and felt able to try them out independently with their classes. However, it also became clear that the teachers wished for more intensive support and guidance, especially with previously unknown tools.

For this reason, a room is currently being set up at PHZH as a Makerspace, which will be available to students, teachers, and classes. Many participating teachers would also like to set up a Makerspace at their school and face similar challenges. With the experience we are gaining in planning the Makerspace, we can provide teachers with targeted support for their projects and offer additional advice in Making.

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Transforming Teaching Science Education: Case Studies on Implementing a Constructionist Curriculum for Middle School Students

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This paper presents two case studies of the implementation of a constructionist curriculum unit tailored to middle school students based on the IDEIA Science Curriculum. The Pedagogical Redesign Teachers from a disadvantaged region in Latin America share their perspectives, experiences, and challenges in adopting a student-centered approach to teaching science. The first case study focuses on seasonal variations, emphasizing the connection between geographical location and seasonal patterns. The second case study explores air masses and climate, aiming to develop students' understanding of the relationship between air mass displacement and observed climatic conditions. Both case studies highlight the positive impact of student engagement and the transformation of the teacher's role from instructor into a facilitator of knowledge construction. Despite challenges, the implementation of these constructionist approaches fosters meaningful learning experiences and enhances student engagement, encouraging other science teachers to consider similar teaching practices.

Keywords and Phrases: Constructionist curriculum, Student-centered learning, Pedagogical Redesign Teacher, Middle School

1 INTRODUCTION

This paper, which is a work in progress, presents two case studies that showcase the implementation of a curriculum unit tailored to middle school students, aligned with newly introduced science standards (Currículo de Ciências Ideia, 2020). Over the past years, a group of middle school science teachers underwent training to assume the role of Pedagogical Redesign Teachers, in which they dedicate themselves to co-designing and implementing a science curriculum rooted in science and engineering practices (Windschitl, Thompson, Braaten, 2020) and utilizing maker labs. The first and second authors of this paper, middle school Pedagogical Redesign Teachers from a disadvantaged region in Latin America, share their perspectives, experiences, and challenges in implementing a curriculum, designed around science and engineering practices, that significantly impacted their teaching as well as student engagement in learning. While scientific practice-based standards have gained traction in schools across the United States, the same cannot be said for this Latin American country. Science lessons in the region continue to be predominantly teacher-centric and instructional, relying on lectures, textbooks, quizzes, and sporadic demonstrations of experiments in front of students (Andrade & Massabini, 2011; Bassoli, 2014).

2 INVESTIGATING EARTH TILT IN 6TH GRADE

The implementation of the curriculum in a 6th grade involved the use of a didactic sequence that centered on the study of seasonal variations, utilizing models and data analysis. The didactic sequence comprised four lessons, where the teacher adopted a group-based approach to facilitate the instructional activities, assigning distinctive roles to each student within their respective groups. The teacher acted as a facilitator, mediating the teaching and learning processes and encouraging

critical thinking and self-directed investigations among students. Throughout the didactic sequence, both the students and the teacher were guided and supported by the Pedagogical Redesign Teacher.

To activate students' prior knowledge, the lesson began with an inquiry: "Why do the seasons vary across different regions of the world?" Subsequently, the students delved into the examination of seasonal characteristics based on latitude, encompassing equatorial, subtropical, and temperate regions. Equipped with activity and resource cards (Cohen & Lotan, 2021), they analyzed the annual patterns of light intensity and temperature in locations such as Sobral, São Paulo, and New York. Furthermore, they explored the influence of geographical location on solar irradiation, temperature, and the manifestation of seasons in each respective region. Both the classroom teacher and the Pedagogical Redesign Teacher actively engaged with student groups during the activity, attentively observing and facilitating discussions. In addition to the aforementioned exploration, the initial two sessions prompted students to construct an explanatory framework by establishing connections between solar light incidence, seasonal temperature fluctuations, and geographical location. Drawing from the information obtained through the cards, the students proficiently elucidated the primary factors contributing to Sobral's distinct dual-season climate.

Furthermore, the students conducted a comparative analysis of the onset and conclusion of seasons in cities located in the Northern and Southern Hemispheres. After sharing their findings, the students individually completed reports using their notebooks, which served as tools for evaluating their learning outcomes and assessing the achievement of lesson objectives. It is worth noting that the majority of students demonstrated a solid understanding of the subject matter through their satisfactory responses in the reports.

In the third and fourth lessons, the students explored the phenomenon of simultaneous summer in São Paulo (Brazil) and winter in New York (US). To explore this topic, each group utilized a comprehensive model of the Earth-Sun system. The model, which was developed in the maker lab by the teachers, consisted of a styrofoam sphere, a barbecue stick, a 3D-printed mobile support for the Earth's axis and tilt, a precision laser-cut mobile phone holder, a Gogo board (a low-cost microcontroller), and an integrated light sensor and charger. The mobile phone's flashlight symbolized sunlight. After a first investigation of the model, the students presented a visual model accompanied by informative captions, which elucidated their findings and the intricate relationship between the tilt of the axis and the variation in light incidence between the hemispheres. In this situation, the students engaged in an investigative process with an object to think with (Papert, 1999), the model, which was constructed by the teachers. Throughout these instructional sessions, the students actively engaged in experiments using the mobile support apparatus to manipulate the Earth's axis tilt and observe the resulting differences in luminosity between the two hemispheres, also using the Gogo Board's light sensors.

In the following two lessons, the students continued to employ the model to examine the impact of different angles of the Earth's tilt on the occurrence of seasons. Experimental trials were conducted, comparing a tilted Earth throughout the year with a non-tilted Earth. Drawing upon the findings from these experiments, the students constructed well-founded arguments, leading to the development of a visual model supplemented by explanatory captions that clarified the phenomenon of seasonal changes on Earth. Most student groups successfully established a causal relationship between the inclination of the Earth's axis and the manifestation of distinct seasons. As part of the final assessment, students depicted the positions of the Earth and the Sun throughout the four seasons. It became evident at this stage that some students encountered challenges in accurately representing their empirical observations in their drawings. Nevertheless, despite occasional struggles with artistic representation, students effectively conveyed the required information as outlined in the assessment.

3 MODELING AIR MASSES AND CLIMATE IN 8TH GRADE

Implementing the curriculum in an 8th grade involved a four-lesson didactic sequence, explicitly focusing on air masses and climate. The primary objective of this sequence was to develop students' ability to construct a model that explains the relationship between the displacement and interactions of air masses and the observed climatic conditions within a particular region.

To enhance student engagement with the sequence activities, the teacher organized them into groups and provided activity and resource cards. This approach allowed the teacher to adopt the role of a facilitator, encouraging students to engage in critical thinking and independent inquiry. Throughout the implementation of the didactic sequence, the Pedagogical Redesign Teacher provided valuable support in organizing materials and guiding the instructional process.

The lesson commenced with thought-provoking questions posed to the students: How and why does air move? How do the movements of air masses influence local climatic conditions? These inquiries aimed to assess the students' prior knowledge. Building upon these questions, the students explored air behavior through a "wind box" video, which prompted a discussion about their observations and facilitated connections between these observations and atmospheric air behavior.

Subsequently, the students engaged in a second activity involving the data analysis of satellite air mass dynamic imagery. In this activity, each student assumed the roles to critically examine one distinct latitude of the globe.

In the subsequent lessons, the groups were reconfigured to ensure the participation of a member of each previous team that analyzed a specific area. This arrangement allowed the students to compare and contrast different latitudes and identify variations and patterns. This collective discussion allowed for the construction of a model and building knowledge on the displacement and interaction of air masses.

4 FINDINGS

As a work in progress, more data collection and analysis is needed as the findings in this paper are based on classroom observations by the Pedagogical Redesign Teachers during the implementation of the sequences. Reflecting on their respective implementations, the Pedagogical Redesign Teachers emphasized that the application of sequences brought to them a different perspective for teaching science that places the student at the center of knowledge construction and the teacher as a facilitator. In the 8th grade implementation, for example, students were able to start with investigations on the behavior of air in its simplest form and progress to analyzing the movement of air masses and how they can affect regional climates, thereby enabling them to build knowledge towards the learning goals. Both teachers highlighted that the didactic sequence favored student learning due to its investigative nature and consideration of the learner's previous knowledge and culture. Designing activities related to students' realities, for example, in the first case study, analyzing the season of their city that is near the Equatorial Line and does not have four explicit seasons, engaged and turned into a meaningful experience. The students felt responsible for their learning as the teacher designed the opportunity for group learning and knowledge construction.

The teachers noted that these experiences increased student engagement during classes compared to their previous teaching model, in which students were mere listeners. Dividing the students in heterogeneous groups and defining responsibilities helped foster active listening and participation of all students. The teachers observed, within this curriculum proposal, students were constantly engaged in the activities, conducting investigations, forming hypotheses, and testing them. Unlike, in the traditional format, when they often witness students becoming disengaged and failing to achieve the desired objectives.

Some challenges were also observed throughout the implementation of this sequence, such as the restructuring of eighth-grade teams during the activity, which was not previously experienced by the group. Another concern was that some students needed help with basic computer skills, requiring additional teacher support.

It is worth noting that changing the teacher's role from being solely an instructor to being a facilitator in knowledge construction took time and effort. However, the implementation phase of these sequences is relevant so that other science teachers in the municipality may experiment a science practice-based way of teaching and learning, observing the practical outcomes of student engagement and performance during classes. In the process, students engage in constructionist learning as they think with objects, such as the models, and create models that are used to build explanations, share ideas, test hypotheses and build knowledge. In further implementations, the Pedagogical Redesign Teachers also consider creating opportunities and scaffolding for students to engage in the building of the earth's tilt model themselves, also using digital fabrication, taking the experience to a next step in constructionist learning.

5 CONCLUSION

In conclusion, the case studies presented in this paper highlight the successful implementation of a science practice based curriculum unit tailored to middle school students. The Pedagogical Redesign Teachers played a crucial role in implementing the curriculum, emphasizing student-centered learning and applying a constructionist approach. The findings demonstrate that didactic sequences, focused on investigations, discussions, group work, and the construction of explanation models, positively impacted student engagement and learning. Implementing these sequences challenged the traditional teacher-centric model and transformed the teacher's role into a facilitator. Despite some challenges, such as team restructuring and the need for additional support with basic computer skills, implementing these sequences resulted in increased student engagement and meaningful learning experiences. The case studies highlight that science and engineering practices through a constructionist approach have a potential to transform science education and encourage other science teachers to explore and adopt similar practices to enhance student learning.

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Cultural Making and Scientific Education:
elements for an ethical-critical approach from the south

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Based on the notion of Cultural Making and Southern authors who draw from an ethical-critical view of education, we argue that maker education should not be limited to mere hands-on activities that address disciplinary knowledge without any connection to the educators' and learners' realities. To achieve this, we introduce the concept of three pedagogical moments that assist in designing activities that are relevant to the learners' realities. We provide examples of potential maker education approaches inspired by these three pedagogical moments, drawing from two cases developed in Brazil.

CCS CONCEPTS • General and reference • Document types • General conference proceedings

Additional Keywords and Phrases: cultural making, science education, ethical-critical pedagogy, epistemologies of the south

1 INTRODUCTION

As the maker movement spreads worldwide [1] we begin to observe potential cultural colonization that dictate certain ways of doing and thinking. These can often lead to injustices rather than addressing them [2-5]. Stories like "Lion Lights" by Kenyan Richard Turere and "The Boy Who Harnessed the Wind" by Malawian William Kamkwaba have gained global recognition as inspirations for the maker movement, but they also prompt us to ponder: "for what purpose" and "for whom" is this making? The presented context triggers theoretical and practical reflections experienced by the authors. Therefore, we aim to delve deeper into the discussion about the relationship between the concept of "cultural making" and ethical-critical education, examining two cases that can inspire contexts for ethical-critical approaches within maker education.

* Place the footnote text for the author (if applicable) here.

2 SCIENCE, TECHNOLOGY AND EDUCATION: FOR WHOM AND FOR WHAT?

The questions posed by Freire, "In favor of what study? In favor of whom? Against what study? Against whom do we study?" [6], inspire us to seek meaning in the processes of teaching and learning. These questions can also provoke questioning in other areas, after all: science and technology for what and for whom? Ultimately, who does knowledge serve? In a way, this reflection allows us to question the role of knowledge (and technologies) as instruments for changing reality, which, in the Freirean sense, aims for the emancipation of historically oppressed individuals.

The notion of "Cultural Making" [4] promotes questioning the homogeneity of forms of making around the world and the imposition of certain techniques and technologies. It highlights differences in the meaning of making by illustrating that certain modes of production might be part of a maker mindset for some (e.g., certain Californian groups), while not for others (e.g., rural producers and artisans). For the children of smallholder producers, for example, making is more of a necessity for survival than a way to explore new skills.

From a decolonial perspective, we can consider that scientific and technological development needs to be grounded in the concrete reality of specific populations in order to contribute to their self-affirmation and improved livelihoods [7]. At the same time, new techniques are often put at the service of "new" hegemonic actors, while other groups remain in less current and powerful contexts [8]. Therefore, scientific and technological progress, based on a neutral and linear view, often doesn't become accessible to the working class and doesn't facilitate the inclusion of historically excluded actors [9].

Thematic investigation [10], as it aims at the development of humanizing educational practices, is linked to an ethical-critical perspective [11] of education. Thus, the need for the agency of the oppressed is present, as well as the recognition of individuals as part of the "community of victims" produced by the current reality. The challenge involves transforming the unjust reality of which we are victims, but in which we also participate. To achieve this, it's crucial to understand existing oppressive situations and to consider both technical-scientific and popular knowledge, which can serve as tools for constructing alternative realities [8].

To break away from common paradigms through "maker education," a dialogical educational process is important. This goes beyond mere conversation between teachers and students. It involves a mutual apprehension of different knowledge and practices that the subjects of the educational act possess about significant situations [12]. Therefore, themes can be identified in the speech and situations experienced by students and teachers, which, after being problematized, can lead to the selection of topics central to the educational process. From these themes, a multidisciplinary faculty can choose scientific knowledge to be explored, aiming for a deeper student understanding of their own experiences. Thus, it's not enough to "do it ourselves," building objects, technologies, and knowledge that support the current system of oppression. It's important for this making to contribute to breaking this logic. Instead of telling others (students) "how" and "what" to think and create, the logic should be to engage in dialogue and investigate relevant themes for the group, using scientific knowledge and technologies to create emancipatory possibilities for redefining reality.

From Freire's ideas, we understand that it is possible to consider the contradictions present in students' lives through three pedagogical moments in teaching and learning. These moments are guided by the stages: S1) "Study of reality," which involves identifying how students and teachers comprehend and communicate the situations they face; S2) "Scientific study," which encompasses the problematization of common-sense ideas arising from teacher-student dialogue; S3) "Application of knowledge," which enables the expansion of constructed knowledge to other phenomena experienced by the group [13].

3 REALITY, EPISTEMOLOGIES OF THE SOUTH AND CULTURAL MAKING IN EDUCATION

To illustrate the possibility of the approach of the three pedagogical moments [13] in conjunction with making, we can discuss two cases in which the pursuit of understanding and redefining reality inspires the development of educational activities in different contexts.

The first case, known as Lindóia Tech, involves a maker education program for students in the final years of primary education in a public school located in the state of Santa Catarina, Brazil. The initial 80 hours of classes occurred over a semester for 25 students aged between 10 and 11. These students had family lives involving pig and poultry farming, dairy production, wood processing, and furniture manufacturing. The activities aimed to develop investigation and prototyping skills based on scientific knowledge. In planning discussions between one of the authors and the school's teacher, it was decided that in the initial classes (S1), students would be asked to observe and note their daily tasks and share them with classmates. This would allow them to think about "improvements" to the observed tasks in subsequent, corresponding to "study of reality." In the following stages, aiming to delve into "scientific studies" (S2), the teacher proposed small experiments both to equip students for observation and recording tasks and to incorporate scientific knowledge into the process. For example, students learned to use measurement tools (ruler and tape measure), explored the construction and strength of structures using sticks, and investigated the relationship between color and temperature. Finally, in the last stage (S3), students had to draw on all their observations and knowledge to create models and prototypes that presented improvements to their reality. This allowed for the "application of knowledge." The proposal of these pedagogical moments inspired didactic decisions, resulting in an organizational structure of activities that potentially made school practices and technical-scientific knowledge much more meaningful for the students. It also enabled them to perceive themselves as agents of transformations in their realities through maker culture.

The second case, called EducaMaker, involved the initial phase of a teacher training program in a municipality of Santa Catarina State, Brazil. This program aimed to implement maker spaces in public schools. In 2021, the authors conducted 40 hours of virtual activities to aid theoretical and practical reflections for the construction of annual thematic courses that the teachers would develop. Ten teachers participated in Saturday meetings, not all at the same time. Inspired by the ethical-critical perspective and the three pedagogical moments, the training proposal involved: (S1) understanding the reality of the teachers (and students) in order to (S2) list the knowledge and skills to be studied by the group, culminating in (S3) the creation of activity proposals or the "application of knowledge". The main challenges for implementing maker-based practices were: (A) teachers with limited technical and pedagogical knowledge about the tools and technologies available in maker spaces; (B) low motivation to participate in training due to factors such as inadequate time to work and lack of interest from students in school; (C) difficulties with the process of methodological innovation, which requires adequate time to study and experiment with new approaches, to plan maker practices based on students' realities; and (D) little sensitivity and support from fellow professionals for planning and implementing new methodological approaches.

Despite the challenges, teachers managed to identify real situations in the community and plan activities involving maker practices based on them (noise pollution and low school attendance). Some proposed activities included studying sound using Arduino and actuators, as well as creating mechanisms for digitally controlling noise levels. They also devised fictional products to encourage students' engagement with knowledge and skills related to financial mathematics.

We understand that the proposal expanded the teachers' knowledge, especially regarding the importance of considering students' reality in the maker projects to be developed. On the other hand, we noted that many proposed activities were "fictional," which indicates that creating teaching-learning situations that involve students in real situations is a challenge to overcome.

This leads us to the question: Could schools be spaces for dialoguing about the unjust reality experienced by students and for creating tools to transform it? Can we, from an ethical-critical perspective, address the technical and scientific knowledge that's part of the school curriculum by knowing the real problems faced by students? This isn't about selecting limited knowledge to address the immediate needs of students (and communities) or ignoring the social and political role of schools in promoting reflections on the mechanisms that determine and condition realities. However, reality seems to hold powerful ingredients for creating deeper meaning in curricula and promoting emancipatory education.

We understand that the ethical-critical perspective underlies an approach that brings schools closer to students' lived reality, promoting collaborative actions with the community, and making what's taught and learned in school more significant. Initiating educational practices based on a concrete reality to list the knowledge and constructions achieved is not a trivial task, especially in the school tradition where the idea of transmitting as much disciplinary content as possible without often questioning its relevance and meaning remains deeply ingrained.

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The Griot Dolls: Black Dolls to Think History

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The Brazilian education system has struggled to provide an inclusive education that integrates Afro-Brazilian, African, and Indigenous History into daily teaching and learning. Law 10.639/03 was intended to promote inclusive schooling and guarantee the ethno-racial diversity rights of the Brazilian population. Despite this legislative progress, the implementation of Afro-Brazilian and African history in the education system faces continued challenges due to structural racism. This paper introduces the Griot Doll, a toolkit designed to help Brazilian schools provide a more inclusive education. The Griot Doll is a constructionist “object to think with” constituted by a set of black dolls without figurative human faces and bodies and featuring interchangeable hair possibilities. It provides a physical representation of Afro Culture that has historically been excluded from the Brazilian education system. Students can use the toolkit to reflect, represent, and create narratives from a black storytelling perspective. The Griot Dolls aim to go beyond a toy, providing a way for students to identify themselves as historical subjects.

Keywords and Phrases: Griot Dolls, Afro-Brazilian History and Culture, Racial Literacy, History Subject.

1 INTRODUCTION

This project is motivated by the urgency for Brazil to fulfill its constitutional duty of providing an education that integrates a critical analysis of Brazilian culture and history, as stipulated by Law 10.639/03 (Brasil, 2003). Currently, schools do not have tools and practices designed to integrate Afro-Brazilian, African, and Indigenous History into daily teaching and learning (Gonçalves & Silva, 2019), although there are consistent didactic and pedagogical experiences at different levels of education and regions of Brazil working towards fulfilling the law (Rocha & Silva, 2013; Sousa-Nogueira, 2017; Alencar, 2021). Thus, despite legislative progress, the implementation of Afro-Brazilian and African history in the education system continues to face challenges due to the structural racism (Lima & Sousa, 2014). The struggle to construct anti-racist practices in education in Brazil is reflected in the lack of pedagogical material and teacher training (Gonçalves & Silva, 2019), hindering efforts to create awareness and promote changes in the school curriculum.

This paper shares part of an on-going project around the Griot Doll, an “object to think with” (Papert, 1980) for learning history. Griot is a term used in West African culture to refer to a professional musician, storyteller, and oral historian (Pereira, 2015). The Griots Dolls are inspired by the Griots' social role as guardians of history by organizing structures of opportunity to play, explore, and enhance children's understanding of Afro-Brazilian culture. A set of black dolls without figurative human faces and bodies and with interchangeable hair possibilities accompanies a learning framework through which students create historical narratives. Grounded in critical constructionist design (Holbert, et al., 2020), the Griot Dolls invite learners to connect with their past and to reflect on their ancestry and identity. This connect-and-reflect cycle (Holbert, et al., 2020) mediated by the Griot Dolls seeks to promote an environment where learners can play and enact

narratives from a black storytelling perspective (Baker-Bell, 2017; Toliver, 2021). The Griot Dolls aim to go beyond a regular toy by providing an in-class physical and aesthetic representation of Afro Culture (Dery, 1994; Santos, 2020), which has historically been excluded from the Brazilian education system (Rocha & Silva, 2013).

2 THE GRIOT DOLLS DESIGN

Braided hair has been a symbol of black cultural resistance since the abduction and enslavement of African communities in the 14th century (Rocha, 2016; Ribeiro, 2021; Byrd & Harps, 2014). The care of black hair is an ancestral tradition passed through generations in hair braiding circles, where women exchange stories, knowledge, and confessions, mirroring each other (Xavier, 2021), while children listen and play (Santos, 2013). This environment, which provides the opportunity to experience the exchange of narratives that discuss the community's past, present, and future, inspired the project.

The 3D-printed dolls (Figure 1) are designed without human figures, creating a blank canvas on which learners can identify themselves or significant others and construct their characters as they engage in play. The Griot Dolls' interchangeable hair is an element that seeks to enable black children to visualize themselves within the story, celebrating their culture's physical appearance and aesthetic. This design feature fosters a personalized experience, empowering learners to create characters that reflect their cultural identities.

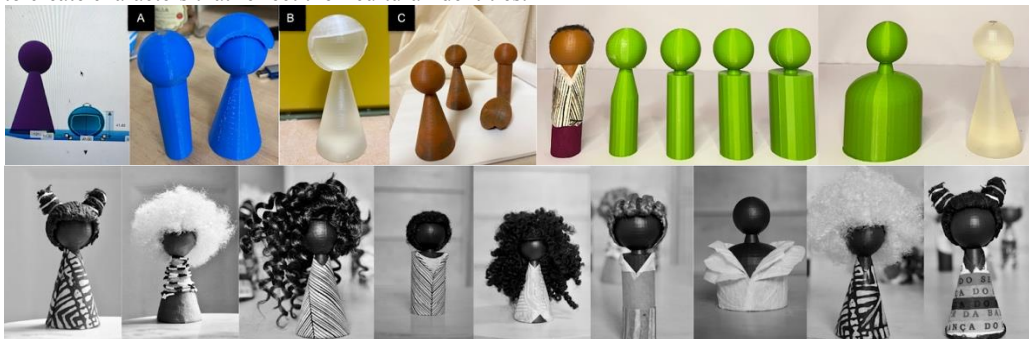


Figure 1 (top): Evolution of the dolls design; (down) Griot Dolls. Photograph by Adaauto Menezes.

While students listen to stories, investigate their cultural background, play with the Griot Dolls, create narratives, and develop stop motions, the toolkit aims to turn into an object to think with that reproduces cultural practices mediated by play (Vygotski, 1980). The Griot Dolls organize structures of opportunity so that children can create characters, play, explore and improve their understanding of Afro-Brazilian culture and identity. The intention is to value the oral history practice that takes them back to their ancestors while developing narratives skills, such as storytelling.

3 THE LEARNING FRAMEWORK DESIGN

Akin to the cultural figures for whom they are named, the Griot Dolls aim to serve as artifacts (Vygotsky, 1980) to support learners in cultural exploration through the creation of oral narratives and recognizing themselves as historical subjects. Aiming to address the powerful idea (Papert, 1980) of recognizing oneself as a subject of history, the Griot Dolls learning goals are grounded in Brazilian National Common Curricular Base (BNCC) (Brasil, 2018), outlining the elementary school curricula. Focused on K-2 to K-5 grades, the Griot Dolls toolkit and activities seeks to develop: 1) Fictional narratives using descriptive details, sequences of events, appropriate images to support the meaning of the text, and markers of time, space, and speech of characters; 2) The capacity to acknowledge and experience stories of different Afro-Brazilian

aesthetic and cultural matrices; 3) Knowledge and valuing of Afro-Brazilian cultures' cultural heritage, material and immaterial; and 4) Recognition of technologies and digital resources (such as stop-motion) as a tool for creative processes.

To support these learning goals, this project uses the Griot tradition to guide learners in becoming historians. It also uses the Circle of Inventions framework - three stages consisting of a "circle of reading (read-aloud), circle of making (crafting meaningful artifacts) and circle of narratives (creating and sharing stories)" - to structure learning activities (Edelstein & Ricci, 2022). In the first stage, educators read aloud a book that includes a black cultural theme, memory accounts, or ancestral legends and facilitate dialogue with questions to engage learners with the story. The goal is to surface students' experiences and initial ideas, which will support the process of investigating their personal histories.

In the second stage, rooted on the concept of creativity as sociocultural act (Vygotsky, 1980), students interview their families and communities based on a structured form they developed in class, to inform the creation of their dolls. In the process of personalizing their dolls, the meaningful making (Blikstein, 2019) process becomes fundamental to resignify in the community what it means to be of African heritage. This creative process is "to heal, restore, and renew the African community by making things better and prettier and offering to the world the best of what it means to be African and human" (Karenga, 1996, as cited in Correa, et al., 2023).

Once the learner has characters inspired by representative people, they enter the third stage of working in groups to draft a story. The collective dynamic is another cultural resistance and way of self-organization from the black community that underlies this design decision. Guided by the word Ubuntu, which means "I am because we are; and because we are, therefore, I am" (Mbiti, 1969, as cited in Correa & Holbert, 2023), learners expand their notion of creating History, which is a collective human process (Dei, 1993; Nobles, 1972, as cited in Correa & Holbert, 2023). The goal is to scaffold the learners to perceive black people as historical subjects who collectively make their own stories and who are important, empowering them to vocalize their right to have History. Lastly, like Griots, the groups share their stories. In this case, they record stop-motion videos with the teacher's support. The stop-motion format is intended to register an oral story, allowing the learner to revisit their narrative from a different angle and role and share their meaningful created artifacts (Papert, 1980).

4 FUTURE DESIGN DIRECTIONS

Upcoming research will test the toolkit design in schools. To this end, the project will be submitted to the Ethics Committee for Research in Human and Social Sciences at the University of Brasília, Brazil. The Griot Dolls, supported by Circle of Inventions, will be presented to children from K-2 to K-5 in the Brazilian cities of Brasília (Distrito Federal) and Salvador (Bahia). This implementation will last six weeks and include four sessions per school. This next stage of the project will focus on building analysis indicators, inspired by the criteria defined by the studies of Twine (2006; 2007), to evaluate the efficacy of the Griot Dolls in mediating (Vygotsky, 1980) the development of racial literacy.

5 CONCLUSION

The Griot Dolls project seeks to contribute to on-going efforts to build anti-racist curriculum in Brazil. The toolkit provides a way for young students to engage with their cultural background and relate to it in a meaningful way. The toolkit's design allows for a personalized experience that empowers learners to create characters that reflect their own cultural identities. The Griot Dolls' interchangeable hair design is a critical element that celebrates the physical appearance and aesthetic of Afro-Brazilian culture. By listening to stories, investigating their cultural background, and creating narratives, students will be able to engage in critical thinking about Brazilian culture and history from a racial literacy perspective. The Griot

Dolls have the potential to be an effective tool for teachers to integrate Afro-Brazilian and African history into the curricula and promote a more inclusive school environment. It is essential to prioritize the implementation of Law 10.639/03 in Brazilian schools to ensure that students have access to an education that is diverse, inclusive, and reflective of the country's rich cultural history.

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ElectricCity: Electrical Block Circuits for Elementary Learners

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ElectricCity is an ongoing project aimed at teaching electrical circuits to students in grades K-3 to K-5, aligning with the Next Generation Science Standards (NGSS). The project incorporates a constructionist approach, utilizing a city environment and mission cards to engage learners in creative problem-solving related to electrical circuits. The project consists of three pillars: blocks, mission cards, and implementation design. The blocks are designed to facilitate quick connections and provide a tangible representation of circuit components. Mission cards offer both creative and problem-solving challenges, allowing learners to explore and fix circuit errors. Comprehensive lesson plans support teachers in scaffolding student learning and facilitate group work. Design principles such as agency, group work, scaffolded learning, personalization, and storytelling are incorporated to enhance engagement and understanding. Future directions include expanding the curriculum, providing additional resources for teachers, and testing *ElectricCity* in K-3 to K-5 school environments. *ElectricCity* aims to create a structured and enjoyable learning environment for students to achieve their science learning goals in the context of electrical circuits.

Keywords and Phrases: Electrical Circuits, Physics, Elementary School, NGSS

1 INTRODUCTION

The Next Generation Science Standards (NGSS) aim to provide students in the United States with a coherent understanding of science within a natural context (Schwarz, Passmore & Reiser, 2017). One of the components of the NGSS physics curriculum is the experiment of electric circuits, which is essential to help students develop a mental model of electric circuits and their use in society (Calmer & Lincoln, 2023). Researchers and companies have extensively explored the learning experience of electric circuits, leading to the development of several tools for learners to build circuits, such as *littleBits* and *Squishy Circuits* (Bdeir, 2009; Thomas, 2013). However, engaging learners in discovery and exploration while accomplishing learning goals requires more than simply building circuits. As Thomas (2013) highlighted, incorporating play into circuit building should be a critical goal. One way to achieve this is by providing learners with an authentic context to make the learning process more engaging and meaningful while assisting the teacher with a lesson plan related to NGSS learning goals.

This paper introduces the ongoing project: *ElectricCity*, a block circuit kit designed for learners in grades K-3 to K-5. The kit enables students to construct electrical circuits while solving contextualized card missions in a city environment. *ElectricCity* seeks to leverage informal learning experiences as an entry point for science concepts and formal curricular goals (Quinn & Bell, 2013). The ability to assemble and disassemble blocks allows learners to experiment and debug their electrical circuits, with the card missions guiding their learning objectives. *ElectricCity* lesson plans and design decisions aim to facilitate learners' exploration of circuits in creative ways, including experimentation, building, and problem-solving through guided play, such as *Squishy Circuits* (Thomas, 2013). We wanted to take the concept one step further by incorporating a situated learning approach using a city environment and mission cards that pose problems to solve. We believe this approach will increase the possibilities for exploration and support teachers in structuring and conducting their

classes. The project's design aligns with the NGSS framework (NGSS Lead States, 2013) and the constructionist theory (Papert, 1980).

2 DESIGN PROCESS

The NGSS standards for electricity learning guided the design of the three pillars of *ElectricCity*: the blocks, mission cards, and lesson plans. Specifically, students in grades K-3 through 5 are expected to attain the following standards: "4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents", "4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another", and "3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled, and failure points are considered to identify aspects of a model or prototype that can be improved" (NGSS Lead States, 2013). For that, we defined the learning goals as identifying the various parts of an electrical circuit; understanding the flow of electricity in a simple circuit; distinguishing between a closed and open loop; explaining how switches turn circuits on and off; building and testing simple circuits using batteries, wires, and light bulbs; comparing and contrasting series and parallel circuits. By combining informal and formal learning approaches, *ElectricCity* seeks to enhance the acquisition of science concepts effectively and engagingly.

2.1 Blocks

The kit includes batteries, wires, switches, resistors, motors, dimmers, buzzers, and LED lights contextualized in a city environment (figure 1, left). The blocks are designed to facilitate quick connections using male and female jumper wires. The batteries and LEDs are labeled with positive and negative signs, aiding learners in proper circuit construction. These components are replaceable in case of burnout or discharge, ensuring longevity and reusability. The kit includes three blocks made of non-conductive materials, such as wood and rubber, to foster the exploration of conductivity and insulators. Furthermore, the *ElectricCity* kit offers pieces that learners can personalize according to their preferences and needs.

2.2 Mission Cards

There are two mission card types: creating and fixing (figure 1, central). The creating missions are designed to foster the learner's creativity and exploration, encouraging them to construct circuits based on their own ideas and problem-solving skills. On the other hand, the fixing missions present city-related problems where the learner must identify and rectify circuit errors. To cater to learners of different proficiency levels, *ElectricCity* offers a range of problem-solving challenges. As learners progress from Levels 1 to 4, they encounter increasingly complex concepts. These include introducing components like resistors, switches, buttons, dimmers, motors, and batteries in parallel. These additional tools expand the scope of exploration, enabling learners to experiment with circuit activation and deactivation. The *ElectricCity* kit includes blank mission cards to enhance customization and engagement further. Learners can create their missions, adding a personal touch to their learning experience and promoting autonomy and creativity.

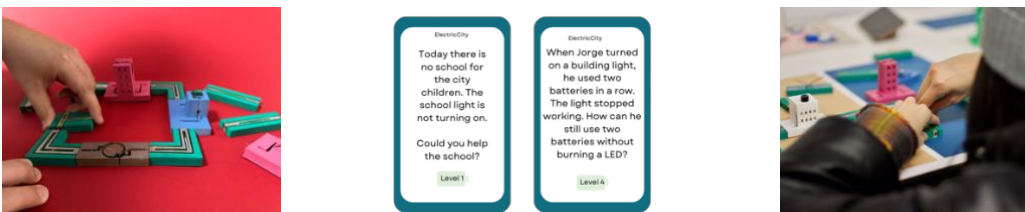


Figure 1: blocks and a circuit with a LED and a button in a building (left), mission cards (central), user testing (right)

2.3 Implementation Design

Recognizing that the kit alone does not guarantee effective learning, we have developed comprehensive lesson plans for teachers to guide and scaffold their instruction. These lesson plans outline each class's big ideas, learning goals, essential questions, science and engineering practices. The unit plan consists of three 70-minute classes, with detailed steps for the teacher to follow, including activity and resource cards (Cohen & Lotan, 2014). The implementation design aligns with the principles of constructionism, placing students at the center of their learning. Students are encouraged to work in groups to solve problems and create products that explain and organize their discoveries based on scientific evidence. Teachers serve as facilitators, guiding and supporting the groups as they test and reflect on their hypotheses.

For example, in a lesson, students will explore the "big idea" that electricity flows in a closed-path circuit, addressing the NGSS standard of making observations and providing evidence of energy transfer. This lesson's learning goals include identifying essential circuit parts, comparing and contrasting series and parallel circuits, and experimenting with switches and their role in circuit activation. These goals align with the science and engineering practices of analyzing and creating models. The lesson begins with discussing students' prior understanding of electricity and its relevance in their daily lives. Students are then divided into groups and provided with two mission cards accompanied by resource cards, which guide them in building a simple circuit to solve the missions. As a group product, students are required to create a video explaining the model they built using *ElectricCity* to solve the missions. The video should identify the circuit components, explain the flow of electricity, define the necessary conditions for the light and alarm to turn on, and pose a question about a topic they wish to understand better. The teacher's assessment criteria for the video include the presentation of the model, the inclusion of evidence in the conclusion, and the integration of information from the resource cards. By providing detailed lesson plans, we aim to support teachers in effectively implementing the kit and facilitating student learning.

3 DESIGN PRINCIPLES

Guidelines and feedback from colleagues in the field influenced the following design principles:

Agency: The block design emphasizes autonomy for students, allowing them to work and play independently in creating circuits. The blocks indicate how to assemble the pieces and highlight the importance of closing a circuit by ensuring a tip sticks out if the circuit is incomplete. Soldering is not required and the design incorporates visible wires, batteries, and switches that visually demonstrate how the parts work together.

Group work: Lesson plans are based on Cohen and Lotan's theory (2014), encouraging heterogeneous groups to engage in open-ended activities using activity and resource cards. This approach enables discussions about phenomena, hypothesis-building, and the collaborative creation of products.

Scaffolded learning: The blocks and mission cards guide learners through different levels of complexity in connecting circuit components. Pre-arranged and secured battery and LED blocks feature clear positive and negative signs, facilitating an understanding of energy flow. In the design decision of black (Hmelo & Guzdial, 1996) the wire direction and connections provide a low entry barrier and enable novice learners to explore circuits. The blocks are labeled with the materials they contain (e.g., metal, wood, batteries), allowing learners to experiment with different conductivity.

Personalization and Storytelling: The kit includes blank blocks and mission cards, empowering students to personalize their city. They can create and decorate additional buildings, fostering a more meaningful and personalized building experience, aiming to enable students to develop their narratives. Blank mission cards and customized blocks are included to encourage learners to create narratives, blocks, and missions. This feature allows students to connect with their city environments and reflect on their connections to the learned topics. By incorporating their experiences and communities, students can discuss electricity-related issues and engage in storytelling about their lives.

4 FUTURE DESIGN DIRECTIONS

We intend to create additional lesson plans to support K-3 to K-5 teachers in their physics classes, as we recognize that they may need more knowledge of the subject. The support will include a resource file for teachers to consult and enhance their understanding of physics concepts before teaching. Additionally, it will provide questions to facilitate student engagement during class. In the future, we plan to expand the curriculum by adding more advanced units. These units will gradually introduce activities that teach the soldering process and designs for 3D printing. Moreover, we will cover topics such as voltage and the need for additional power in different objects and connecting multiple objects in the same circuit. At the same time, we seek to test *ElectricCity* in K-3 to K-5 school environments.

5 CONCLUSIONS

ElectricCity is an ongoing project that aims to provide an approach to teaching electrical circuits in K-3 to K-5 grades aligned with the NGSS standards. Based on the constructionist theory, the project design seeks to engage learners creatively, using the city environment and mission cards to solve problems related to electrical circuits. The diverse blocks allow learners to experiment, build and problem-solve through guided play. The project's pillars (blocks, mission cards, and implementation design), pursue a structured and fun environment for learners to achieve their learning goals, through agency, collaboration, and creativity. The next goal is to test *ElectricCity* with our target audience and continue developing the implementation design.

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Making Floats for the Brazilian Carnival Parade: the Emergence of the “Situating Maker Space”

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This paper explores the production process of “allegorical floats” at a Brazilian samba school and asks whether the school’s production environment—which involves a combination of art, engineering, and science—can be considered a maker space. The samba schools, originally considered “dancing societies,” are now competitive communities with the annual Carnival parade as their endpoint. The data collection and analysis involved participant observations and semi-structured interviews conducted over a period of two years. We suggest that samba schools can be considered maker space situated between community and educational ones. The making process at the samba school is reflective, creative, and public, but education is not its main function. The paper concludes with reflections on different modalities of maker spaces and how they relate to diverse community needs and dynamics.

Keywords and Phrases: constructionism, maker culture, cultural making, samba schools, diversity and inclusion

1 INTRODUCTION

The samba schools were traditionally considered “dancing societies” which activities were a preparation for a large public parade during the Brazilian “Carnaval” (Alvarenga, 1950, p. 293; Carneiro, 1974). Later, they were redefined as a manifestation of urban folklore (Jório & Araújo, 1969), although they became goal-oriented communities that have the competitive Carnival parade as a common, yearly endpoint. However, samba Schools can be considered a foundational element of Brazilian culture and have been mostly studied as artistic and community organizations (Ferreira, 2012).

One of the early mentions of Samba Schools in the learning context was a talk by Seymour Papert in 1975 at the HUMRRO Conference. His interest was evoked from a single participation in a rehearsal session of a Samba School in Rio de Janeiro in 1975. He expanded his observations in *Mindstorms* (Papert, 1980), describing how samba school community members would meet frequently to learn about the music, costumes, and dance routines to prepare for the samba school parade. He discusses how these gatherings connected people of different ages and experience levels to achieve a common goal, and how this kind of peer-based learning should be at the heart of learning organizations (Papert, 1980). These observations motivated Papert to see a samba school as a “*Learning Society*” where “learning is not separate from reality. The samba school has a purpose, and learning is integrated in the school for this purpose. Novice is not separated from expert, and the experts are also learning” (p. 179).

Papert understood the samba school as an environment designed to stimulate creativity and learning. Since his remarks, several authors have related the process that takes place in a samba school community to different constructionists’ activities (Zagal & Bruckman, 2005; Rose, 2020; Brennan & Jimenez, 2020; Fields & Grimes, 2020; Stager, 2020). However, there is a surprisingly small amount of research on Samba Schools as learning organizations: their popularity in the literature became limited to commentaries of Papert’s now almost 50-year-old observations (with a few exceptions, e.g., Brunet, 2012).

It is worth noticing that every year, many Brazilian cities (especially in Rio de Janeiro and São Paulo) witness what many consider “the biggest show on Earth”: thousands of people participate in carnival parades of unparalleled complexity. In Rio de Janeiro, which is better known for its carnival, the parade consists of several samba schools, each one presenting 5 to 6 allegorical floats carrying dozens of dancers and 10 to 15 wings formed by 150 to 200 dancers. These 3.000 to 5.000

participants wear elaborate costumes. They must dance in perfect musical synchronization, all in the service of a nail-biting, fierce competition often decided by one or two percentage points.

The preparation for the parade is a collective endeavor that involves thousands of people, requiring an extensive production process that may take a whole year (Ferreira, 2012). The motivation to our study was to understand how the samba school is organized to be able to produce all the costumes and floats that are shown in the parade. Who makes them, and how are they made? These questions led us to consider studying the samba school and to find out whether they could be considered a maker space in which all these different productions are done. Thus, the main questions that guide this study can be stated as: is it possible to characterize a samba school as a maker space?

This article focuses on the allegorical float-making process as part of a field study conducted over a period of more than two years in the samba school in the city of São Paulo, Brazil. The article is organized into five sections, including this Introduction. The next sections discuss the theoretical background, the methodology used in the study, the results describing the production of costumes and production of floats, the discussion of the main results, and finally, the conclusion.

2 BACKGROUND

In this section, we describe two main themes that are considered the foundation of the study conducted: what is a samba school and the carnival parade? and what is a maker space?

2.1 What is a Samba School and the Carnival Parade?

Historically, the Samba Schools emerged at the beginning of the 20th century during the popularization process of Carnival and samba itself - a typically Brazilian dance rhythm that originated in the urban Afro-Brazilian communities of Rio de Janeiro. It is not by chance that these associations appeared in the same popular neighborhoods and suburbs of the city of Rio (Albin, 2009) in which there are more than 70 samba schools, all of which are seen parading during the four days of Carnival (Grupo Transversal de Trabalho, 2020). Each of them has its own flag and style, which are reflected in its parade.

The samba school parade consists of wings and allegorical floats presented in a logical sequence that it is possible to tell the plot (*enredo*) - the story the samba school will tell during the parade (Sireyjol & Ferreira, 2010). As mentioned by the critical artistic Tinhorão, the samba school is a walking opera-ballet. Each parade, always outdoors, has a plot developed through music, singing, and dance, with illustrative allegorical floats and creative costumes (Tinhorão, 1975).

During the parade, each samba school is evaluated by a jury composed of 45 members, divided into groups of five judges evaluating respectively nine items such as harmony, fantasy, allegories, master room and flag bearer, front commission, samba-plot, drums, plot, and evolution. The school with the lowest performance from the Special Group is lowered to the Access Group, and the best one from the Access Group is promoted to the Special Group.

Although we have focused on the carnival in Rio, the carnival in São Paulo also has a long history (Carvalho, 2009). The parade has a similar structure to Rio, with a quality that is compatible with Rio (Albin, 2009). Both in Rio and in São Paulo, workers from several categories accomplish the samba school preparation for the parade, carrying on parallel production of the allegorical floats and costumes. These samba schools have been studied from different points of view. Matos and colleges focus on the productive and innovative system of the carnival, made up of several types of productive agents as well as a wide network of institutions dedicated to teaching and training, representing, supporting, and promoting the carnival (Matos, 2007; Matos et al., 2016). Prestes Filho (2009) focuses on the carnival economic productive chain. Other researchers studied the activities in the warehouses and described the sequence of creative activities that are developed by different workers (Ferreira, 2012; Júlio & Tureta, 2018); or sought to highlight the various positions of the people involved in relation to their perception (or not) of the creative and artistic value of their functions (Sireyjol & Ferreira, 2010). These studies do not describe in depth the process and strategies used to produce the allegorical floats, which are the focus of our work.

2.2 What is a maker space?

Maker spaces, at least in their early “official” definition by the MAKE organization, can be defined as a space created by a community of people who have a passion for making things and who want to share that with others by making with others (Maker Media, 2013). They are created using different tools and materials, from traditional ones, such as cardboard,

glue, and wood sticks, to digital fabrication tools, such as laser cutters, digital routers, and 3D printers. Also, they may serve different purposes. Community maker spaces are state-of-the-art collaborative spaces set up for makers and doers of different ages and skills to develop and improve their production. In general, they are open to the community or offer monthly and annual memberships as well as day passes. Artists, designers, and people, in general, can use these spaces to have access to tools, skills, and communities that support their creative purposes or to build and test ideas and objects that can, in some cases, be commercialized (Vossoughi & Bevan, 2014).

Educational maker spaces are created with different purposes and are grounded in theory and research. They are set up as active learning environments in which students are encouraged to develop, design, and create their own projects and products. In this case, the activities developed should be connected to the curriculum (Anonymous, 2020), and the students' production should contribute to their process of knowledge construction (Anonymous, 2019).

One of the theoretical frameworks that support the creation of these spaces is the concept of constructionism, described by Papert in a proposal to the National Science Foundation in 1986. In this proposal, he stated that "learning is particularly effective when it is embedded in an activity the learner experiences as constructing a meaningful product (for example, a work of art, a functioning machine, a research report, or a computer program)." (Papert, 1986, p. abstract).

Later, Papert explained that constructionism (with N) was conceived by adding to Piaget's constructivism (with V) (Papert (1991). According to Piaget, knowledge about the world is constructed by learners actively interacting with the objects and people around them through mental processes he called accommodation and assimilation (Piaget, 1985). When a new situation is encountered, learners try to interpret this new information by applying to it what they already know (assimilation). If this information does not fit, it is necessary to make minor changes to the existing knowledge (accommodation).

Thus, Papert's constructionism implies that knowledge is constructed not only by interaction with objects but by producing one. However, this production has special characteristics: the learner must be engaged in making a meaningful product, the external artifact can be public, and the production process is done through assimilation and accommodation, which is accomplished through several types of reflection¹. Another important explanation regarding constructionism is that the public entity the learner is constructing can be "a sandcastle on the beach or a theory of the universe" (Harel & Papert, 1991, p. 1). This means that this entity can be done with or without the use of digital technology.

These clarifications about constructionism have important implications for the creation of maker spaces. First, the making process in maker spaces, according to the constructionism framework, should be a reflective doing, allowing assimilation and accommodation. Second, it can be done using traditional materials and digital technologies. There are examples of maker spaces in which the making is only possible by using traditional materials. However, as mentioned elsewhere (Anonymous, 2019) digital technologies play a significant role in maker spaces by making explicit the concepts and strategies learners use to develop their products (Anonymous, 2005). Also, as observed by Erin Riley (2015), technologies add precision, scalability, and reproducibility to the students' work. Third, prevalent discourse around the maker movement states that "everyone is a maker" and "everything can be made." This view contributed to an approach that ends up focusing on the mere act of constructing objects without specificity about their context, purpose, the learning that takes place, and the technical and cognitive achievements of students (Vossoughi & Bevan, 2014). Finally, the rapid growth of the maker movement initially happened at the expense of demoting or ignoring other forms of sophisticated engineering that communities around the world have been doing for decades. Scholars have pointed out, for example, that the maker movement ignores forms of making that communities have engaged with for centuries, around textiles, food, objects, architecture, and other daily tasks (Anonymous, 2020). While this criticism is correct, it is somehow clouded by the fact that there are different contexts for making in diverse contexts around the world. Understanding those is crucial to framing, investigating, and comparing them.

This present study is an attempt to address this criticism. It is part of the XXX Project [description removed for anonymity]. The objective of our study is to understand the production process that goes on at a samba school. This article focuses specifically on the production of allegorical floats, and questions we proposed to address are:

Q1 - Can the samba school production environment be considered a maker space?

Q2 - What kind of production process takes place in making the allegorical floats?

¹ One of the authors thanks Natalie Rusk and Ann B. Valente for a discussion to clarify these ideas.

3 METHODOLOGY

The method used in this study is based on a qualitative field study taking an ethnographic approach. The field can be characterized by the production settings of a samba school and the ethnographic approach is justified by the methodological procedures in which it was possible to do direct and extended participant observations of a group of workers by one of the authors who was immersed in the day-to-day activities at the samba school settings (Creswell, 2013).

The locus of the study was one of the samba schools of São Paulo city, Social Cultural Recreational Guild Samba School “Unidos de Vila Maria” (Grêmio Recreativo Cultural Social Escola de Samba Unidos de Vila Maria), or simply Unidos de Vila Maria. The production process takes place at the Samba Factory (Fábrica do Samba), a common space set up by the city’s Samba School League (Liga das Escolas de Samba) in which the costumes and allegorical floats are built and tested.

The study population was participants from the samba school who work in two sites as administrators as well as people developing different activities. Most participants were intentionally chosen because of their extended involvement in the production processes. They were selected to be observed or to provide information according to the status or position they occupy. The objective was to observe and to interview as many people as possible to understand how the samba school operates and how everyone contributes with ideas and the construction of different artifacts.

The data collection and analysis procedures consisted of two interconnected tasks of gathering information and analyzing it in terms of categories that emerged related to the maker culture. The gathering process consisted of participant observations and semi-structured interviews. During the years 2020, 2021, and 2022 one of the authors visited both sites regularly, with 30 visits and 224 hours of observations, gathering data about the physical spaces and people working in different activities. These observations were kept as written notes, photos, and videos. The interviews were recorded in videos, which were then transcribed. The field observations, interview recordings, videos, and photos were analyzed, and the authors held periodic meetings from 2020 to 2022 to understand and categorize the collected data. These analyses determined the collection of more in-depth information that supported the identification of different themes.

4 RESULTS – MAKING THE ALLEGORICAL FLOATS

“Allegorical floats” are vehicles decorated for the carnival parade. These vehicles are not motorized but are pushed by people during the parade. These floats carry large sculptures and 10 to 50 people. Each samba school features four to five floats in a parade. Figure 1 shows the “Abre Alas” float of the 2022 Vila Maria carnival parade.



Figura 1 - The Float "Abre Alas," 2022 Carnaval Parade

To sustain all these people and materials, schools modify the chassis of large vehicles, such as buses or trucks, creating a rectangular base, which they call a table. On the table, structures/sculptures made of iron, wood, foam, fabric, and styrofoam are positioned and assembled, molded according to the proposed design. The body of a large sculpture is made of iron, covered with foam and fabric. More detailed parts, such as heads and limbs, or smaller structures, such as animals and statues, are made of Styrofoam and covered with fabric or painted.

The process of float production starts from the carnivalesque conception, described in the synopsis, and materialized in an artistic drawing that will serve as the project for the development of the allegory, shown in Figure 2 left.

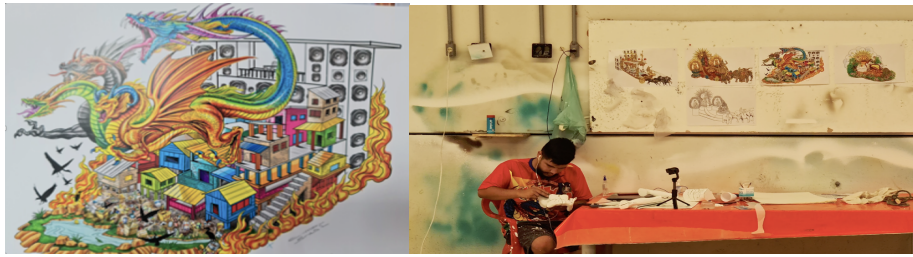


Figure 2 - Left, the drawing of one of the allegorical floats; right, a worker developing a Styrofoam model of one of the elements of the float

Based on the drawing, a miniature version of the float is produced, made with Styrofoam (Figure 2 right), which will serve as a float model. This mockup is marked to obtain measurements that will be scaled to produce the element for the allegorical float. The model also serves to indicate that iron structures will support some elements, and some will be sitting on the allegorical float table. In Figure 2, right, it is possible to observe the drawings of the four floats that will be part of the parade.

During one of the visits, it was possible to follow the creation of a four-headed dragon for a 2022 carnival float, inspired by the drawing shown in Figure 2 left. Figure 3 left shows the dragon Styrofoam model, and on the right, the lines marked on the model indicate where the iron structure will support the Styrofoam sculptures that will compose the four-headed dragon. The iron structures are created and positioned according to those marks made on the model but are subject to some alterations if the workers verify the need to alter this structure, as shown in Figure 3 right.



Figure 3 - Left, the styrofoam dragon model; the center, the lines marked to indicate where the iron structure will support the elements of the four-headed dragon; on the right, the iron structure that supports the four-headed dragon

The iron structure is constructed based on the artist and on the workers' intuitions. The dancers composing the allegorical float can move freely, contributing to the structure's sway. This requires that the iron structure be strong and, at the same time, flexible. In an interview, the carnival designer explained that "the process of tying the iron structure in V leaves enough slack so that it can swing without breaking." The V shape involves a mooring process connecting three different points, so the iron structure is always triangular. According to him, this is sufficiently secure not to cause any accidents. He uses as "proof" the inexistence of accidents during all the years he has worked, accumulating technical experiences learned in other parade settings. Once the lashings are done, a giant iron "skeleton" structure is obtained, as shown in Figure 3.

The construction process continues with the addition of Styrofoam sculptures to the giant iron skeleton. For this, iron rods are placed inside the Styrofoam pieces that are hoisted to the fitting point and welded to the larger structure. Figure 3

shows the construction of the iron skeleton, where it is possible to see how it is positioned on the float table as predicted by the model and how this structure supports the dragon heads made from Styrofoam. The Styrofoam sculptures are produced in parallel with the iron structure, so their aesthetic effects can be evaluated as they are produced.

In the iron structure construction process, it is possible to understand that several engineering concepts are used. However, they are expressed in terms of tacit knowledge that was acquired through years of experience. Also, it is possible to identify in the float construction process concepts related to math, science, and art -- thus, in a way, a "STEAM" environment.

5 DISCUSSION

Our immersion in the Vila Maria Samba School warehouse made it possible to document these productions and to observe that what is produced is complex, sophisticated, creative and is accomplished by professionals with different levels of expertise who combine all kinds of tools and knowledge to achieve their collective goals. Thus, regarding the first research question, we can assert that the Samba school warehouse can be considered a maker space.

According to our understanding of what a maker space is, the allegorical floats' production processes are accomplished by workers from the samba school community who are passionately involved in their activities. Also, all the distinct phases of this production are shared by them as well as shared with the public during the samba school parade. It is a highly distributed and completely informal practice using a mix of high- and low-tech tools to make creative and aesthetic elements to express a narrative that the parade judges and the audience can understand and appreciate.

While the Samba school warehouse shares characteristics with a typical maker space, it is a distinct type of maker space that is unique to the Samba school community. It is important to note that the workers in the Samba school warehouse do not consider themselves as "makers," and the warehouse cannot be considered a community-type or educational maker space as defined in the literature. A community of people carries out the production process. Still, it is not open to the public, and the objective of the activities is not educational, although some learning may occur. Instead, the samba school warehouse can be considered a "situated maker space," which is centered in a community of practice, as proposed by Rogoff (1994) and Lave and Wenger (2006), and is designed to produce all the elements for the parade of the year. The creative and reflective production processes that occur in the Samba school warehouse are noteworthy. As highlighted by Sireyjol and Ferreira (2010), each worker involved in making the floats adds their own creativity to the process. They innovate by mixing various materials and technologies while working within resource constraints. The production process is also reflective rather than using an assembly line approach. For instance, the Styrofoam prototype model used to create the allegorical float is not simply a copy of the drawing. The iron structure may have unforeseen details that were not predicted in the model. Despite the fact that education is not the primary function of the samba school warehouse, the production process shares the characteristics of a constructionist maker space. The workers are engaged in creating a meaningful product that is public and evaluated by the local community, and the production process is reflective through assimilation and accommodation. However, the creation of knowledge is not the primary goal of the process, unlike a school maker space, where knowledge construction is the main objective. Thus, the samba school warehouse can be seen as a situated maker space that is neither entirely educational nor entirely community-based but rather a unique hybrid that reflects the specific cultural context of the samba school community.

6 CONCLUSION

The [Anonymous] Project has offered a unique opportunity to explore the making process of one of Brazil's most significant cultural institutions, the samba school. This study has shed light on the samba school warehouse, which functions as a situated maker space for the samba school community to produce the intricate costumes and allegorical floats that are showcased during the carnival parade. This finding has highlighted the importance of considering new and diverse types of spaces for making beyond what is currently known. Moreover, this study has the potential to expand our understanding of constructionism in the sense that we were able to identify the reflective process that occurs during the production of meaningful products, with or without the use of digital technologies. This study also highlights that constructionism is not limited to a technological context but applies to any reflective process that leads to creating meaningful products. Additionally, and fundamentally, the data suggests that the intention of the activities determines whether a maker space is

considered educational or situated. A space might be established for educational purposes, but its users may engage in activities aimed at creating products rather than constructing knowledge. The samba school exemplifies this case, as it possesses similar characteristics of an educational space, yet its users' primary objective is to produce carnival products rather than gain knowledge.

The study of spaces for making, such as the Samba School, is significant because it reveals that there are many more variations of such spaces than the mainstream versions seen in typical "Maker Culture" venues. The Samba School offers an interesting space because it serves a specific and competitive endeavor with a high level of engineering sophistication but with little explicit concern for traditional knowledge construction and systematization, as recognized by academics. In this situated space, newcomers learn their trade, and old-timers perfect their skills without the usual heuristics and routines of schools. This unique approach to making, which is not constrained by traditional academic norms and structures, may offer valuable insights for rethinking maker activities in schools. By exploring alternative ways of working and learning, while still achieving impressive technical feats, we may be able to develop more inclusive, diverse, and accepting approaches. This diversity challenges the traditional view of maker culture as solely focused on technological innovation and reinforces the importance of cultural and artistic practices in the maker movement. By recognizing and valuing the different forms of making, we can create more inclusive and equitable spaces for makers and expand the possibilities for what can be created and learned through making.

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Fostering Literacy Development through Constructionist Pedagogy: A Case Study in Elementary Education

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This paper explores the implementation of constructionist approaches to restore literacy skills among elementary school students in Brazil affected by the COVID-19 pandemic. By drawing on Piaget's constructivism and Papert's constructionism, the study explores the active role of learners and the supportive role of teachers in the literacy process. While constructionist approaches have been applied to various disciplines, their use in language literacy education is still limited. Through a case study, this research demonstrates the effectiveness of a constructionist approach using a poster as a thinking tool. The teacher models reading skills, collaboratively develops a poster with the class, and facilitates the creation and presentation of posters by student groups. This process fosters students' creativity, innovation, and communication skills, all crucial for literacy development. The findings highlight the positive impact of constructionism on students' reading abilities, comprehension, and sense of ownership in learning. The paper concludes by emphasizing the significance of constructionist literacy and encourages further discussions and contributions to broaden the scope of constructionist approaches in literacy education.

Keywords and Phrases: Literacy , Constructionism, Object to think with, Elementary Education

1 INTRODUCTION

As children returned to schools after Brazil's COVID-19 social isolation phase, 1.4 million first and second-year elementary school students were deemed illiterate, a rate nearly 15% higher than before the pandemic (Avancini et al., 2022). With the data suggesting that elementary students are reading significantly behind grade level, it is crucial to develop strategies that create meaningful literacy experiences. While classes during Brazil's social isolation period were predominantly led by teachers ill-equipped to handle online classrooms, this research investigates how schools can restore students' literacy back to grade level. Faced with this problem, we reflect on Piaget's (1984) constructivism and Papert's (1980) constructionism to investigate their impacts on literacy education. Through this combined lens, the learner is positioned as the author of their literacy process (Ferreiro, 2011). While the teacher occupies the role of a "more knowledgeable other" (Vygotsky, 1978) as they model critical research and literacy skills.

While constructionist approaches have been implemented to support computational literacy (diSessa, 2000), mathematics and science learning (Blikstein, 2013; Davis, Zembal-Saul & Kademian, 2020), little constructionist research has approached language literacy besides Papert (1980). Through an exploratory case study, this paper reflects on how literacy is an endpoint for constructionism using a poster as an object to think with (Papert, 1980). The teacher models reading skills, collectively develops a poster with the class, and facilitates the construction and presentation of posters developed by student groups. By involving students in the constructionist process, the teacher aims to go beyond traditional reading and writing skills, and develop higher-level language skills such as creativity, innovation, and effective

communication (Papert & Harel, 1991). These skills, crucial to students' success both inside and outside the classroom, promote literacy development through meaningful products that students present as public entities (Papert & Harel, 1991).

2 DESIGN

In consultation with the school's pedagogical coordinator, this case study investigates a teacher's constructionist literacy lesson, created to intersect their 14 first-grade learners' interests with the literacy curriculum. At the beginning of the year, the teacher recognized their class's interest in their pets and other animals as they played with an Animal Kingdom card game, read books about dinosaurs and marine animals, and explored the school's natural environment. The teacher created a project-based unit plan, further described below, that used a poster as an object to think with to enhance literacy skills. Data were collected over six months of 2022 in a constructivist-centered Brazilian private school. The teacher shared classroom artifacts via email and participated in more than 40 hours of video calls with the researchers, discussing constructionist theory and analyzing each design stage. The artifacts included curriculum expectations, lesson plans, learner observations, and lesson outcomes. The teacher documented students' literacy processes based on engagement and contribution to group and individual tasks. The authors analyzed the artifacts, including the student's final products and instances of student empowerment, as a case study to investigate the project's results.

3 THE CONSTRUCTIONIST ANIMAL KINGDOM UNIT

The project started as learners showed interest in researching the animal kingdoms using resources available in the school (Figure 1, left) and books from their homes. To determine the literacy learning goals, the teacher observed how students applied their reading skills to locate relevant information while reading from the collected resources in small groups. By interacting with various genres, they explored the different purposes that each text serves.

In the following meeting, the class established the purpose for their research and discussed how to identify relevant information from the class collection. Discussing which animal the class should research together, the group concluded that "the animal that appears the most in the books [provides] the most information" (student quote) to design a poster with. Deciding to research elephants, they located four books with relevant information. During two meetings, the teacher read the four collected books, focusing on the children's understanding of the readings. The teacher engaged the learners in connecting the text to its structure and purpose, comparing the roles of different textual features (e.g., titles, data, and image captions). The students, practicing their reading skills, made comparisons between texts, finding similarities and differences between sources. Students then identified which details were important, synthesizing the information and suggesting how to express the information in writing. The teacher typed these insights into a PowerPoint slide (visible to the entire group).

Using the full-class poster as a model, students split into small groups to research new animals and design their own artifacts. The main criterion for locating information was to search for words they already knew. At first, they took some risks in reading and succeeded in short and highlighted texts (titles, subtitles, and image captions). At this point, the focus of the activity was not on decoding but on fostering a safe and comfortable environment for students to practice their reading skills (Figure 1, middle and right). The teacher observed learners' reading procedures and supported the construction of students' posters through guiding questions such as (a) Why did you choose this animal? (b) What materials can contribute to the research? (c) Which kinds of text will you use? (d) What role will each group member have in constructing the poster?. Throughout the constructionist process, students shared their initial findings and exchanged feedback regarding each other's posters. The teacher facilitated these collaborative reflections and helped groups integrate relevant insights into their final posters.

Finally, the students presented their work during a poster exhibition. As hosts of the exhibition, the students wrote invitations to the school community, inviting them to visit and learn about their creations. The teacher encouraged the learners to display their drafts alongside their final posters to showcase the constructionist learning process and continual development of students' knowledge. Each learner presented their findings and visited other groups' exhibits.



Figure 1: Resources available at school (left) Student reading and identifying relevant information (middle) and student constructing poster draft (right)

4 FINDINGS

By encouraging the practice of reading through research, we found improvement in students' reading procedures, such as pattern recognition. For example, one student recognized the word "elephant" and decided to mark pages containing the word with a post-it for future reference. This process revealed the engagement and strategy of the student that could find information by himself. In addition, other students attempted to find "elephant" in different sources as a way to find more information about the animal and bookmark them; we see that the reading culture in the classroom was fostered when students learned reading strategies from each other. Tasked with designing a poster about elephants, they demonstrated an understanding that information shared between different scientific texts could provide evidence for more relevant and important information. This suggests that research- and construction-based reading is an effective endpoint for literacy instruction since it required students to synthesize the most pertinent information into their posters. Further, the students had the opportunity to learn text structures as the teacher occupied the scribe role. The teacher's guidance was important as he modeled different written tools such as lists, curiosity questions, and figures with captions, providing the learners with a variety of ways to express their ideas textually. Following the teacher's model, the students realized that the poster was an object to think with (Papert, 1980). They understood it was an authentic artifact to learn and develop literacy skills. As a scribe, the teacher recorded students' discoveries, allowing them to dictate their findings by exploring the collected materials and making words visible to the community of learners.

The small groups were able to exchange and share different methods of recording information, researching sources, and defining essential research criteria to be included in the final posters. This way, the groups could refine their literacy skills together, while the teacher facilitated the poster revision process and ensured each group designed a product that contained the criteria they defined. Based on maker-centered learning and problem-solving (Clapp, et. Al., 2016), the small-group poster production enhanced students' sense of belonging to a group, dealing with similar challenges and a common purpose. Considering the students' common interest in the animal kingdom, the poster-making process became a meaningful learning experience since each learner contributed and felt like a valuable member of their team (Figure 2). During the collaborative reflections, students developed metacognitive thinking by analyzing their work and implementing peer feedback to refine their literacy and research skills.

During the exhibition, the learners felt proud of their product authorship and their team presentation. They demonstrated fluency and deep knowledge not only about the animal that they studied but also about the research process. The presentation was a key part of the project since the students made the constructionist process visible to the greater school community. The open-ended poster production permitted that each group could choose their animal and create a different

poster that represented their process and research findings. The significance of this constructionist activity was encapsulated in the choice and independence students were given and in the teacher's respect for the ways students expressed their ideas.



Figure 2: students searching animal information for their poster

5 CONCLUSIONS AND IMPLICATIONS

In this construction-based literacy learning environment, students were encouraged to connect with prior knowledge, take risks with reading and writing, and explore their questions and curiosities, critical points from Piaget's (1984) and Papert's (1980) theories. Our findings suggest that constructionism is a powerful learning theory that can contribute to literacy instruction. By emphasizing the process over the product of learning, students felt comfortable and confident in taking risks and making their thinking visible. Students construct knowledge by using a poster as an object to think with and designing their own to demonstrate the development of literacy skills. Transcending traditional literacy instruction, students were empowered to express and communicate original research free from the constraints of conventional grammar and spelling. Students assume positions and social roles that involve critical thinking and problem-solving skills essential to literacy development. Using posters as artifacts allowed students to become authors of their learning, expressing ideas through group discussion, research, text production and presentation.

The teacher used constructionism to align student's interests with the school's literacy curriculum, and the students met the expected learning goals while feeling like valuable members of the classroom community. While the findings of this initial case study are limited, we understand the importance of discussing constructionist literacy in a broader community. With literacy as an endpoint for constructionism, we invite the community involved in children's literacy to discuss their experiences and contribute to the expanding vision of constructionist literacy.

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Designing a Middle School Curriculum to Critically Explore Socioscientific Issues with Machine Learning

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This paper presents the design and research of a Machine Learning (ML) curriculum for middle school students to critically explore socioscientific issues. Ten middle school students from diverse backgrounds participated in the second iteration—a 4-week free online afterschool program. They were engaged in hands-on practices of solving real-world problems with AI/ML technology, such as collecting photos of themselves wearing and not wearing masks to train their own ML models that can automatically recognize if a person wears mask or not. The designed learning environment provided them the opportunity to learn through social interactions with ML tool, physical tool, peers, and instructors. As a result, students showed improved AI/ML knowledge and practices and good understanding of AI ethics.

CCS CONCEPTS • Applied computing ~ Education ~ Interactive learning environments • Computing methodologies ~ Machine learning • Social and professional topics ~ Professional topics ~ Computing education ~ K-12 education

Additional Keywords and Phrases: Artificial Intelligence, Constructionism, Ethics, Socioscientific Issues

1 INTRODUCTION

As Artificial Intelligence (AI) becomes familiar to the public, it is necessary to prepare youth for the future AI-driven society. Young students need systematic learning to develop a deep understanding of AI, especially Machine Learning (ML)—computational algorithms that function as the “brain” of AI to support its intelligence [3]. However, there are very few age-appropriate AI/ML curricula for K–12 students. Research has shown younger students are able to learn AI/ML after adjusting the difficulty level according to their ages [7, 11]. Despite some recent explorations to designing K–12 AI/ML curricula [4, 12, 13], much more curricula-development and research on AI/ML education are needed in K–12.

One type of curriculum that is lacking but necessary in K–12 AI/ML education is about how to apply ML in addressing socioscientific issues (SSIs) — social issues with “conceptual or technological ties to science” [10, p. 513]. A curriculum of applying ML to address SSIs can engage students in authentic problem-solving. Therefore, to fill in this gap, I designed and researched an innovative middle school AI/ML curriculum that centers around applying ML to address SSIs [1]. The guiding question is: How does the curriculum design support students’ development in ML knowledge and practices, and their understanding of ethics of applying ML/AI in addressing SSIs?

2 CONSTRUCTIONISM

The learning design of this research follows the theoretical perspective of constructionism, which suggests that students learn through constructing sharable and personally meaningful artifacts [8]. Constructionism includes two key ideas: knowledge construction and learning cultures [6]. This research aims to create a synchronous online learning environment, where students can engage in hands-on practices of solving real-world problems with AI/ML technology. Working on real-

world SSI problems can connect students with what they already know. The learning environment is also designed to engage them in the social process of interacting with computer tools (ML platforms), SSI context and physical tool, and peers and instructors. These interactions provide students with the opportunity to build up new knowledge.

3 METHODS

This research is design-based [2]. It has gone through two iterations of online afterschool programs named Artificial Intelligence for Middle School Students (AIMS): A 5-day pilot in July 2022 and a 4-week spring program in 2023. After the pilot, I improved the curriculum and assessment for the second iteration. This paper focuses on the second iteration.

3.1 ML-SSI Curriculum Design

The curriculum outline can be found in Table 1. ML contents in the curriculum include the following five aspects: Definition, Data, Algorithm, Application, and Ethics. I selected the application of AI for automatic check of mask-wearing during the COVID pandemic as the SSI topic for the curriculum. Projects and discussions are key components to form the constructionist learning environment.

In the hands-on projects, students worked with different ML platforms, Teachable Machine (TM; <https://teachablemachine.withgoogle.com/>) and Orange (<https://orangedatamining.com/>), to make ML models for assigned tasks. With TM, students collected data by taking photos of themselves, used that data to train ML models to achieve automatic recognition of mask wearing, and tested and improved model performance (see Module 1 in Table 1). With Orange, students made k-means clustering models by themselves, using embedded datasets or importing their collected data to Orange (see Module 2 in Table 1). All project sessions allowed students to share and discuss their ML products with peers and instructors.

The curriculum also included a debate activity in the fourth week to develop students’ understanding of AI ethics (see Module 3 in Table 1). Students had a free discussion on an assigned topic: Should AI technology be used to automatically check mask-wearing during the COVID pandemic? This activity was designed to provoke students’ thinking about pros and cons of using AI to address SSIs and develop a deeper understanding through exchanging of ideas with each other.

Table 1: ML-SSI curriculum outline for the AIMS 2023 Spring Program

Module Info	Selected Core Class Sessions
Module 1 (6 hours)	Projects: Use TM to achieve automatic recognition of you (and all your team members) wearing mask or not.
ML type: Supervised learning	<ul style="list-style-type: none"> Each student uses his/her own photos to train a model, test, and improve. Generate a sharable link so that peers can test each other’s model; or use Zoom screen share to present their own models.
ML tool: Teachable Machine (TM)	<ul style="list-style-type: none"> Share & discuss.
Module 2 (6 hours)	Projects: Each student works on Orange to perform K-Means clustering, with the “Traffic Sign” dataset provided by Orange, or with the class photos they collected previously.
ML type: Unsupervised learning	Share & Discussion: Students take turns to share and interpret their own clustering result.
ML tool: Orange	<ul style="list-style-type: none"> Look into the cluster result and interpret the similarities shared by data in each cluster. Find out the incorrectly clustered data and try to explain why. Compare the results of K-Means with Orange and supervised learning with Teachable Machine.
Module 3 (4 hours)	Lecture: A brief introduction to reinforcement learning
ML type: Reinforcement learning	Practice: Use Orange for image classification; share and discuss.
ML tool: TM & Orange	Debate: Should AI technology be used to automatically check mask-wearing during the COVID pandemic? Free-style debate in two teams (confirmative vs. negative). Then the instructor shares the response from ChatGPT.

3.2 Implementation, Participants, and Data

This study has been approved by IRB and has obtained informed consents from students and parents. A total of 10 students (Grade 6 – 8) participated in the spring program and 8 of them completed. Students were diverse in terms of their gender, race and ethnicity, and physical location. This free online program was completed over three (Saturday cohort) or four (Sunday cohort) weekends, from 10:00 am to 2:30 pm one day each week. Each cohort included 5 students based on their own choice. The Saturday cohort missed Module 3, but the other parts were almost the same between the two cohorts.

Major research data includes pre and post tests (on ML contents) and surveys (e.g., prior experience, interest in STEM, feedback on this program) delivered by Qualtrics, Zoom recordings of all class sessions, and some short episodes of students' computer screen recordings. Supplementary data includes observation notes and students' learning journals. The ML test was adapted from [9]. Paired samples *t*-test was conducted to compare students' pre and post test scores. Interaction analysis methods [5] were applied to study the recordings for in-depth analysis of students' learning processes.

4 FINDINGS

Five students' pre and post test scores were valid to be included in the paired samples *t*-test. It showed a significant improvement in the post test performance ($M=86.4$, $SD=23.8$) than the pre ($M=48.6$, $SD=7.6$), $t(4)=4.7$, $p<0.01$. In the final presentation by the Sunday cohort, they listed pros and cons of using AI technology for automatic detection of mask wearing. As pros of AI, they argued that “people won’t get sick in public that much” and “AI doesn’t get sick”. They also pointed out possible situations that AI may not function well, e.g., “Can be avoided by anti-maskers by covering their face with their arm”, “people who have different masks than the ones covered by data will be classified as ‘not-masked’”.

The hands-on ML practices were found to be highly engaging for students, based on class recordings and learning journals. Preliminary video analysis showed some shared learning patterns among students. With TM, students demonstrated learning through the process of “share-observe-improve-reshare”. For example, Carlos (pseudonym; male, Hispanic) shared to the class his initial version of TM project for recognizing mask-wearing. In Figure 1 (left), when he was demonstrating with his mask on, he identified some situations where the ML model did not work well. Note there was also the issue of class imbalance in this version. Then he stopped sharing. About 6 min later, when he shared again, as shown in Figure 1 (right), his model was significantly improved. He explained he added photos that the initial version could not recognize, e.g., photos when he moved far away from the camera, photos when he turned around his faces.

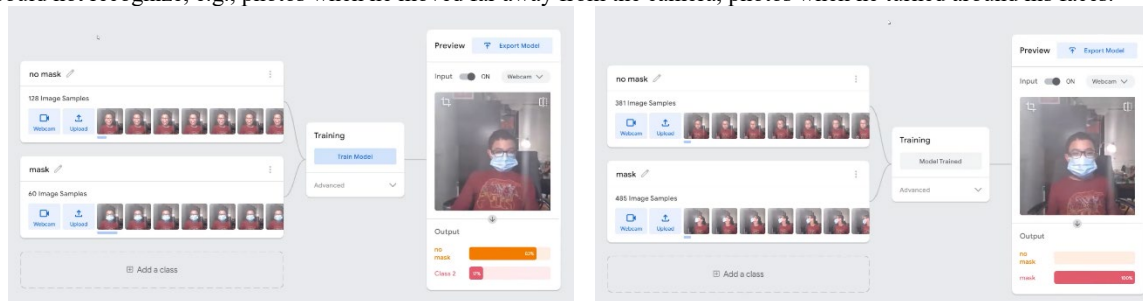


Figure 1: The initial version (left) and improved version (right) of Teachable Machine projects made by Carlos.

With Orange, students demonstrated learning through the process of “share-observe-discuss”. In Figure 2, Jack (pseudonym; male, Latino) was sharing the k-means clustering result of clustering their own photos of the Sunday cohort into five groups. When he opened the “image viewer” to view the photos in each group, he and the whole class discussed

to understand the machine behavior, especially after they observed there was a single yellow dot (circled out in red in Figure 2) being clustered in the green group (representing one student's photo mixed with another students').



Figure 2: Jack demonstrating the k-means clustering result of the Sunday cohort's photos with Orange.

5 UNIQUE CONTRIBUTIONS

This study provides a successful example of AI/ML curriculum in the SSI context for middle school students. Students showed improved AI/ML knowledge and practices and good understanding of AI ethics after the program. Through hands-on practices of collecting data, training ML models, and revising, they experienced the process of authentic problem solving with AI/ML technology. The study also uncovers students' learning patterns with different ML platforms, which can shed light on future designs of AI/ML practices and curricula for K–12 students.

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Act Happy! Act Crazy!

Using Emotion-based Commands to Engage Young Learners in Robotics Programming

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This paper explores the use of emotion-based programming commands as a means to engage young learners (ages 4-6) in robotics programming activities. Using the VEX 123 robot and its Coder card programming approach, young learners are invited to program a robot to recreate well-known stories. To support storytelling, the VEX 123 includes emotion-based commands including act sad, act crazy and act happy, each of which produce a predefined robot behavior associated with the emotion. The paper reports on learners in two elementary classrooms showing how these emotion-based programming commands were productive scaffolds to help novices engage in the task of programming a robot.

Keywords and Phrases: Programming Environment, Educational Robotics, Emotion-based commands

1 INTRODUCTION

Programming is becoming an increasingly important skill for learners to develop. While environments designed to teach programming have historically focused on older learners, there are a growing number of tools and environments designed to teach younger learners to program (Angeli & Valanides, 2020; Bers, 2018b; Duncan et al., 2014). Across these environments for young learners, a growing array of approaches is being used, including direct control, tangible programming tools, and virtual programming environments (Bers, 2018b; Horn et al., 2009). Newer environments, such as the VEX 123 (Figure 1, left), combine multiple programming approaches into a single device in an effort to support and scaffold learners as their programming knowledge and skills grow. The VEX 123 has a unique tangible programming approach that utilizes a novel, unplugged Coder and Coder Cards (Figure 1, left) where commands written on plastics strips can be sequentially arranged in the Coder and then sent to the robot. There are Coder Cards for basic robot behaviors, such as `drive 1`, `glow blue`, and `turn left`, conventional programming constructs including `if`, `else`, and `end if`. Additionally, we designed the emotion-based coder cards for VEX 123 with the intention of incorporating social-emotional learning into the robotics education (Figure 1, right). In including emotion-based commands, we sought to foster both playfulness in the learners, as well as to provide a mechanism to help anthropomorphize the robot as a means of scaffolding storytelling where the robot is the primary actor. VEX 123 includes three

emotion-based commands which are pre-coded multi-step behaviors that can be used as part of a program alongside conventional robot commands. The use of the verb *act* and the accompanying icon on the commands helped clarify the meaning of the movements being performed by the robot when it executes the command. In this paper, we explore if and how these novel emotion-based coder cards support young learners in engaging with programming activities, specifically in the context of storytelling.

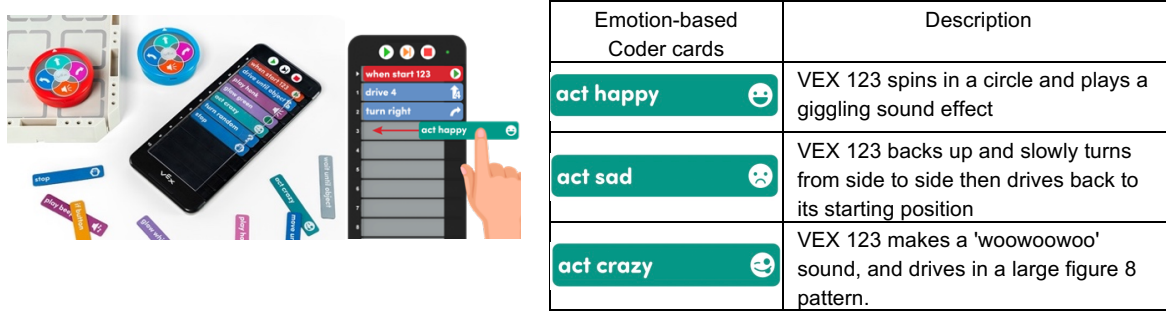


Figure 1: Left: VEX 123 robot and Coder Cards. Right: The 3 emotion-based Coder cards and behaviors.

2 LIT REVIEW

This research seeks to build on the growing body of research looking at ways to introduce younger learners to programming (Angeli & Valanides, 2020; Bers, 2018b; Duncan et al., 2014). This research is a continuation of the work started by Papert and colleagues and their research with Logo (Papert, 1980). Over the last decade, there has been a resurgence of interest in exploring ways to support youth programming (Bers, 2018a), youth programming robots (Bers, 2018b), and tools and kits designed to engage young learners in computing (Yu & Roque, 2019). The introduction of emotion-based commands as a means to support storytelling builds on prior work on educational digital storytelling broadly (Wu & Chen, 2020) and, more specifically, work on storytelling as a means to engage youth in programming (Burke & Kafai, 2012; Kelleher & Pausch, 2007). This approach has been successful in motivating novices particularly those from populations historically excluded in computing. For example, (Kelleher & Pausch, 2007) found that students were three times more likely to use their extra time to work on their programs, when using Storytelling Alice. (Burke & Kafai, 2012) combined writing workshop and digital storytelling with Scratch to engage diverse populations of youth in programming and found that the word “storytelling” was on nearly all of students’ post feedback forms.

3 METHODS

To begin to understand if and how emotion-based commands support young learners programming robots, we conducted a pilot study in one first grade and one second grade classroom in a private school in a midwestern city. The study was part of their yearlong computer science class and had learners program the VEX 123, a small robot about the size of a hockey puck that supports press-and-go programming as well as programming via Coder and Coder cards. A total of 15 students participated in the study. The 1st grade class was made up of 4 male students (3 Black and 1 Multiracial) and 2 female students (1 Black and 1 Multiracial). The 2nd grade class included 3 male students (all Black) and 6 female students (5 Black and 1 Multiracial). Across the whole school, over 70% of students are from economically disadvantaged households. The pilot study lasted for 10 sessions, with students spending 40 minutes, once a week on VEX 123 activities. Students worked in groups

of two or three on the programming activities. Two experienced teachers taught the lessons. Both teachers are White females with over a decade of teaching experience each. The data for this paper is drawn from the second-half of the 10 week sessions during which the learners programmed the VEX 123 with the Coder and Coder Cards. While using the Coder and Coder Cards, the students worked through a series of narrative-based activities, including “Defeat the Dragon” (use the robot to push a paper dragon across the floor), “Gather Supplies” (navigate the robot to move to several different spots on the floor), and “Little Red Riding Hood” (re-enact the little red riding hood story via moving the robot). Each class session was filmed, resulting in 14 hours of classroom video and 28 hours of videos of small groups. At the conclusion of the 10 sessions, we semi-structured interviews were conducted with all students, asking them to recreate program they authored.

4 FINDINGS

The VEX 123 pilot study had students listen to and then recreate the story of Little Red Riding Hood with their robots. To do this, the teacher asked the students to sequence Coder cards to move their robot to either grandma’s house or the wolf and then have their robots react. This provided a context for learners to use the emotion-based commands. On the first day of the Little Red Riding Hood activity, the teacher asked “*Now [the VEX 123] gets to Grandma’s house, it sees grandma. We want him...?*” One student shouted out “*Act happy! Act happy!*” After the teacher showed students the VEX 123 act happy in front of the grandma’s house, the teacher put the big bad wolf paper character out (Figure 2a) and said “*The big bad wolf! I want to scare him off.*” The teacher prompted students to choose an Act card to add to the sequence. “*Crazy! Crazy!*” Students shouted out. Then she swapped `act happy` with `act crazy` and ran the code. With the pre-defined `act crazy`, the VEX 123 pushed the big bad wolf away. The students all laughed as they watched the story unfold. Students were then invited to write their own versions of the story (Figure 2b & c).

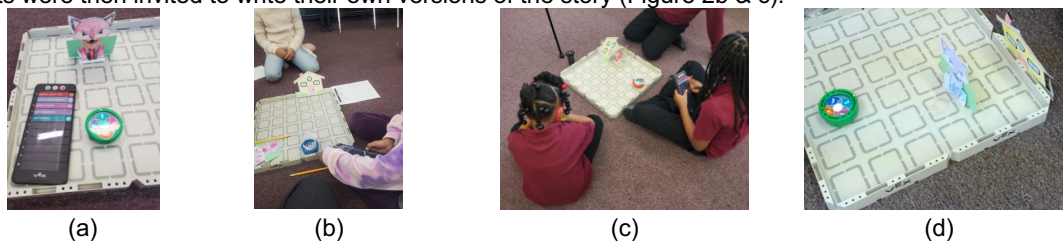


Figure 2: (a) The big bad wolf, (b) Grandma’s house, (c) students working, (d) the grandma’s house activity

To support the students programming on their own, the teacher provided all students with a subset of coder cards to work with, including all three emotion cards. In her comments after the lesson, the teacher reflected: “*One student had a cool idea of really retelling the story - he put the house first, he drove to object, acted happy, then he moved the house and directly behind was the wolf, and then the robot acted crazy.*” The teacher went on to comment that this was a child who struggles academically and had been diagnosed with a learning disability, “*to see him so clearly be able to retell the story with code was amazing!!!*” In reflecting on the activity, the teacher said, “*A huge strength to this STEM lesson was the storyline that kept the students very engaged in their various computer science tasks, bringing a social emotional engagement and a purpose to the coding tasks.*” During the end-of-class activity, the teacher asked students share one thing they liked or learned in the class. Several students said they like the `act happy`, `act sad`, and `act crazy` behaviors. One student said

“saving the grandma!” What these quotes highlighted is how the programming activity was perceived as a storytelling activity and how the emotion-based commands helped novices engaging in programming.

At the end of the 10 sessions, we conducted post-interviews with students. In the interviews, students reference the emotion-based coder commands. As part of the interview, students were asked to recreate a program/activity they found meaningful. Nine out of 13 students interviewed included emotion-based commands in their meaningful programs. When asked to recreate a program, one student started by setting up grandma’s house and the big bad wolf (Figure 2d). Then he browsed through the coder cards and mumbled “what can we use?” He located the blue card `drive until object` and the green `act crazy`. “I put together [the code] to get to grandma’s house.” He was very excited after insert both commands into the Coder and said “Ready? Ready! Set go!” After the robot starts moving, he said “I did it!” From this vignette, we can see how young learners can use the emotion-based cards, alongside conventional programming constructs, help scaffold learners in creating short programs. Situating the programming activity in the context of a story helped produce a memorable learning experience.

5 DISCUSSION & CONCLUSION

Building on work showing the potential of storytelling to support novice programmers, this work presents a novel implementation of emotion-based programming commands as a means to engage young learners in programming and scaffolded their ability to author complex programs. Students were able to make the robot act out key plot points of a story in the correct order and re-enact a story using the robot. By situating programming tasks within a storytelling activity, the emotion-based coder cards also helped young learners with little prior experience engage and excel in programming activities. In doing so, this work adds a technique to the growing array of strategies that can be employed to help young learners have positive early experiences with programming and serve as an effective and engaging introduction to the field of computer science.

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Constructing various learning activities on the Semantic MediaWiki playground

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The article showcases the successful integration of various forms of collaborative learning on a single platform, the Semantic MediaWiki. Drawing on the theoretical framework of constructionism and the work of Papert and Minsky, we utilized object classes in the Semantic MediaWiki environment as initial building blocks. The categories of programming languages, video games, data sets, multi-agent models, diagrams, scripting tutorials, and online communities yielded the largest number of objects. By leveraging MediaWiki extensions, we transformed wiki pages into executable articles, which included flowcharts in graphviz, mermaid, and plantUML languages, as well as visual blocks of programs in Scratch and Snap! languages. Furthermore, we were able to embed running projects in multi-agent modeling languages such as Scratch, Snap!, StarLogo Nowa, and NetLogo Web to executable wiki-pages. The article demonstrates how these learning activities on the wiki foster the creation and modification of datasets, the use and modification of simulations, and scripting tutorials. Extending MediaWiki capabilities through Semantic Mediawiki, EmbedScratch, ScratchBlocks4, Snap! Project Embed, graphviz, mermaid, Widgets:iframe, Widgets:YouTube, allows teachers to collect projects created in various online educational communities in one field. This helps students learn from simpler to more complex examples of how to solve similar problems in different multi-agent programming environments. Website address - <http://digida.mgpu.ru>

Keywords

Agency, collaboration, Semantic MediaWiki, Scratch, Snap!, NetLogo, StarLogo Nova

INTRODUCTION

The article discusses the area of the educational landscape where a designer creates a digital environment for a trained person to act as a learning demiurge for trained software agents. In the zone of intersection of a teaching student and a learning software agent, a field of computational didactics opens up before pedagogical design, where students teach digital performers the rules of behavior. This field of computational didactics has been developing for a long time and involves the formation of the student's computational thinking as a person's ability to use the capabilities of computing systems. The peculiarity of this field of knowledge is emphasized by the simple and compact definition of computational thinking given by A. Repenning - "synthesis of human abilities and the capabilities of computing systems" [14].

The use of the adjective "computational" to describe a field of knowledge was first proposed by Seymour Papert and Marvin Minsky in their 1969 book, *Perceptrons: An Introduction to Computational Geometry* [9]. Marvin Minsky was a pioneer in the field of artificial intelligence, and his work has had a profound impact on the development of computational thinking. Minsky believed that computational thinking is essential for the successful coexistence of people and machines in a hybrid environment. He argued that computer programs are a powerful tool for creating and telling stories, and that they can be used to teach children how to think like computers. Minsky's vision of the computer world as a source of endless children's cubes is particularly inspiring. He saw the potential for computer programs to allow children to create their own artificial worlds, and to learn how to control and manipulate these worlds. This vision is now being realized in the form of block visual programming environments, such as Scratch and Snap!. These environments allow children to create interactive stories and games using simple drag-and-drop blocks. Minsky's work has helped to lay the foundation for a new generation of computational thinkers. His ideas about the power of computer programs to teach children how to think are more relevant than ever before. As we move into a world where technology is increasingly ubiquitous, it is essential that our children have the skills they need to understand and use technology in a responsible way. Minsky's work can help us to achieve this goal.

Minsky's critical article on learning the Logo language [8] was a significant contribution to the field. He argued that language acquisition does not occur through the study of rules alone; instead, language is mastered through engaging stories that people want to read and tell. For pedagogical designers of learning microworlds, this means anticipating the creation or use of existing collections of "wonder stories" that can happen to agents in the digital environment. To this end, providing collections of examples with which students are familiar before they enter the microcosm of creativity can be immensely helpful. Video games, for instance, are a great resource for introducing students to the behavior of agents-executors within the framework of a given scenario. Even if students don't initially understand why certain behaviors are implemented or what algorithms game developers used, they become familiar with patterns of performer behavior that they can then incorporate into their own stories. Simply creating a rich environment for construction is not enough; it's also essential to provide examples of what can be built. In other words, it's not enough to give children an educational printing press and let them loose; they should first have access to a school library where they can view examples of wonderful stories that they might

want to create with their printing press. Similarly, the modern digital school library should be a collection of video games used to build students' digital literacy, imagination, and creativity. By exploring these games, students can imagine possibilities for what they might construct in the microworlds of agents and robots. Overall, Minsky's insights highlight the importance of engaging stories in language acquisition and the value of using familiar examples to introduce students to new concepts. By doing so, we can help students develop their digital literacy and equip them to tackle the challenges of the future. By playing and studying video games, students get acquainted with possible patterns of behavior of computer agents of performers. Inside the educational microworlds, students implement patterns of behavior through the creation of algorithms that control the behavior of agents. The amazing educational world of possible stories with objects that are assembled from digital building blocks in video games and educational microworlds has undoubtedly been influenced by the work of James Gibson on an ecological approach to the visual perception of the world around us, when parts of the landscape and individual things are described in terms of the possibilities that they open up [3,5]. In front of the character, and this description looks like a prototype of an instruction for a computer game like a quest - in front of you is a cave in which you can hide, and here lies a stone that you can take. And this same ecological approach to the actions of objects in the natural or artificial world, where they hide or push each other, we can find in the works of Michot [7]. The same ecological approach in education is implemented in the work of Repenning and his colleagues in the field of educational game design, where they managed to identify a list of simple behavioral patterns that a student in an artificial world can teach creatures consisting of digital bricks [1].

Papert and Minsky's ideas on educational microworlds have been highly influential in the field of computer science and education. Over the past fifty years, a wide variety of microworlds have been developed, drawing on the legacy of Papert and Minsky's work with the Logo turtle. These microworlds provide students with the opportunity to learn through exploration and experimentation in a digital environment. One of the most popular and widely used educational microworlds today is Scratch, a block-based programming language developed by the MIT Media Lab [15]. Scratch allows students to create interactive stories, games, and animations, and has been used in classrooms around the world to teach coding and computational thinking. Another popular microworld is Snap!, which is based on the Scratch programming language but includes additional features for more advanced learners. Snap! is used by educators to teach programming concepts, game design, and more [4]. StarLogo Nova is another educational microworld that is particularly active today. Developed by the MIT Scheller Teacher Education Program, StarLogo Nova allows students to create and simulate complex systems, such as ecological networks and social systems [6]. NetLogo is another microworld that is widely used in education [13,16]. It allows students to create and simulate complex systems using agent-based modeling, and has been used to teach a wide range of topics, including ecology, economics, and social dynamics.

SEMANTIC MEDIWIKI AS A MEDIA FOR ACTIVE ESSAY

The task of collecting various learning microworlds in a single field poses a significant challenge for educators and technologists alike. However, Alan Kay's proposed concept of the "Active Essay" offers a promising solution. An active essay is a multimedia document that incorporates text, images, video, and interactive elements to create an immersive and engaging learning experience. Unlike traditional essays, which are often linear and static, active essays are dynamic and interactive enabling students to explore ideas and concepts in a more flexible and engaging manner. One approach to realizing the Active Essay concept is through the utilization of Semantic MediaWiki media. Semantic MediaWiki is a platform that enables users to create and manage structured data in a wiki-like environment. By leveraging Semantic MediaWiki, we can establish a centralized platform for collecting and organizing various learning microworlds.

Over the past twenty years, wikis have become an increasingly popular tool for collaborative knowledge sharing in education [10,11]. However, the true potential of wikis for collaboration goes beyond simply creating and editing text-based articles. With the Semantic MediaWiki extension, wikis can be transformed into semantic wikis, greatly expanding the possibilities for collaboration on a shared knowledge ontology. We are excited to present our experimental platform, <http://digida.mgpu.ru>, which utilizes Semantic MediaWiki technology to create a dynamic and interactive environment for knowledge sharing. By focusing on creating classes for articles, we are able to categorize objects based on certain properties and categories, allowing for a more structured and intuitive way of organizing information. Our platform provides an interactive collection and presentation of knowledge using forms, templates, and properties of the Semantic MediaWiki system. This approach ensures a uniform collection of data about entities that represent a new area of knowledge. Additionally, the platform allows for the ability to search and generate reports on queries formulated in the ASK language, providing a powerful tool for educators and learners to explore and engage with complex topics. By creating classes for

articles, we go beyond simply creating separate articles on specific topics, such as "recursion" or "big data" or learning languages like Scratch or Snap!. Instead, we are able to create a more interconnected and meaningful knowledge base, with articles relating to specific classes and categories.

The category of programming languages and educational microworlds was one of the first categories of objects that we began collecting on our wiki site. While this category may seem simple, it provides a rich and complex history of programming languages, including their creators, predecessors, and descendants. By collecting this information, we can create a timeline of programming languages and educational microworlds, providing a valuable resource for educators, researchers, and students alike. This timeline allows for a deeper understanding of how programming languages have evolved over time, and how they have been used in education to teach computational thinking and problem-solving skills.

```
{{#ask: [[Category:Programming language]] [[launch year::+]] |format=moderntimeline |?launch year |? Ancestors |?Descendants }}
```

It should be noted that both Semantic MediaWiki pages and properties function as fundamental components that can be utilized to construct diverse forms of content. In addition to these building blocks, visual programming blocks in languages such as Scratch and Snap! will be incorporated into the experimental site's repertoire. For instance, if a wiki page contains a particular sequence of textual blocks, it can be transformed into visual blocks (Figure 1).

```
<scratchblocks version="2">
```

```
when @greenFlag clicked      ::control
```

```
say [Show these possibilities at the Constructionism-2023 conference] for (2) seconds:: looks
```

```
visit [https://www.constructionismconf.org/] ::sensing
```

```
</scratchblocks>
```

The aggregation of projects completed in different learning environments on a single wiki page provides a valuable opportunity to compare the features and differences in the implementation of algorithms across various programming platforms. Additionally, this approach allows for the transfer of solutions and experiences gained in one programming environment to the space of another programming language. The same principles apply to the aggregation of projects made in environments such as StarLogo Nova and NetLogo Web. In particular, agent-based modeling web environments have the capability to generate data that can be leveraged by students in further research projects [12]. To facilitate access to this data directly from the Semantic MediaWiki site, we employ the External Data Extension. This extension enables the retrieval, processing, and presentation of data generated in Scratch, Snap!, StarLogo Nova, and NetLogo Web on wiki pages.

Many examples of such access to external data can be found in the article from the DataSet category - <http://digida.mgpu.ru/index.php/Category:Dataset> For example:

```
{{#get_web_data:url=http://www.uic.unn.ru/pustyn/data-sets/mesh/giant_recicrop_component.csv
|format=csv with header
|filters=subject=Chemistry
|data=from=from,to=to,subject=subject,date=date_of_action}}
```

Overall, the aggregation of projects from different learning environments on a single wiki page provides a powerful tool for educators and learners to explore and compare various programming platforms. Furthermore, the use of agent-based modeling web environments and the External Data Extension enables the integration of data generated in different programming platforms, providing a valuable resource for further research and exploration.

DISCUSSION

In conclusion, our interactions with computer entities share similarities across different design environments. Whether we are accessing turtle performers in NetLogo or pages in Semantic MediaWiki, our requests to these entities follow a similar format. For example, when we ask blue turtles in NetLogo to show themselves and provide information about themselves, we use the command

```
Ask turtles with [color=blue] [set label who]
```

Similarly, when we ask pages in Semantic MediaWiki to appear on the screen and provide information about themselves, we use the command

```
{{#ask: [[Category:DEG]] [[Assistance_tools::+]] |?Assistance_tools }}
```

This command asks all pages from the category of digital educational games for which support tools are defined to go to the screen and show their support tools. These similarities in our interactions with computer entities highlight the importance of understanding the underlying principles of computer science, such as computational thinking and problem-solving skills. By developing these skills, we are better equipped to navigate and utilize the vast array of digital tools and environments available to us today. Overall, our interactions with computer entities may vary across different design environments, but the fundamental principles of computer science remain constant. We must continue to prioritize the development of computational thinking skills and embrace the power of technology to enhance learning and creativity in the digital age. Extending MediaWiki capabilities through Semantic Mediawiki, EmbedScratch, ScratchBlocks4, Snap! Project Embed, graphviz, mermaid, Widgets:iframe, Widgets:YouTube, allows teachers to collect projects created in various online educational communities in one field. This helps students learn from simpler to more complex examples of how to solve similar problems in different multi-agent programming environments. Website address - <http://digida.mgpu.ru>

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Introducing Digital Design Research (DDR): Constructionist Principles at the Methodological Level

Introducing Digital Design Research (DDR)

Constructionist principles at the methodological level

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This paper recounts the evolution of Digital Design Research (DDR) as a research methodology designed to document the construction of digital artifacts. DDR is an extension of Design-Based Research where change and collaboration are embraced during interventions in educational settings. Constructionism has been described in various ways as a learning theory, epistemology, and theoretical framework, but constructionist principles can also be applied at the methodological level, particularly when working with digital artifacts which embody the learning.

Keywords and Phrases: constructionism, digital scholarship, Digital Design Research

1 INTRODUCTION

Floridi [1] proposed six constructionist principles in relation to conceptual models but perhaps the most all-encompassing principle is that the creation of artifacts can embody learning. Harel and Papert [2] wrote about this over 30 years ago:

“They [the children] became software designers, and were representing knowledge, building models, and teaching concepts on their computer screens. They were thinking about their own thinking and other people's thinking - simultaneously - to facilitate their own learning” (p. 45).

A much older principle is also at work in the preceding statement, namely, learning by teaching, which can be attributed to the ancient Roman magistrate Pliny the Younger who famously said, “He [/she] who does the talking does the learning” [3] (p. 240). As researchers, we can probably think of examples of this principle in our own teaching practice, but this same principle can also work at the methodological level due to the affordances of multimodality and digital scholarship.

This paper uses an autobiographical approach to explain the background to DDR including some discussion of digital scholarship. Having completed a master's degree which involved the creation of explanatory animations to teach musical theory back in 2007, it was already apparent to me that the animation creation process has a consolidating effect on the animation author, which in that study was myself as it was my first foray into animation. The purpose of that study was to demonstrate how the animations could benefit the viewer so the rationale for further PhD study was to understand how the animation artifact can simultaneously embody and direct the learning of the animation author. That research became the Storyboard project [4].

2 THE STORYBOARD PROJECT

The Storyboard project was a practitioner action research case study involving four boys and four girls in upper primary school whose ages ranged between 10 and 12 years. The research question was, “In what ways can storyboarding and explanatory animation creation enable primary school students to articulate and consolidate their conceptual

understanding?” This research was inspired by other important figures in the story of constructionism such as Resnick [5] who wrote:

“We never expect to get things right on the first try. We are constantly critiquing, adjusting, modifying, revising. The ability to develop rapid prototypes is critically important in this process. We find that storyboards are not enough; we want functioning prototypes” (p. 5).

The animation technique used by the eight participants in the Storyboard project involved Microsoft PowerPoint as the ability to create imagery using auto shapes and then duplicate each slide/frame using the ‘insert duplicate slide’ function was a fast and efficient way to create a series of animation frames. In this sense, the storyboard literally became the animation. The multimodal nature of the explanatory animation creation task required twelve data sources to be generated throughout the project. The students each produced three videos: (1) a prior knowledge video at the start of the project, (2) an explanatory animation at the end of the project, and (3) a director’s commentary about their animation to conclude the project. I kept daily reflections in my (4) reflexive journal and assessed the students after each session on a (5) conceptual consolidation rubric. I also wrote a (6) researcher reflection on each student each week and created (7) lesson plans for each session. Attendance was documented on an (8) attendance roll and the students and I also made video recordings of our (9) debriefing session at the end of the project. Component parts of the children’s animations included their various (10) imagery files (i.e., PowerPoint files) and a (11) voice-over script that evolved during each session until it was eventually recorded as an audio file for narration purposes. The students also made audio recordings at the end of each session about their progress and plans as (12) weekly reflections that were later transcribed for closer analysis. Of these twelve data sources, two were found to be particularly significant as follows:

1. What each student could articulate about their topic through their voice-over script.
2. What I knew about the topic as documented through my researcher reflections in weekly reviews.

The grounds for comparison (i.e., why compare the children’s voice-over scripts and my researcher reflections?), is based on the notion that storyboards are semiotic tools for cross-modal cognition. The term ‘cross-modal cognition’ describes the ways in which learners in a multimodal environment creating explanatory animations are simultaneously working with different modalities, such as images and words, as different aspects of the same pedagogical task. The co-construction of knowledge as evidenced through the evolving digital artifacts also surfaced my own understanding of the topic. This provided a logical context for analysis as I would not have been able to make any judgments about each student’s work without reference to my own understanding [6]. The Storyboard project advanced our understanding of animation pedagogy and demonstrated how the children’s mental models, as depicted through their animation key frames and storyboards, functioned as both flexible models and diagnostic tools.

A distinctive element from the Storyboard project is that the research was constructed and presented on a dedicated website due to the digital nature of the animations (<https://brendanpauljacobs.com/>). Researchers who conceptualize their research as fully digital, multimodal constructions such as dedicated websites, can let the research evolve to become fit for purpose, taking its own shape as generative practice. The dedicated website is now understood to be an early example of digital scholarship in education [7]. Ayers [8] also noted a disconnect here as “researchers routinely use electronic tools in their professional lives but not to transform the substance or form of their scholarship” (p. 26). Digital scholarship is not about the technology. Like all research, it is about the creation of new disciplinary knowledge. Due to the additional time

required to generate, curate and present multimodal data, researchers would only consider using digital scholarship to develop a multimodal thesis or dissertation if they were working with data which is intrinsically digital, rather than data which has been digitized. Ayers [8] has reduced this argument down to its simplest form by stating that digital scholarship exists “to do things that simply cannot be done on paper” (p. 30). For the Storyboard project, the rationale was to allow viewers to interact with the data in its native digital format. The fact that links to the raw data for each iteration of the children’s work were available on the website was a methodological innovation which enabled people to see a chronology of the children’s learning. This also increased trustworthiness in addition to Guba and Lincoln’s [9] other measures of credibility, transferability, dependability and confirmability.

3 INTRODUCING DIGITAL DESIGN RESEARCH (DDR)

DDR is a research methodology for educators which has been devised to document the process behind the construction of digital artifacts. There are three minimum requirements for DDR as follows:

1. The first requirement is that the author of an explanatory artifact is using digital tools in a digital environment. This accounts for the ‘digital’ in DDR.
2. The second requirement is that multiple versions of the artifact are retained and archived, preferably after each significant iteration. This evidence-based approach accounts for the ‘design’ in DDR.
3. A third requirement is that the rationale for changes is documented, usually in the form of a reflexive journal. This record of theoretical and pedagogical reasoning accounts for the ‘research’ in DDR.

The digital environment sets the prerequisite condition, the multiple iterations provide the evidence base, and the date-based rationale functions as a running commentary outlining the emergent themes. This last point is important because the decision-making process recounted by the author of a digital artifact could be characterized as being subjective which is an issue pertaining to data analysis.

Data analysis in DDR blurs the boundaries between subjectivity and objectivity in a unique way because DDR is a research methodology for educators. Changes to an artifact in DDR are largely subjective due to the professional judgment of the educators involved but definitions of subjectivity often relate to the lack of an evidence base. DDR is all about the evidence base so it is here that DDR can be leveraged to raise the profile and status of professional judgment by making such judgments visible. This principle also applies to tacit knowledge. Tacit knowledge is generally not written down or recorded but DDR can surface this tacit knowledge as pedagogical and/or theoretical reasoning. According to Tripp [10], it is “professional judgment which makes teaching a profession rather than a technically expert occupation or vocation” (p. 10). Tripp defines professional judgment as “those expert guesses which result from combining experience with specialist theoretical knowledge” (p. 7). Teachers make countless decisions every day, but, unlike researchers, the decision-making process which guides such decisions is rarely articulated. DDR seeks to elicit these decision-making processes by providing both the rationale for changes to an artifact and various versions of the artifact itself. In this sense DDR, is equally concerned with both process and product.

Arts-based research has some obvious parallels with DDR as it is quite common for academics in the arts to research their own process throughout the creation of artifacts. Mäkelä [11] spoke of “knowing through making” (p. 157) and the role of the artifact in practice-led research. The parallels with the arts-based research and DDR are clearly evident but the commonality between the arts and DDR is even stronger when considering the wider concept of design. Simon [12]

proposed this back in the late 1960s as the ‘science of design’ as he found common ground across the arts, sciences and technology as an interdisciplinary field.

The distinctive methods involved in the Storyboard project such as the dedicated website, access to multiple iterations of digital artifacts, and directors’ commentaries, can be seen retrospectively as precursors to DDR. A more current (although incomplete) example of DDR is a longitudinal STEM integration project which does not fit neatly into any existing research methodologies (<https://silo.edu.au/>). This alone would not constitute sufficient grounds for devising a new methodology but DDR also involves data analysis protocols and procedures which are unique to the various iterations of digital artifacts. In DDR the data is analyzed in real time whenever changes are made.

4 CONCLUSION AND RECOMMENDATIONS

The research done under the umbrella of constructionism until now has been done with a variety of methodological approaches which have served the researchers well, but the affordances of DDR might provide new insights into the construction of digital artifacts which have an explanatory purpose due to the strong evidence base which DDR provides. DDR is also well suited to longitudinal studies as there are no limits to the file naming conventions which can provide a chronology of the construction of an artifact. A distinctive element of DDR is the abundance of digital data documenting the construction process, but researchers must be diligent, consistent, and logical with their file naming and saving conventions. Ultimately, it is the quality of the reflections made to justify the rationale for each iteration and change which makes DDR unique as the data analysis occurs concurrently with the construction of an artifact. Animators, video editors, audio engineers, graphic designers, and other creative professionals make countless decisions on a daily basis, but these decisions are intrinsically pedagogical when the media has an explanatory purpose. The issue of whether DDR necessarily requires the use of a dedicated website is yet to be determined, but the two examples listed in this paper suggest that it does. This would further distinguish DDR as a specific methodology for research projects where the central focus is the development of digital artifacts, including websites as the quintessential multimodal artifact.

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Discover BBC micro:bit board as part of a dynamic and experimental AI learning process

Constant technological progress is a key challenge for Education and Society in the 21st century. This fact reflects the need of educational communities to stay updated in relation to technological tools and new pedagogies. This article describes experiences in the use of micro:bit programmable boards as part of a dynamic and experimental process of Artificial Intelligence (AI) educational projects. Micro:bit's design allows users without prior knowledge to develop their first programming skills, to use AI platforms while creating models that can respond intelligently to different stimuli and use data provided during training.

The experiences presented rely on the TeachableMachine platform to create a machine learning model for classroom projects. These experiences are recorded in pedagogical sheets that ensure the applicability of these concepts and tools on different types of curricular content in diverse educational contexts.

Keywords: Micro:bit, Machine Learning, pedagogical sheets, education technologies

1. INTRODUCTION

Although the first AI concepts were generated in the mid-20th century, it was in recent years that this technology has grown dramatically. Hundreds of companies, platforms and universities worldwide develop applications and tools that involve AI user experiences. The possibilities offered by this new technology are endless. However, exploring these possibilities requires a basic understanding of the operational processes necessary for the models to work¹.

Within this context, it is important to highlight that machine learning is a subfield of Artificial Intelligence. Lasse Rouhiainen (2018) defines Artificial Intelligence as “the ability of computers to do things that normally require human intelligence” (Rouhiainen 2018: 17). More specifically, the author refers to the ability of machines to use algorithms, learn from data, and use what they have learned to make decisions just as a human would.

On the other hand, the concept of Machine Learning refers to one of the main approaches to Artificial Intelligence. According to Rouhiainen, this concept refers to computers or machines having the ability to learn without being explicitly programmed to do so. A typical outcome would be suggestions or predictions for a specific situation.

This paper focuses on the development of pedagogical worksheets that explain AI projects combining micro:bit boards and the TeachableMachine platform. These sheets present activities involving the generation of supervised learning models, the most popular Machine Learning application. In supervised learning, a model is trained on a tagged data set and then asked to predict an output or label it has not seen before.

In supervised learning, Machine Learning algorithms are trained on labeled training data. In other words, the training data has been labeled by a human expert to indicate which examples are positive and which examples are negative. For example, a supervised learning algorithm may be trained on a set of labeled images of a certain disease to determine whether a new image is a positive or negative example of the disease. Supervised learning is often used to create a classifier

¹In this regard, Pereiro et. al. (2022) state: “Although the discipline began in the mid-twentieth century, today is the most effervescent historical moment of this field. There are at least two large companies that are working towards achieving a general artificial intelligence, this refers to being able to emulate human intelligence with all its complexity” (E. Pereiro, et. al. 2022:6).

that can be used to determine whether new examples are positive or negative examples of the concept in question (Pereiro et. al. 2022:7).

This project is part of several educational proposals developed by Ceibal in Uruguay and has two fundamental antecedents: on the one hand, the development of the micro:bit project, as a program for massive distribution of programmable boards in the one-to-one model for Uruguayan students and teachers. On the other hand, the implementation of the Computational Thinking program as a large-scale intervention program in computational thinking in primary education. In this line, for the present work, pedagogical contents developed by both programs were used as a basis to investigate possible applications of Machine Learning with the micro:bit programmable board. As explained by Pereiro, et. al. (2022), there are some incipient proposals in Artificial Intelligence for educational systems suggesting that digital education generates the necessary conditions for the incorporation of AI into educational projects².

To learn with AI, learn about AI and prepare for AI, teachers must play and have a central role. The process by which both tools and platforms are incorporated and used and the way these topics are integrated into the curriculum depend, to a large extent, on the empowerment of teachers, and therefore the real impact of AI in education. Working on computational thinking, computer science, robotics and programming has a transitional effect towards the incorporation of AI, it is the next stage in the development of these competencies, and it can serve as a milestone to follow this path (Pereiro, E. et. al. 2022:22).

2. MACHINE LEARNING AND SUPERVISED LEARNING: AN OPPORTUNITY FOR STUDENTS AND TEACHERS TO WORK ON ARTIFICIAL INTELLIGENCE

The main objective of the learning sheets on AI applications that use micro:bit boards is to disseminate basic concepts so that students and teachers can learn more about them.

As explained above, an elementary concept closely linked to the TeachableMachine platform is the so-called Machine Learning and its different types. Apart from providing a generic definition for Machine Learning, this paper also states that supervised learning is the technique to be used with the TeachableMachine platform. This means that our model will receive a large sample of tagged data for each of the categories set. From that initial data series, the model will recognize a new element in the category. It is important to note that data used should be images or sounds.

A simple example is a Machine Learning model that, based on photos, can identify three different types of birds. Initially, tagged photos with the name of each species must be uploaded. In general, the larger the amount of tagged data, the more robust the system becomes. If the photos are different from each other, the system will probably have a greater chance of success when shown a new image. In parallel, an audio model can be made using the birds' songs.

Another fundamental concept is that, once the model is generated, a confidence threshold should be defined to validate predictions. More specifically, if our model indicates that a new piece of data (image or audio) reaches a certain matching percentage in any of the categories, that piece will be considered valid. The trust threshold is determined by the user.

It is stated that models are not infallible and therefore can make mistakes. Much of the learning lies in understanding the sources of error and how to improve our Machine Learning models.

3. PEDAGOGICAL SHEETS: A GUIDE TO CLASSROOM WORK

The pedagogical sheets begin with a general introduction to basic concepts of AI and Machine Learning. Next, they delve into fundamental aspects of the different platforms that will be used to create the AI- micro:bit project. Finally, they recommend steps to continue learning and creating models.

² There are different backgrounds of pedagogical worksheets for AI project work in the classroom. You can find some examples on the following websites:

- https://ec.europa.eu/futurium/en/system/files/ged/mit_ai_ethics_education_curriculum.pdf (last access 4/8/2023).
- <https://pensamientocomputacional.ceibal.edu.uy/wp-content/uploads/2023/06/Guia-Maquinas-que-aprenden-Inicial.docx.pdf> (last access 4/8/2023).

The first sheet also describes the main differences between traditional programming and Machine Learning; they also explain essential features of the Teachable Machine platform and give the user a detailed guideline to create a new model³. The step-by-step guide describes the whole model creation process. This could be summarized in three steps:

- **Data collection:** the stage in which the data set is loaded into the model. Possible data types include images, sounds and poses.
- **Model training:** the stage in which the Teachable Machine platform processes the information and generates the model. Once this stage is complete, the model can be tested and edited if necessary.
- **Model exportation:** the final stage to export the model; it can be downloaded or hosted online. The model created in this stage is the main pillar of the final project.

The second sheet focuses on the final linking process between the Teachable Machine model and the micro:bit board⁴. The series of steps required could be summarized as follows:

- **MakeCode programming:** the stage in which the user creates the micro:bit code that will allow the board to receive and interpret the information from the Teachable Machine model. This code sets the configuration that allows for serial communication between the micro:bit board and the computer. At the same time, the user determines the actions the micro:bit will execute based on the information received from the Teachable Machine model. The code must be flashed to the board using USB connection.
- **Linking platform:** the stage in which the user is explained how to configure ai-training.glitch.me. This website is the online platform that creates the link between the micro:bit board and the Teachable Machine model. The micro:bit board must be paired through a USB connection. Then, the user uploads the Teachable Machine model created to this platform.
- **Final result:** the platform interface shows data being received by the machine learning model, and at the same time displays the matching percentage of the different classes established. When percentages are high, a string is sent to the micro:bit board through USB connection. The possible strings are exactly the same as the class names defined in the Teachable Machine model. The micro:bit receives the string and takes actions based on the program previously created by the user.

It is important to note that the projects included in these worksheets require a computer with a microphone, webcam and Internet connection.

Based on the content of these two pedagogical sheets, new activities and in-depth projects are under development. The use of these sheets in the classroom is a great opportunity to work on curriculum content related to different disciplines, while putting into practice different skills such as computational thinking, creativity, critical thinking and programming. Autonomous recognition systems, pictures or pose classifiers, automatic counters, gesture or voice controlled micro:bit applications are some examples of what can be created using these tools.

4. PRELIMINARY CONSIDERATIONS

The following preliminary considerations are based on this first approach to working with micro:bit and AI to generate educational content.

The educational material generated allows teachers and students to discover a new area of knowledge. Those who complete their learning through the different sheets will have more tools and confidence to delve in the world of AI.

³ To see the sheet 1 click on the following link: https://microbit.ceibal.edu.uy/storage/app/media/Sheet%201%20-%20First%20steps%20with%20micro_bit.pdf (last access 11/8/2023).

⁴ To see the sheet 2 click on the following link: https://microbit.ceibal.edu.uy/storage/app/media/Sheet%202%20-%201A%20model%20and%20micro_bit%20connection.pdf (last access 11/8/2023).

The use of different resources that combine and complement each other develop the ability to work in stages and see the whole picture once the project is finished. This mechanism promotes the development of computational thinking and it also highlights the importance of working processes and their different stages to achieve the ultimate goal.

The elaboration process can be considered a path to learning, one of the great values of the maker movement where learning by doing is an essential concept.

It is vital to highlight the link between a powerful existing technology such as the micro:bit programmable board and the new and emerging universe of AI. These learning sheets encourage users to discover and create an unlimited universe of new applications. As Pereiro et. al. (2022) state, the development of AI in education can have a great impact on the teaching, learning and evaluation process. Moreover, the use of AI in education can be a way to achieve different learning objectives and can provide students with technical and conceptual elements to understand and reflect on the changes that AI will bring in the near future.

Finally, the fact of making content available through various open networks is an invitation to discover these tools in the most diverse spaces and contexts. This invitation also seeks to promote peer exchange as a way to encourage support among teachers, students and users interested in the subject. Open audiovisual materials have been developed to be used together with the sheets, but it is important to take into account that there is a very wide range of possibilities to discover and generate new pedagogical contents⁵.

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WEBS SITES:

Ceibal Computational Thinking website: <https://pensamientocomputacional.ceibal.edu.uy/> (Last access: 2/8/2023).

Ceibal micro:bit (AI pedagogical sheets with micro:bit): <https://microbit.ceibal.edu.uy/articulo/ia-con-microbit> (last access: 11/8/2023).

Ceibal's website: <https://ceibal.edu.uy/> (Last access: 2/8/2023).

Ceibal STEAM Youtube: https://www.youtube.com/@CeibalSTEAM_Uy

⁵ For more information, see Machine Learning with micro:bit playlist on Ceibal STEAM Youtube channel: <https://www.youtube.com/watch?v=31mVot1Nxoo&list=PL65Zsdp0e9GrcfXKblZ241YuGDRLVwxKX> (Last access: 2/8/2023).

Reconsidering a Picture Rewriting Rule-Based Programming Language for Preschool Children in Japan

A Comprehensive Study Using Viscuit

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In Japan, in response to the mandatory implementation of programming education in elementary schools there is a growing trend in the private sector to offer programming education services for preschool children, and some kindergartens and nursery schools have started their own programming education programs. Furthermore, worldwide, the start of programming education is being accelerated at an early age. However, there has been little discussion about what kind of programming education should be provided to preschoolers and whether such education is possible. In this study, we draw a picture of how preschoolers can express themselves through programming as an ideal form of programming education for preschoolers using Viscuit that adapts picture rewriting rule.

Keywords and Phrases: Picture Rewriting, Visual Programming Language, Pre-school Programming Education, Viscuit

1 INTRODUCTION

In Japan, programming education has become a mandatory subject in elementary schools since the academic year 2020 (MEXT, 2017). As a preparatory stage for elementary school, there is an increasing number of private classes that offer lessons and workshops for preschool children. On the other hand, There is much room for debate about the state of preschool programming education.

The report issued by the Japan Academy (Japan Academy, 2020) suggests the necessity of programming experience for children before entering elementary school. Additionally, according to the kindergarten curriculum guidelines (MEXT, 2017), education in kindergarten is positioned as "education through the environment," which is said to be conducted through comprehensive guidance through play.

Saeki (2014) explains the learning process in the context of interaction with the environment in two phases: the "familiarization" phase and the "cultural practice" phase. When infants and young children play with any object, they try out various ways of using it and explore how it works. Through this practice, infants and young children fully experience the object and "familiarize" themselves with it as if it were a part of their own body. As a result, they want someone to "see" their actions of utilizing the object. If the object is a tool, infants and young children immediately want to create something interesting with it. At that time, they hope and expect to make someone laugh or happy with their actions. This act of having their own values towards others is cultural practice, and through this practice, infants and young children gradually participate in society. Reddy (2008) also describes the relationship with the second person in development.

Furthermore, from an international perspective, there is a growing interest in improving the quality of early childhood education in advanced countries represented by OECD member countries (Suzuki, 2014). In this regard, examples of high-quality early childhood education and care curricula are cited, such as the Reggio Emilia approach (Edwards & Forman,

1998) in Italy and Te Whāriki (Lee, 2013) in New Zealand. These practices are designed to facilitate effective learning through children's expression and comprehensive play-centered activities. It is evident that learning through play for preschool children is emphasized worldwide.

In this study, we examine preschoolers' programming activities using Viscuit, give them meaning, and propose a research method for such activities.

2 PROGRAMMING LANGUAGE “VISCUIT”

The programming language Viscuit is a visual programming language that was developed in 2003 by Harada (2003). The instruction format of Viscuit is called the "Picture Rewriting Rule Base," and various studies have been conducted on it since the 1990s (Repenning, 1993; Anderson, 2010; Bell, 1993; Smith, 1994). Viscuit does not require any text input and can be used on tablet devices, making it accessible even to preschool children who have difficulty operating a mouse. Therefore, Viscuit is particularly well-suited for use with preschool children.

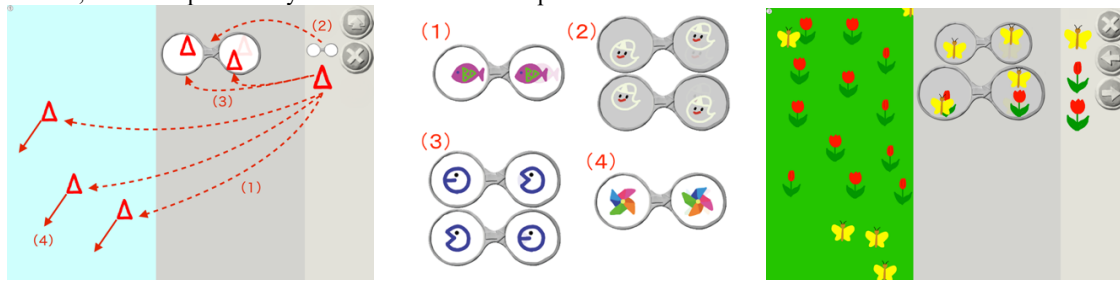


Figure 1: How to make a program (Left). Examples of rule in Viscuit (Middle). Conditional programming in Viscuit (Right)

Figure 1 (Left) illustrates how Viscuit programs are created. (1) Pre-supplied or originally drawn pictures are placed on the stage (light blue area). (2) An empty rule (shaped like eyeglasses) is placed in the gray middle area. (3) Pictures represented by triangles are then dragged inside both circles of the rule. (4) This instantly makes the pictures move on the stage. In this figure, three triangles move toward the bottom left because the layout of the triangle in each circle shows that the triangle in the right circle has moved from the position of the triangle in the left circle to the bottom left of the right triangle. The rule created in step (2) represents a change from the properties in the left circle as the "before" state to the properties in the right circle as the "after" state.

Figure 1 (Middle) depicts four different ways to use the rule. Users can make pictures move by placing the same pictures in the left and right circle, where the distance between the positions of the picture in the left and right circle reflects the direction and speed. If the distance is greater, the speed increases (Figure 1 (Middle), upper left (1)). "Random Move" is created by making multiple rules that have the same picture in each circle (Figure 1 (Middle), upper right (2)). "Change of Picture" is created when different pictures are placed in each circle, causing the picture in the left circle to change to the picture in the right circle (Figure 1 (Middle), lower left (3)). "Rotation" is created by rotating a single picture (Figure 1 (Middle), lower right (4)).

Conditional programs are created by placing more than two pictures in the left circle of the rule. While putting the same picture in both circles of the rule makes the pictures on the stage move immediately, putting multiple pictures in the left circle means "if there are pictures positioned in the layout of the left circle on the stage, then the pictures of the left circle change to the pictures of the right circle". For example, in Figure 1 (Right), the left circle of the rule means that if a

butterfly and a tulip are positioned in the layout of the left circle, the butterfly moves upwards, and the tulip changes to a blooming tulip.

3 THE POSITION OF PRESCHOOLERS' LEARNING IN VISCUIT.

Papert (1980) advocated the potential of learning through programming and asserted the necessity of constructionist learning. In constructionism, children are viewed as individuals who actively construct knowledge by combining their existing knowledge with new knowledge. Children are not seen as passive receptacles who can be filled with information they lack. The idea is in accordance with the guidelines for Japanese kindergarten curriculum, as well as with Saeki's perspective.

Papert further emphasizes that the role of computers and programming in such learning is to make abstract concepts more concrete and to enable children to integrate them with their existing knowledge.

In current programming education, there is often a focus on concepts such as sequential, conditional, and iterative programming. However, it can be argued that the significance of the emergence of computers was that abstract concepts became concrete with their use, enabling children to build new knowledge by working with them, rather than simply being able to think abstractly. Taking this into consideration, it is believed that Viscuit enabled preschoolers to learn programming because abstract concepts such as coordinates and language became tangible through the placement of glasses and pictures.

In Viscuit programming, preschoolers are not explicitly taught the concepts of sequential, conditional, and iterative programming. However, through the process of creating programs and experimenting repeatedly, they are constantly thinking about what they want to create and going back and forth between what they know and what they can achieve with Viscuit. Through this process, they become familiar with the unique characteristics of computers, such as "computers move by instruction," "computers do not make mistakes; incorrect operations are due to human instructions," and "multiple pictures move simultaneously with one instruction", which are features that do not exist in the physical world.

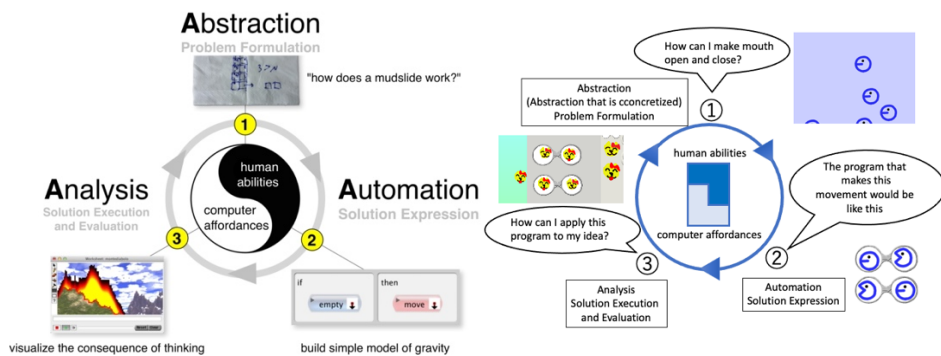


Figure 3: CTP cited from (Repenning, 2016) (Left). CTP in Viscuit (Right).

Repenning (2016) introduced the process of expressing ideas using computers as a computational thinking process (CTP). CTP is a process of (1) formalizing (abstracting) a problem, (2) representing a solution (automating), (3) executing and evaluating the solution method (analyzing), and then returning to (1) (Figure 3. (Left)).

The authors considered that preschoolers experienced CTP using Viscuit. First, Viscuit concretized abstract concepts, as Papert pointed out the significance of computers. Therefore, preschoolers could move and change pictures even without

knowing the concepts of numbers or coordinates. In other words, the abstract concepts became concrete. On the other hand, the concepts were not perfectly concretized. Distinctive features of computers such as "moving in response to instructions," "multiple objects moving with a single command," and "even if an instruction is incorrect, it will still execute the command," have been retained. While utilizing these characteristics of computers, preschoolers went through a process of imagining what they wanted to create, drawing a picture to create glasses, executing the movement, checking the result on the screen, and creating a new work again. The authors considered that through this process, preschoolers became familiar with commanding the computer to perform the process they wanted, which overlapped with the cultural practices pointed out by Saeki. The authors regarded this CTP process as a cultural practice in programming and made it the research question of this study whether preschoolers could express cultural practices through programming (Figure 3. (Right)).

4 CONDUCTED LESSONS AND ANALYSIS TO BE DONE

In this research, we view programming as a tool for expression. Mixed-methods research (Creswell, J. W. 2017) is an effective approach for investigating the relationship between children's expression and programming, rather than learning concepts themselves. However, there are currently not many studies using mixed-methods research for programming expression in preschool children.

The authors focus on the operation logs as an aspect of "play" programming and analyze them quantitatively. However, since the operation logs alone do not reveal communication with others, the programming activities will also be recorded on video and analyzed qualitatively. Finally, the quantitative data from the operation logs and qualitative data from the video recordings will be integrated and analyzed. Through this mixed-method research, the study aims to clarify what kind of play exists in the children's programming activities and how programming is beneficial to their abilities through play.

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THE STORY MAKER MACHINE

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INTRODUCTION

The purpose of “The Story Maker Machine” project is to encourage students to create narratives from simple material and a lot of fun. After they travelled to many places around the world through a book named “The illustrated book of fairy tales”, by Neil Philip. With these activities, we could notice that our kids were needing more repertory about narratives. After we worked with the orality, an idea came by: we could play with the main features of a story. So, we started a project to build a “story maker machine”.

First, we discussed which topics were going to be part of the project, and we ended up with these three questions: Who? Where? What?. The “magical W’s” is a reference to think about the characters, the places and the plot/action.

It is important to mention that we used only recycled materials such as toilet paper rolls, cardboard boxes and paper with drawings. Each class customized a part of the machine, working in groups to decide the colors, the design and the most important: the cards. The choices of the options of each topic were made by discussing and voting with total independence and protagonism of our children.



Figure 1: Students painting the toilet paper rolls



Figure 2: The game board was made with cardboard

One group made the characters: bull, prince, lion, princess, dinosaur, and grandma. The other one made the places: under the sea, forest, outer space, maze, playground and castle. And the last one made the actions: earthquake, fire, wedding, to save, to stroll and to hurt.



Figure 3: Characters drawing.

Our focus is to bring the main characteristics of a narrative effectively. Thus, the kids don't have to write the whole story, but they could choose if they want to draw, to record or to write their plot.

Thereby, we encourage our kids to create their own stories, stimulating their creativity, promoting interaction and letting their imagination carry their own trips around the world. We could do this with traditional classes with expository didactics, but we choose to do this differently, with action, fun and meaningful learning.

STORY MAKER MACHINE



Figure 4: "The Story Maker Machine" made by five-year-old students with recycled materials only.

The machine works with interaction and protagonism. One at a time, the player throws a small ball in the path and cheers to see which elements they get by fate. Another special fact is about the "surprise element" that this game brings to us. When a child gets unusual things like "bull-castle-earthquake", he needs to use many strategies and imagination to create stories that make sense.



Figure 5: The 1st grade students playing and making their essays.

With the machine's success, we invited the 1st grade to use our ideas to make their first essays, and the results were amazing.

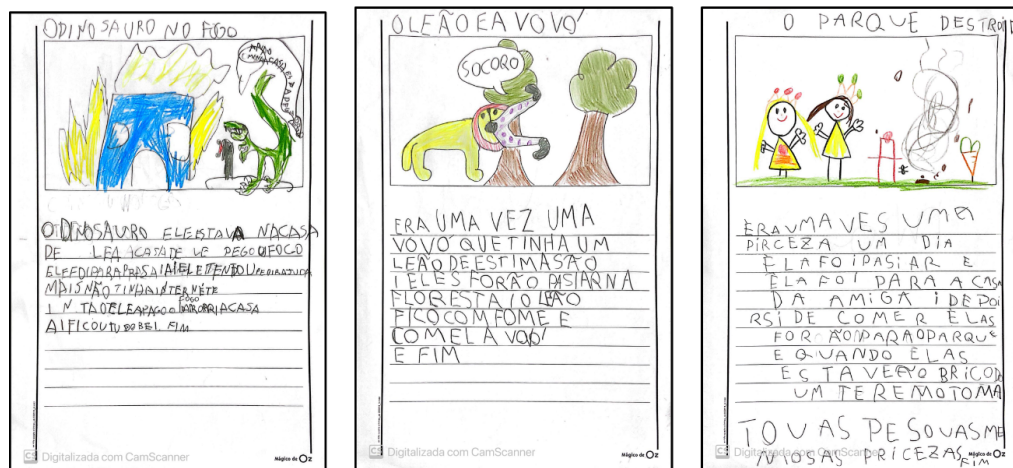


Figure 6: Stories made by 1st grade students.

ACKNOWLEDGMENTS

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Lab das Minas: Inspiring a New Generation of Female Scientists through Workshops

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ABSTRACT

The Lab das Minas is a research group created based on the perception that in order to overcome the reality of low female participation in science and technology, it is necessary for girls to have early contact with women who study and work in the field of exact sciences (Lima, 2013), as well as being encouraged to explore this domain of study. With the main objective of promoting women in science and technology, the group conducts weekly workshops that address topics such as physics, robotics, and astronomy with adolescents (aged 11 to 17) since the year 2016. Within this context, the present project aims to promote encounters with teenage girls, during which they can experience hands-on programming experiences with Arduino. The main goal is to analyze and encourage changes in the students' interest and involvement in the field of technology.

Keywords and Phrases: Gender disparity; Women in STEM; Motivation; Programming for teenagers; Robotics.

1. INTRODUCTION

Through a historical analysis, it is evident that until the year 1990, women were the majority in computer science courses. However, starting from 2000, a significant transformation was observed, with a growing gender representation balance in this field of knowledge, culminating in a substantial increase in male presence. This change in the landscape is supported by illustrative graphs, as exemplified below, which highlight a recurring phenomenon in academic institutions such as ICMC-USP and IME-USP.

This gender imbalance trend in the field of computer science has also been identified in other countries. According to data provided by the National Center for Education Statistics in the United States, during the period from 1984 to 1985, women represented approximately 37% of all undergraduate students in computer science. However, from 1985 onwards, despite an increase in female presence in other fields of study such as law, physical sciences, and medicine, there was a sharp decline in computer science courses, with female representation decreasing to less than 20% by the year 2015 (Andrade, 2019). These numbers underscore the importance of understanding the underlying causes of this shift in proportion and promoting gender equity in this field of knowledge.

The graph below shows the reality of the female presence in Computer Science, a branch that falls under STEAM (Science, Technology, Engineering, Art and Mathematics).

Figure 1: Percentage of women in computer science from 1955 to 2022.



Source: Girls Who Code - About Us

In studies with children, when asked to draw a scientist, without specifying gender, girls were twice as likely to draw a man as they were to draw a woman. (Berwick, 2019).

Research indicates that gender disparity in the field of exact sciences cannot be attributed to differences in abilities between men and women. Scholars such as Janet Abbate (2012), Judith Butler (2006), and Iris Marion Young (2005) argue that the alleged gender differences are used as a justification for perpetuating power inequalities and divisions of labor, being social and cultural constructions.

These stereotypes have a negative impact on girls, undermining their confidence and motivation to pursue scientific fields. It is crucial to investigate and better understand these gender stereotypes in order to combat their consequences and promote a more inclusive and egalitarian environment in the exact sciences.

Furthermore, there is no direct relationship between gender and interest in technology. A study conducted by the organization Girls Who Code in 2016 revealed that, in the school environment, 74% of girls demonstrate interest in science and technology fields, but only 0.4% of them pursue a career in this field.

One explanation for the low female participation is the social association of technology with the field of computer science. Technology is often perceived as something powerful, incomprehensible, and scientific, characteristics that create a social association of technology with the male figure (Wilson, 2003). At the same time, culture considers women incapable of dealing with complex tasks (Amaral, 2016).

This association is one of the main obstacles to women's interest in the field, as girls are encouraged from childhood to like subjects socially associated with the feminine universe, such as caregiving and communication areas (Castro, 2013). On the other hand, boys are encouraged by family, media, and social relations to engage with instruments associated.

1.1 Lab das Minas

In the mentioned context, Lab das Minas (Lab of the Girls) is composed of a group of students from the School of Arts, Sciences, and Humanities (EACH) at the University of São Paulo (USP), where the workshops are also held. The main objective of these activities is to show that the Maker movement, with its focus on "Do It Yourself," is also intended for women. The project aims to engage adolescents through weekly workshops, covering areas such as Programming, Robotics, Astronomy, and Sciences, using easily accessible materials.

The Lab das Minas project is an extension of the Banca da Ciência project (Piassi, Vieira & Santos, 2017), which was initiated in 2009 with the goal of promoting communication and scientific dissemination through interventions in non-formal educational spaces. These interventions are carried out by undergraduate students, under the guidance of professors, researchers, and graduate students from the USP, UNIFESP, and IFSP universities (Piassi et al., 2018).

2. OBJECTIVE

The objective of the project was to provide a safe environment for girls to explore science and technology. All-female workshops promoted an inclusive space, encouraging active participation of the participants. Introductory teachings on electrical circuits, Arduino, and programming were offered. The girls learned basic concepts, built circuits, and programmed devices with Arduino. The learning environment allowed for experimentation and hands-on projects. The goal was to spark interest and confidence, encouraging them to pursue studies and careers in science and technology. The aim is to create a new generation of empowered and engaged women in these fields.

3. METHODOLOGY

The data collection strategies in this study involved two main forms of analysis. Firstly, the teenagers were encouraged to record their thoughts after each workshop, expressing their opinions on what was developed, highlighting the positive and negative aspects of the application, and reporting any difficulties encountered. Additionally, other relevant questions were incorporated as needed. The monitors, in turn, met at the end of each workshop to discuss the points raised by the

teenagers, seeking to evaluate possible improvements and analyze the progressive impact of the Science Club on the participants.

In addition to data collection through written records, we used photographs taken during each session as an additional form of analysis. We recognize that nonverbal language plays an important role in evaluating the success of the workshops and the adopted working methods.

Furthermore, informal conversations were held with the teenagers, during which they shared insights on how the project was impacting their personal lives in terms of empowerment. Although these conversations provided valuable insights, the main evaluative method adopted was the reports developed by the teenagers themselves, as mentioned earlier.

These data collection strategies were implemented to obtain a comprehensive understanding of the impact of the workshops, allowing for a deeper analysis of the perceptions, experiences, and transformations experienced by the participants throughout the project.

3.1 Workshops

The workshops introduce concepts in a didactic and accessible manner. In the programming workshop, we use the Scratch platform to teach algorithms. The girls interact with a robot and program an interactive maze. This hands-on approach allows them to apply their knowledge and progressively develop skills. The goal is to create an engaging learning environment that facilitates understanding of the initial programming concepts. Through the use of Scratch and the proposed activities, we aim to stimulate the participants' interest and build a strong foundation in this field.



Figure 1: Programming workshop with Scratch - Personal collection (2019)

We conducted a practical workshop on circuits, where we provided the teenagers with an understanding of the operation of experiments with LEDs. Then, we offered a brief lecture on electrodynamics to facilitate the assembly of electrical circuits using conductive playdough, which was produced together with the participants. During the workshop, the teenagers had the opportunity to manipulate wires, batteries, and were able to light up an LED by assembling the electrical circuit. This activity allowed them to experience the principles of electricity in a concrete way, promoting hands-on learning and stimulating their interest in related sciences and technologies.



Figure 2: Arduino workshop - Personal collection (2019)

Throughout the year, a workshop was held that provided participants with the opportunity to explore the intersection between fashion and technology through wearable circuits. During this activity, the teenagers had the chance to develop a wearable, an electronic device incorporated into fabrics, which was touch-sensitive between the skin and the fabric and emitted sound when detecting specific touches. Maria Paulina Gutierrez, an expert in wearable circuits, kindly offered to share her knowledge and guide the entire process of creating this innovative device. This workshop allowed the participants to experiment and gain hands-on learning in this exciting field of technology and fashion.

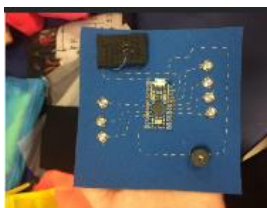


Figure 3: Developed wearable circuit - Personal collection (2019)

4. RESULTS

Throughout the project's development, there was observed a greater involvement and interest from the teenagers in the exact sciences, with some of them seeking to deepen their knowledge through courses in the field. The progression of the girls' learning was remarkable, as they can recall topics covered months ago with precision and are able to explain concepts of electricity, programming, and robotics with ease.

Considering that the project is still ongoing, we have the expectation of introducing the participants to a new wearables project, in which we will apply the concepts absorbed during the previously mentioned workshops. This new project will present a higher level of complexity, involving programming and electronic circuits. This will provide a solid foundation to assess the girls' progress in their technological learning and allow us to evaluate the results achieved so far.

5. CONCLUSION

Lab Das Minas, an initiative integrated within L.I.R.A. (Laboratory of Innovation and Applied Robotics), provided direct contact between female adolescents from socially vulnerable areas and technology, aligning with the established objectives for the Science Club. Through the offered workshops, the participants were able to explore different areas of the exact sciences and broaden their perspectives on career choices. It can be concluded, therefore, that the project is in line with its main objectives and has generated a positive impact in the lives of the participants, both for the monitors who enhance their communication and didactic skills and establish regular contact with technology, and for the teenagers who acquire innovative knowledge, empower themselves, and broaden their understanding of the various aspects of the sciences.

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Investigating Invasive Species by Constructing Data Visualizations with Teachable Machines and Coding

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While many educational projects utilize computer science, data collection, and data visualization through construction, very few utilize all of these aspects. Here, we present our work in progress on the *Investigating Invasive Species: Exploring Coqui Frog Population Data Across Hawaii* project. Inspired by the Maker Movement, this project was designed for students to collect and engage with data by creating computational data visualizations of the population density of the invasive coqui frog across the island. The project affords students with multimodal and personalizable opportunities for data collection, analysis, and visualization. By combining scientific inquiry, constructionism, and computational thinking, we hope to provide students a better sense of authentic data practices and elucidate a better understanding of what combinations of these practices could prove particularly effective for teaching students about scientific investigations.

CCS CONCEPTS • Data science • Data visualization • Computational thinking

Additional Keywords and Phrases: data science, data visualization, programing, computational thinking.

1 INTRODUCTION

With technological advancements proliferating the amount of data we interact with on a daily basis, the ability to interpret data visualizations has never been more important. Further, authentic data collection, analysis, and visualization lends themselves well to constructionism, as active learning facilitates meaning-making for students [1]. As our world becomes more supersaturated with data, computer science is almost a necessity for understanding how to manage large datasets [2]. Despite the clear need for the incorporation of computer science, data science, and constructionism, there is still a need for more research on how to design learning experiences for this combination of thinking and procedural skills. The few studies that incorporate these elements demonstrated positive results. For example, Wagh et al. [3] found an increase in student disciplinary engagement while tinkering with the code of an ecology simulator. However, the authors also argued that future projects that allowed students to personalize their inquiry and visualizations could prove fruitful. Other recommendations for teaching data visualizations through construction include keeping visualizations simple, allowing expression in the visualization, and creating visualizations that are compatible with data dynamics [4]. Many data visualization studies within science education involve a simulation that provides secondary data for students [e.g. 5]. Although there is evidence that students also think about secondary data in meaningful ways [6], evidence also suggests that directly collecting or manipulating data can prepare students to understand statistical patterns, data analysis, and inferences made with data [7]. Therefore, creating opportunities for students to engage with an authentic, personalized data collection, interpretation, and visualization process could help researchers understand how students engage with those processes in a holistic fashion.

Here, we present our work in progress, *Investigating Invasive Species: Exploring Coqui Frog Population Data Across Hawaii*. We designed this curriculum for secondary students (grades 6-8) in Hawaii. By using one of Hawaii's most notorious invasive species as a model, *Eleutherodactylus coqui*, we teach ecology by starting with something that students are already familiar with. These frogs (coqui) have exceptionally loud calls, and are often cited as a form of sound pollution; in fact, they are so loud that their presence decreases property values [8]. However, this arguably obnoxious call makes their population density so easily measured that it can be done with Google and a cell phone. This project incorporates data collection, physical science, art, journaling, artificial intelligence, data visualization, computer science, inquiry and construction into a personalizable and authentic scientific investigation. While this project is extremely localized to one area of the world, it models an approach that is highly transferable to future projects and contexts. Although our work in progress has not been implemented yet, we present our work in progress within an existing larger project. With so many facets of this project, there are multiple opportunities to find how students make sense of data within the context of constructionism and computer science.

2 CONTEXT

Coquis are named for their call, which consists of a distinct “co” sound followed by a “qui”. The sound is nearly unmistakable, allowing students to easily identify them during casual observation. In our project we introduce students to our collaborative work by asking them to record their initial emotions after playing them their instantly recognizable sound. From there, students are tasked with selecting from a list of animals that they are interested in learning more about. While we have created a pre-identified list of animals, we also provide space for students being able to choose their own organisms of interest. After creating a rough sketch, students are tasked with creating an ecosystem interaction between all of the students selected animals and the coqui. In order to discover the potential interactions, we task students with various readings and internet research to explore the relationships. We selected primary literature about the coqui as our starting point, and then simplified them into short readings. We also allow students to find their own resources that they wish to contribute.

As students discover the ecological interactions between their selected organisms and the coqui, they create their first visualization. This visualization serves as a way for students to make sense of the ecological dynamics of introduced species. Students then use paper circuits to display ecological interactions (see **Figure 1**). Students are afforded the opportunity to define the meaning of each color of LED light. This can be as simple as a red LED indicating a negative relationship between populations or as complicated as detailing which interactions are hypothesized vs. which are empirically documented. Students then use this data visualization to come to their own conclusions about the ecological impacts of the coqui. Coqui, like most invasives, have detrimental effects on the local ecosystem [e.g 9]. However, coquis may also have localized redeeming qualities, such as competing with other invasives for food [10].

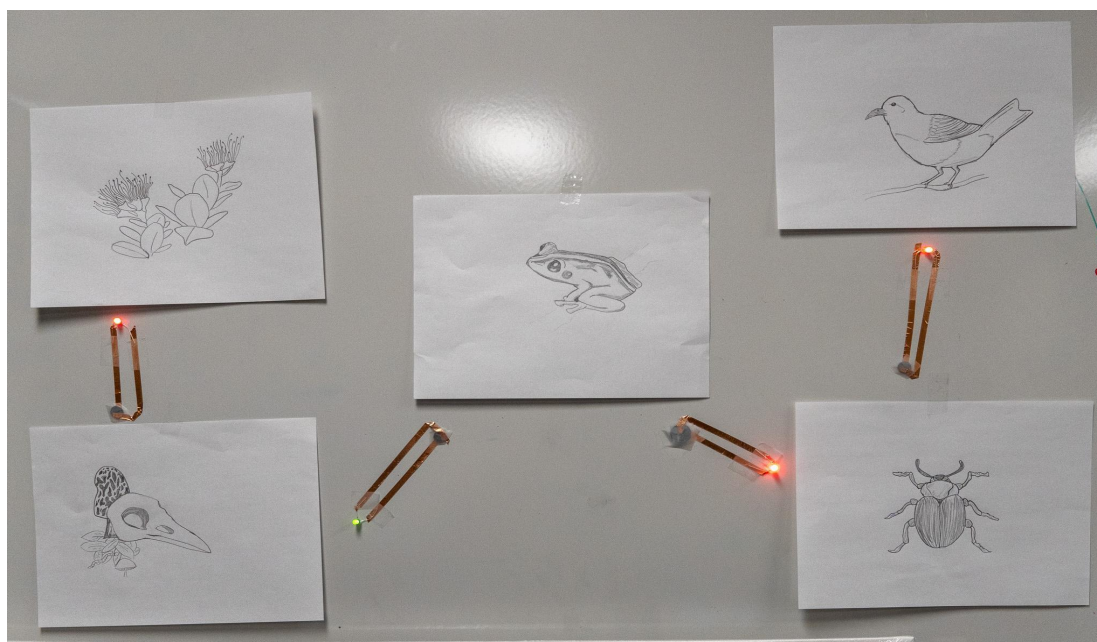


Figure 1: Example of ecosystem connections adapted from Smith 2016

3 STUDENT LEAD DATA COLLECTION

After developing an understanding of the ecology of coquis, students are tasked with determining the population of coqui in their local neighborhood. This is done with a cell phone. Students use their phones (or phones provided) to record their neighborhood for coquis for 30 minutes. Students then use GPS on their computers to find their exact location that they recorded the coqui calls. Students are also given the opportunity to decide what data they want to collect through the use of covariates. With cheap and simple thermometers and hygrometers, students are introduced to the concept of covariates. They make hypotheses about how temperature and humidity could affect the density of coqui in their area and are taught the basics of recording covariate data. While recording data comes in many forms, nature journaling is arguably one of the better methods for allowing students to express themselves while collecting data. After a brief activity recording humidity and temperature, students are introduced to the broader concept of field journaling. As a class, students go outside and practice documenting the world around them using field journals (or notebooks). This activity is followed by a class discussion of potential covariates that they want to investigate. As students record their neighborhood, they record the time, date, temperature, humidity, and any other covariates they want to add. An example of a journal entry can be found in **Figure 2**.

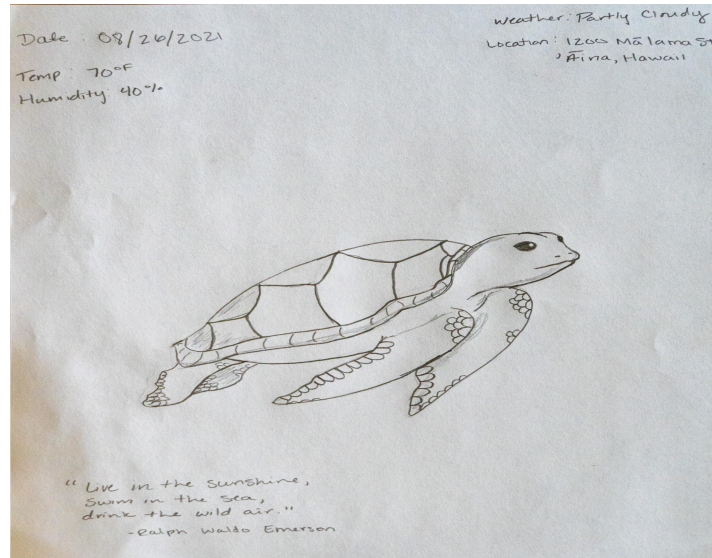


Figure 2: Example of journal entry

4 USING TEACHABLE MACHINES FOR DATA ANALYSIS

Once students have initially recorded their neighborhoods for coqui calls, they must analyze the data. To do this, we have designed Google's Teachable Machine (teachablemachine.withgoogle.com) to detect the presence of coqui calls (**Figure 3**). The machine displays the prevalence of the coqui call as a percent over time. Students tally the number of times that it reaches 100%, records how long it stays at 100%, or any other viable method of using the machine to determine the population. Again, students can decide which ways to use the machine in order to guide the analysis. Additionally, students can even add more audio files to further train and tailor the machine towards their own research requests.

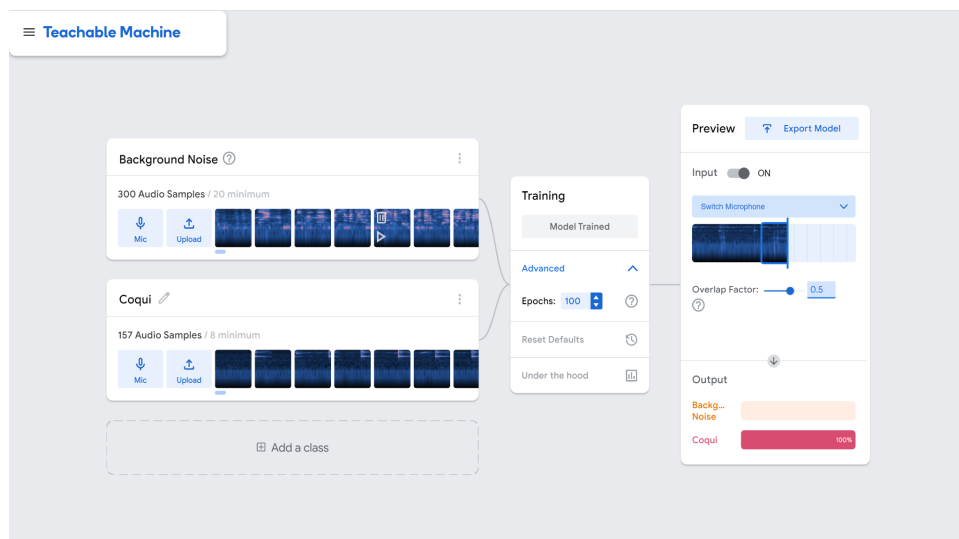


Figure 3. Coqui calls in teachable machine.

5 DATA VISUALIZATION CONSTRUCTION

Finally, students are tasked with creating a meaningful visualization of the coqui population density and their desired covariates. Since we are looking at population density by location, we used 3D printers to print topographical maps of Hawaii. By using copper tape, LED lights, and Circuit Playground Express microcontrollers, we are able to create a personalizable data visualization on top of the printed map. A simplified example is shown in **Figure 4**. Students use the free website, MakeCode in order to program their LED lights to create a unique visualization of their own. Coding is one of the few ways that can accommodate such a variety of potential data types [4]. Different lights can blink at different rates, display different colors, or play sounds that have personalized meanings to students.



Figure 4. An example of a data visualization

6 CONCLUSION

This work in progress provides a multimodal opportunity for students to meaningfully engage with data. While this project is highly specified towards a particular location, we argue that it is broad enough to be easily edited to fit another location for a different group of students. Due to its multifaceted nature, it might also serve as the substrate for future research endeavors. With so many methods of collecting, analyzing, interpreting, and visualizing data, we can identify particularly promising combinations that would not be present in other studies. Further, an exploration of the combination of authentic data collection with the construction of data visualizations could pioneer novel methods of understanding how students make sense of the scientific process in a way that couldn't be done by simulations or secondary data sets. While data has not been collected yet, we look forward to this first implementation. Our analysis will be looking at the personal connections that students make with data via field journaling and the conclusions that students come to when they understand the population density of their home area, how students convey personal data that they collect with computational circuits, what decisions teachers make when they implement this curriculum, and the affordances given when data is centered on a community.

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Design Thinking as Part of Design and Maker Education

An Explorative Case Study

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In this work-in-progress paper, I present my incomplete dissertation case study. The study aims to develop new research-based knowledge on the dimensions of design thinking as part of participatory design and maker education. First, I introduce the theoretical background for the research work. Second, I briefly present the case study, its methods of data collection and analysis, and the findings so far. Lastly, I reflect on the significance of the study and the pedagogical implications it offers for designing participatory design and maker projects for formal education.

Keywords and Phrases: Design Thinking, Design Education, Maker Education, Participatory Design

1 BACKGROUND AND OBJECTIVES

Young generations must cope with and solve the increasingly complex societal, cultural, and environmental challenges (Binkley et al., 2012), and formal education should democratically offer opportunities to all students to develop the competencies needed in the future (Blikstein, 2013). Dindler and colleagues (2020) argue that Participatory Design (PD) can engage and empower students in the process of designing, making, and learning with and about new technology and how it affects the world around them. PD and maker education, in which students are involved in solving real-world challenges and co-creating new artifacts and solutions for and with their communities, can support the learning of important future competencies, such as creativity, empathy, and agency (Clapp et al. 2016).

This dissertation study is built on the concept of design thinking (DT), an approach to creative problem-solving in which several cognitive and affective processes, skills, methods, and mindsets are applied (Goldman & Kabayadondo, 2016). DT can be approached as a process of teaching and learning, a set of tools, methods, and materials that guide the design process, and the mindset needed and developed during the design process (see Figure 1). DT shares many perspectives with PD, such as the idea of design being a socially innovative and collaborative effort with diverse participating stakeholders and competences, and that the ideas must be prototyped and explored in a hands-on way and tried out early in the design process, emphasizing human centeredness and empathy (Björgvinsson et al., 2012).

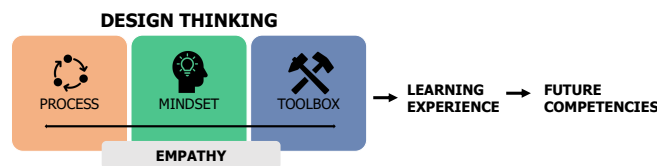


Figure 1. Design thinking definition in this research (based on Brenner et al. 2016).

Many researchers believe that DT can be used to support teachers and students to act with open curiosity and creativity in today's world, which is full of challenges and uncertainties (see e.g., Carroll & McBain 2021; Rusmann & Ejsing-Duun, 2022). The rising interest amongst educational researchers in participatory design (PD) and co-design approaches and ideology (Cumbo & Selwyn, 2021) offers new ways and options for applying DT in the fields of learning sciences, to develop and transform its practices (DiSalvo & DiSalvo, 2014). Nonetheless, we lack empirical research and knowledge on how design and maker education can be systematically used in building the future competencies that young people need (see Papavlasopoulou et al., 2017). This dissertation produces new research-based knowledge on the dimensions of design thinking (DT) as part of participatory design and maker education in lower-secondary education.

2 METHODS

2.1 Research settings and participants

I designed and collected the data from a community-based PD case study, that was conducted at a public lower secondary school in Helsinki as part of an elective eighth-grade craft course in the spring of 2019. The idea of the project was to offer a meaningful learning experience for students (aged 14–15 years) and engage them in a collaborative and open-ended real-world project, in which students designed and made useful products for local kindergarteners (aged 6–7 years). The design brief for this project was to “co-design and make an e-textile product for the kindergarteners according to their wishes and needs”. The task emphasized collaboration between team members, considering other people’s ideas, feelings, and needs, and thinking creatively about how technology could be used in the products. The project structure was collaboratively designed with the responsible craft teacher, and the plans were discussed and revised weekly. The class met 10 times in weekly 90-minute sessions; the final sessions were dedicated to student presentations and post-questionnaires. My role as a researcher and a teacher as well as the craft teacher’s role in the process was active yet more facilitative than authoritative. The students were supported in finding their paths to contribute to the design process.

2.2 Data collection and analysis

The data from the case study comprise approximately 18 hours of video recording, photos of the sketches, mock-ups, ideation notes and final design products, researcher’s field notes, voice memos, and diary, teacher’s interview and voice memos, students’ pre-and post-questionnaires, and other pedagogical material. The video recordings captured shared design activities and social and verbal interaction between team members and the teachers and students. The method of data collection produced a large amount of data but also provided a rich and holistic view of DT and making processes, actions, and experiences in a formal school context. To reduce (selecting, focusing, abstracting, and transforming) the video data for the publications, I followed the instructions by Derry et al. (2010). After viewing all the data, a rough content log was built to get to reveal the main contents and various activities of the videoed sessions in the design process. All the interviews and other audio recordings were transcribed. I utilized MAXQDA software to support the work, and different qualitative analysis methods (like content, narrative, and thematic analysis) in analyzing the data for separate publications.

3 FINDINGS SO FAR

My article-based dissertation will explore the various dimensions of design thinking as part of participatory design, and maker education. The first article (see Bosch et al., 2022a) focused on exploring how design empathy, a significant dimension in DT and one of the important future competencies, was manifested in students’ design processes. Our findings indicate that the students considered, discussed, and referred to topics concerning end users during the process. Signs and

dimensions of design empathy were found in the various end-user-related discussions and empathetic considerations, through which end-user-friendly design products were materialized.

The second publication (see Bosch et al., 2022b) describes how the DT approach structures and facilitates the creative process, explores the teachers' roles in building the classroom culture for students' creative confidence, and describes the various competencies for creativity involved and required in invention projects. The chapter illustrates the theoretical considerations with narrative examples from the video data and students' post-questionnaires. The chapter suggests that invention projects can focus on developing many competencies for creativity if they are carefully implemented in the process. Competency development is both a learning process and a learning goal.

The third publication (*article in progress, see WiP paper Bosch 2022c*) will take a holistic perspective for designing the participatory learning experience in lower-secondary education. The paper first describes the key elements based on the previous studies and the researcher's experiences in design and maker education in Finland. Second, it analyzes how those elements functioned from the researcher's and teacher's viewpoints. An abductive thematic analysis focuses on the essence of key elements in pedagogical material, the researcher's and teachers' reflections, and the research diary.

4 SIGNIFICANCE AND PEDAGOGICAL IMPLICATIONS OF THE STUDY

The current dissertation develops research-based knowledge on the dimensions of design thinking in both students' and teachers' community-based participatory design and making processes. These distinct dimensions were employed as learning objectives, as vehicles for learning, and as support for planning and facilitating the learning experience. This 3-month-long project was integrated into regular craft classes, providing an authentic portrayal of the design and implementation of participatory design, and making processes in lower-secondary education.

Findings indicate that participatory design and maker education can encompass the practice of numerous future competencies if the creative design thinking (DT) processes are deliberately structured and guided. This necessitates teachers to embrace new roles as learning designers, to possess empathy, and to have an extensive understanding of creative learning processes and environments. The call for further research on creative pedagogies in K-12 education (Cremin & Chappell, 2021) and the roles of teachers in design and maker education is recognized (Rusmann & Ejasing-Duun, 2022; Voldborg Andersen & Pitkänen, 2019).

Dindler et al. (2020) have suggested that STEM education should adopt a more critical and reflective approach toward the digitized society. The inclusion of real end-users in this project provided students with an opportunity to assume roles as designers and makers, enabling them to identify novel possibilities for utilizing digital technology in innovative ways within their community. This dissertation project could serve as an illustration of culturally relevant and impactful STEM education (Thanapornsanguth & Holbert, 2020).

Based on the research conducted, the dissertation will propose design principles to support the creation of participatory design (PD) and maker projects within formal education. New pedagogical materials will be developed based on the findings, offering best practices and guidance for teachers on how to design and implement community-based PD and maker projects effectively in formal education settings. Furthermore, the dissertation will explore how to meaningfully incorporate new digital technologies into school environments.

Given the rapid advancement of new technologies, economic challenges, and climate change, our future is likely to bring unpredictable environmental and societal issues. Design presents novel avenues for addressing the uncertainties and complexities of the world. The potential of employing e.g., participatory, sustainable, critical, and systemic design methods at lower educational levels warrants research and development.

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Create2Solve DIY STEAM Kits: Youth Participation in Making Activities to Solve Real-World Sustainability Challenges in Socio-Economically Vulnerable Communities

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How do Do-It-Yourself STEAM (science, technology, engineering, arts and mathematics) kits encourage youth to solve real-world sustainability challenges? In this work, I describe the key design tenets of my research project in Pakistan's socio-economically vulnerable communities. In this project, eight youths from a non-profit school in an at-risk community participated in interdisciplinary STEAM activities using Do It Yourself (DIY) kits. These kits were designed to address the real-world sustainability challenges existing within local communities. Particularly, youth used Create2Solve Waste Management and Recycled Electronics kits to solve the problems of ineffective waste disposal and electricity shortage in their community through making projects. Based on the preliminary work, I establish that youth are keen to engage and participate in sustainable development projects: 1) relate to their local community contexts; and 2) allow them to substantially contribute to the personal, community and societal transformation.

Keywords and Phrases: DIY Kits, STEAM education, youth participation, sustainability, community-relevant design

1 DESCRIPTION OF PROJECT: CREATE2SOLVE DIY STEAM KITS

1.1 Introduction and Background

As a pragmatic initiative aimed at engaging youth participation in the community's sustainability challenges, the Create2Solve DIY STEAM Kits project is part of a more extensive community-based program known as the Create2Solve After-School Program. Drawing upon the community-relevant STEAM curriculum approach, such as using culturally relevant daily life materials in experiential class projects (Cavallo et al., 2004; Kant et al., 2018), this Program intended three primary outcomes: 1) promote interdisciplinary STEAM education in informal learning settings; 2) encourage youth from low-income communities to implement socio-environmentally sustainable actions in their neighbourhoods through STEAM model; and 3) shift the focus from 'STEAM curriculum IN community' to 'STEAM curriculum FOR community.' In the first phase of this Program, students participated in interdisciplinary STEAM projects designed to solve the local community problems identified by themselves and their elders/other community members. I discuss the details of the action research process behind developing this STEAM curriculum based on community generative themes elsewhere (Kiyani et al., 2020a). The next phase of this After-School Program involved the design of portable and DIY STEAM kits based on the interdisciplinary STEAM projects created in the first phase.

1.2 Methodology and Methods

In Create2Solve DIY STEAM Kits programming, eight youths from the same community participated. The data used in this case study came from multiple sources to allow for triangulation. After obtaining informed consent, I collected student artifacts and captured photographs of their final work while recording their in-field reflections. I also conducted semi-structured interviews (Gubrium & Holstein, 2002) at the end of the Program to elicit detailed student feedback about the Create2Solve kits. Interviews and student reflections were audio-recorded and transcribed verbatim using data transcription software. The interview transcripts and students' reflections were coded in a series of coding cycles using the

constant comparison method (Kolb, 2012; Maykut & Morehouse, 2002) with qualitative data analysis software NVivo. The relevant codes were then pulled from NVivo, consolidated, and further analyzed on word processing software using an inductive thematic analysis approach (Guest et al., 2011).

2 PROJECT DESIGN: CREATE2SOLVE STEAM KITS

Create2Solve DIY STEAM kits were designed and deployed in three key phases, as described below.

2.1 Identification of Community-Relevant Themes for Create2Solve Kits

A significant design consideration and question for this project was: how can STEAM DIY kits be designed to be community-relevant in order to encourage youth participation in sustainable development within their communities? Therefore, my primary focus for this study was to critically engage youth by giving them a chance to work on 'real issues' and contribute towards community transformation, as suggested by Freire's approach of critical pedagogy (Mahmoudi et al., 2014).

The study took place in the registered trust high school in an underdeveloped and low-income village, Nurpur Shahan, in the country's capital city, Islamabad. The culturally diverse community surrounding the school identified the lack of access to basic resources, such as ineffective waste disposal arrangements and severe electricity shortage issues. Observing the severity of these issues, the dire needs of the community, and local community problems highlighted by the students and community members (Kiyani et al., 2020a), the themes (waste disposal and electricity shortage) for the Create2Solve DIY STEAM kits were identified. These themes were locally important for students to work on real problems based on their community needs and issues instead of alien and 'imported' problems (Freire & Macedo, 2000). By linking the school, learners and their community, grassroots problems of the learners' community were used as objects of study (Rhem, 1998).

2.2 Community Relevant Design of the Create2Solve Kits

Considering the community issues and kit themes identified in the previous phase, I designed two low-cost and ready-to-use STEAM DIY kits, which I called Create2Solve Waste Management Kit and Create2Solve Recycled Electronics Kit. These kits were called 'Create2Solve' to highlight the agenda where design and creation are intentional, meaningful and geared towards solving prevalent community problems. The use of low-cost technology offers accessibility and affordability of kits in disadvantaged settings (Nair et al., 2019; Penzenstadler et al., 2018; Stark et al., 2019; Zidny et al., 2019). Therefore, I used low-cost daily-life household and recycled, reusable items to design the kits. Each kit had: 1) assembly materials to design the products (such as electric motors to design hand-held fans); 2) stationery items; 3) reflection note-pads to enable students critically reflect on their learning content and process; 4) customizable, online digital teacher guide with multi-modal resources (such as videos, images, hyperlinks) to engage diverse learners (Courey et al., 2013; Kiyani et al., 2020b); and finally 5) students' self-assessment STEAM rubrics for summative assessment along with short quizzes and exit tickets for formative assessment. To allow the students to use familiar and locally available materials, I provided them with all items except recyclable and reusable waste materials such as used plastic bottles and old cardboard boxes. Before the program commencement, youth collected the required recyclable and reusable items from the neighbouring community through their facilitator's guidance and support.

2.3 Reflection on Youth Participation in Create2Solve Kits: In-Field Experiences

After finalizing the design of the kits and facilitator guides, followed by the interactive dialogic discussion with facilitators, the last phase of the Program was to invite students to participate in the kits' programming and activities. All activities

were monitored and assisted by the facilitators (school instructors who signed up to become program facilitators) and myself as program lead and researcher. Youth first participated in a 1-week Program using Create2Solve DIY Waste Management Kit. Some notable activities of the Program included: 1) critical discussion on general practices of waste disposal and its negative impact on the community; 2) a community field trip where young students went on a trip to neighbouring communities to do community waste assessment, followed by the collection of recyclable and reusable items and photo-prompted whole-class reflection on what steps can be taken to mitigate some of these challenges; 3) designing creative baskets and bird feeders from torn clothes and discarded plastic bottles; 4) initiating the 'Green Community' where students appointed themselves as 'Green Leaders' to lead and drive similar sustainability initiatives in the school and community. Figure 1 includes selected images captured during both Create2Solve programs.



Figure 1: Photographs of students from the Create2Solve DIY STEAM Waste Management and Recycled Electronics program

Similar to the waste management program, youth used Create2Solve Recycled Electronics Kits to participate in the recycled electronics program, spanning over five days with a maximum interaction of 2 hours with the kits each day. Youth in this Program designed small-scale, localized solutions for the electricity cut-off issue in their communities, drawing from their knowledge about waste management from the previous Program. Some key activities of this Program include: 1) engaging in critical dialogue and reflection on the alarming situation of electricity cut-off in the country, particularly in their community; 2) designing electric circuits using home-based materials; 3) creating battery-operated hand-held fans and flashlight using recyclable and reusable materials, such as plastic bottles, bottle caps, and cardboard boxes; 4) designing electronic cards (with LEDs) as a token of appreciation for the facilitators and memorabilia to continue engaging in such green initiatives. By the end of this Program, it was an inspiring moment for the Create2Solve program when one of the participants reflected on the potential of such programs to motivate others in their community to contribute towards community transformation. For example, when reflecting on the recycled electronics program, Abdullah said, *"I will make a flashlight to be used at night. When I use it, my community members will see it and then ask about it. Then, I will teach it to them, and this way, a learning cycle will start. Due to this, less electricity will be consumed by everyone."*

3 SIGNIFICANCE AND IMPLICATIONS FOR FUTURE WORK

Based on the preliminary analysis, it seemed evident that youth were engaged and keen to participate in sustainable development initiatives that allowed them to impact the life conditions for themselves and their communities positively.

The preliminary results of this study imply that community-relevant low-cost DIY STEAM kits, tailored to youth and community needs, can potentially engage, motivate and empower youth to address local community issues, as also noted in similar studies (e.g., Lopez et al., 2019; Nair et al., 2019; Wijayawardana & Kaumal, 2017). Unique to this study, viewing youth as valuable "citizens" and "resources" (Checkoway & Gutierrez, 2006; Golombek, 2006) in Create2Solve program revealed that the use of anti-deficit lens support youth in developing confidence in their design skills as well as their ability to initiate collective community development. The legitimate participation of community members and youth throughout the Create2Solve program further sets this study apart from most STEAM research, where youth are often presented with predetermined, imported problems determined by researchers.

The current stage of this work calls for further exploration to fully uncover the affordances and challenges inherent to the design of similar community-relevant DIY STEAM kits. Drawing from the preliminary findings, several potential future directions emerge, such as: a) (re)designing the STEAM DIY kits after collecting comprehensive feedback from all participating stakeholders, including program facilitators and community members, to optimize the design impact; and/or b) disseminating the comprehensive research findings and design methodologies through creative formats like participatory workshops, zines and community exhibitions. Nonetheless, in its current state, I hope that the comprehensive articulation and documentation of the design of Create2Solve STEAM kits, built upon (critical) theoretical and pedagogical foundations, will create meaningful insights for fellow researchers and learning experience designers. This paper will open new pathways and create promising vistas for like-minded design scholars and constructionist communities interested in implementing similar community and learner-centric design principles and methodologies in their making activities.

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Agent JS – A JavaScript Programming Library for Agent-based Modeling

Agent-based Modeling with JavaScript

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The Logo programming language was used to introduce generations of pupils into the world of programming. Turtle graphics, graphics programming, and agent-based modeling are popular approaches to teach programming through constructionist learning activities to this day. With time several tools and environments emerged for both single and multi-agent drawing and modeling. In this paper we present a new under development programming library called Agent JS, that can be used for both graphics programming and agent-based modeling. This new tool enables teachers to combine a widespread, multi-purpose programming language with best practices and constructionist methods to teach programming and modeling.

Keywords and Phrases: Turtle graphics, Agent-based modeling, JavaScript, Logo, NetLogo, Constructionism

1 INTRODUCTION

Since its introduction in 1967, the Logo programming language had a huge impact on programming education. With the use of the language and related programming environments it is easy to introduce various concepts of programming through the creation of complex graphics (Papert & Solomon, 1971; Papert, 1981). In the heart of Logo is the turtle (a.k.a. the “agent”) that can be controlled by our computer program. Some environments allow users to create and control multiple such agents to create even more complex graphics, or even simulations and multi-agent models of complex systems.

The pioneers of the educational use of agent-based modeling were Mitchel Resnick, the creator of StarLogo¹, and Uri Wilensky with the NetLogo² environment. Wilensky’s goal was to create a programming environment in which there is a “low threshold and no ceiling”, and that can be used for teaching programming and computational thinking (Tisue & Wilensky, 2004; Wilensky, 2001; Bernát, 2014). Like Logo, NetLogo has strong connections to the constructionist learning theory (Papert & Harel, 1991; Blikstein & Wilensky, 2009; Wilensky, 2003). With agent-based models it is also possible to create complex, constructionist learning activities that combine computer science with other disciplines (Wilensky, 2001; Wilensky & Resnick, 1999; Wilensky & Rand, 2015). The model library of the NetLogo environment³ contains example models from biology, chemistry, physics, mathematics, and human sciences as well.

Several programming environments have been created based on Logo and its principles since its inception. These environments include NetLogo, the ever-popular Scratch⁴ that allows the control of characters with block-based programs, and the Turtle extension of the Python programming language⁵ that allows the creation of turtle-based geometry with a modern and widespread script language. Another noteworthy new tool is the XLogo⁶ online environment that provides an incrementally more complex set of tools for creating turtle graphics. For the youngest students it offers a block-based environment, for more experienced learners it provides a full Python environment with the `turtle` library.

Script languages such as Python are also becoming more and more popular in the programming education landscape. In addition to Python, the other script language that is very popular in programming education platforms and curricula is

¹ <https://www.slnova.org/>

² <https://ccl.northwestern.edu/netlogo/>

³ <https://ccl.northwestern.edu/netlogo/models/index.cgi>

⁴ <https://scratch.mit.edu/>

⁵ <https://docs.python.org/3/library/turtle.html>

⁶ <https://xlogo.inf.ethz.ch/>

JavaScript. For example, in the popular Micro:bit⁷ educational toolkit, JavaScript is the programming language behind the block-based program editor, and students can use it directly to create their programs for their virtual or physical Micro:bit boards. Of these two popular script languages Python has a built-in turtle graphics library already. While graphics libraries, such as p5.js⁸ exist for JavaScript, these do not focus on the turtle graphics approach of programming or have a higher level of abstraction behind them as with the case of the TurtleGFX⁹ add-on for p5.js.

The usage of JavaScript could mean a new option for creating turtle-based graphics and multi-agent models in education, as it has many benefits and favorable properties when it comes to teaching programming (Horváth & Menyhárt, 2014). The goal of the Agent JS project is to provide an easy-to-use educational toolkit for JavaScript to create such programs.

2 THE AGENT JS LIBRARY

2.1 Goals and design philosophy

The main inspirations for the Agent JS library were the “turtle” library of the Python programming language and the NetLogo modeling environment. Our goal was to create a toolset for JavaScript that makes it easy to create turtle-geometry graphics, agent-based models and to simulate cellular automata with different levels of complexity. To achieve this, the Agent JS library provides a set of classes and functions for JavaScript, that can be combined with native tools of the language, such as variables, loops, functions, and built-in APIs.

Another important principle for the design of the library was to make it versatile and flexible. This means that while it provides a lot of tools for tasks of different complexity, the use of these tools is optional depending on the educational purpose. While some pre-written functionality can be useful for beginner students to make it easier for them to quickly achieve results, for more experienced learners it can be an interesting challenge to create this functionality themselves with the built-in features of JavaScript. This essentially means that we wanted to design a tool that can be used as-is, but also exposes the parts that are needed to build a similar framework ourselves.

The JavaScript programming language along with web browsers have strong graphics capabilities that can be used to build an environment for drawing and modeling for constructionist learning activities (Visnovitz & Horváth, 2020). The Canvas API¹⁰ provides a native tool to create complex graphics and animations with simple programs. While developing the Agent JS library we wanted to stay as close to native APIs as possible, so that the acquired technical know-how can be applied in native JavaScript software development as well.

2.2 Using the library

The Agent JS library provides a set of abstractions for creating graphics on a drawing canvas (`Canvas` class) and to build agent-based models (`Model` class). The `Canvas` class provides easy access to the native drawing capabilities of the JavaScript language. By creating an instance of this class, we can immediately use the methods of the native `RenderingContext2D` API to create images with our program. With this set of tools students can start building abstract shapes and forms, while learning about the fundamentals of programming, i.e., loops, functions, recursion, or random number generation (Figure 1).

⁷ <https://microbit.org/>

⁸ <https://p5js.org/libraries/>

⁹ <https://github.com/CodeGuppyPrograms/TurtleGFX>

¹⁰ https://developer.mozilla.org/en-US/docs/Web/API/Canvas_API

```

let canvas = new Canvas({ width: 200, height: 200 });
function drawCircle(x, y, size, color) {
  canvas.fillStyle = color;
  canvas.beginPath();
  canvas.arc(x, y, size, 0, Math.PI * 2);
  canvas.fill();
}
for (let i = 0; i < 100; i++) {
  let x = getRandomInteger(0, canvas.width);
  let y = getRandomInteger(0, canvas.height);
  let size = getRandomInteger(0, 10);
  let color = getRandomColor();
  drawCircle(x, y, size, color);
}

```



Figure 1: A sample program that creates abstract graphics with the Canvas class.

The `Model` class provides a higher level of abstraction based on the `Canvas` class to create turtle-based graphics or multi-agent models. Agent objects work like “turtles” in a Logo environment. By adding an `Agent` object to our model, we can create our turtle geometry graphics just like in Logo (Figure 2).

```

let model = new Model({ width: 25, height: 25 });
let turtle = new Agent({ penWidth: 4 });
model.addAgent(turtle);
turtle.heading = 180;
turtle.putPenDown();
for (let i = 25; i > 0; i--) {
  turtle.forward(i);
  turtle.left(90);
}

```



Figure 2: A sample program that uses a single agent to create graphics.

When we create a new `Model`, we also immediately have access to a grid of `Field` objects that can be used to create cellular automaton models similarly to how NetLogo patches work. It is also possible to add multiple `Agent` objects to a `Model`, resulting in an environment with multiple moving agents. The `Agent JS` library also contains a `Timer` class that can be used to run a simulation loop, allowing the creation of a model with a time component. With the combination of `Agents`, `Fields`, and a `Timer`, it is possible to create a vast variety of different programs (Figure 3).

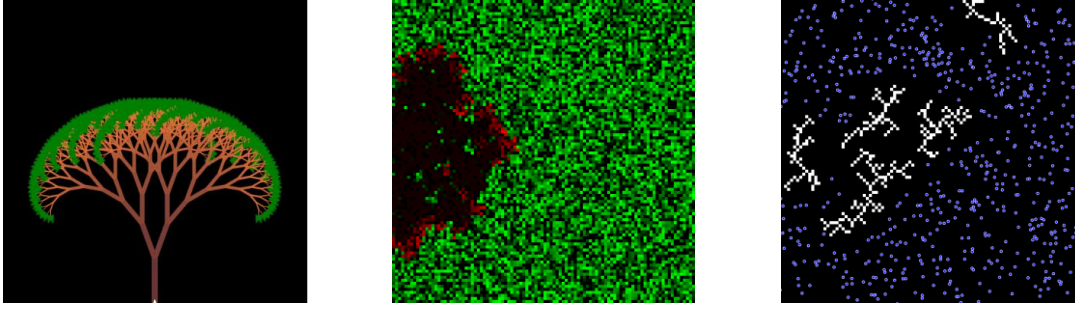


Figure 3: Examples of graphics and models created with Agent JS
(from left to right: recursive tree, forest fire model, ice formation model)

3 CONCLUSION AND PLANS

Turtle graphics and agent-based modeling are popular tools to use the constructionist learning theory to create complex learning activities for students. We created the Agent JS project to provide a new tool for educators so these powerful methods can be utilized to teach programming with the usage of JavaScript, a widespread and popular programming language.

While the Agent JS library already supports many activities in its current form, we plan to extend its capabilities further. The primary source of inspiration for further development is NetLogo and the Python with Turtle environments. We also hope that we can gather feedback from teachers who deploy Agent JS in their classrooms, to have a better understanding of the features that we need to focus on developing, to make the library more versatile and easy to use.

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